Structural Priming and the Mental Representation of Agentive and Temporal *by*-Phrase Constructions: An Eye-Tracking Study

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Abstract

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The phenomenon in psycholinguistics known as structural priming happens, during language comprehension, when a prime sentence facilitates the processing speed of a target sentence, when both bear the same syntactic structure. In the present study, two specific passive constructions were investigated, the agentive *by*-phrase and the temporal *by*-phrase, to evaluate whether these structures primes each other or whether they prime themselves. On-line sentence processing measured by eye-tracking data in the form of duration of fixations within the AOIs (areas of interest) as well as fixation regressions to those AOIs corresponding to the prepositional *by*-phrases, the NP (det N), and the VP (aux V) respectively. The study yielded significant findings for priming of agentive targets with agentive primes and a failure to find priming in all other combinations of agentive and temporal prime and target conditions. The implications of these findings for an understanding of the mental representation of syntax of these constructions are discussed.

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1. Introduction

1.1 The Evolution of Theory and Research on Structural Priming

Participants in a reading task are likely to process a sentence more rapidly if that sentence is preceded by a prime sentence with the same syntactic structure; this phenomenon in psycholinguistics is known as syntactic persistence, syntactic priming, or structural priming (Bock, 1986; and Pickering & Ferreira, 2008). I begin this dissertation with a review of the literature which motivated the empirical study I conducted. Here, I will trace the evolution of the empirical and theoretical work done on structural priming starting with language production. From there I will continue and specifically focus on empirical and theoretical work on structural priming in language comprehension. The research on structural priming has a longer than thirty-year history (Dell & Ferreira, 2016) and I will highlight the more influential work that has been done during that time, from the original studies up to the most current research.

Throughout the review, I will unite the discussion with a principal thesis, which is that structural priming can provide an understanding of syntactic representation specifically, and linguistic knowledge more generally. In doing so, I will focus on the theoretical frameworks that have been developed regarding structural priming in production and in comprehension and connect these to the contention that structural priming can illuminate how the processor parses, or syntactically analyzes, the constituents of a sentence into a meaningful whole. Structural priming has helped linguists and psycholinguists to better understand that the representation of syntax has elements of the two main frameworks for understanding syntactic representation: that which is autonomous in nature and that which is functionalist in nature. The study of priming also reveals that what is primed ultimately, is abstract syntax, or the phrase structures of sentences by way of lexical-syntactic interactions.

The other relevant issue is one of thematic role assignment – specifically, the thematic role assignment to the arguments of passive verbs. Thematic roles are assigned on the basis of the argument structure requirements of the verb in its lexical representation. In generative grammar, a theta role (or θ-role) is the formal device for representing syntactic argument structure – that is, the number and type of noun phrases required syntactically by a particular verb (Jackendoff, 1972). In the present study, the passive construction is particularly significant because of the principal research questions (described below) wherein I will investigate the agentive *by*-phrase (which is assigned a theta role by the matrix verb) and contrast it with the temporal *by*-phrase (which is more adjunct-like in nature). The results ultimately should speak to questions about how these types of constructions are processed and how they are mentally represented.

1.2 The Discovery of Syntactic Priming

In the original study of structural priming, Bock (1986) had participants first repeat prime sentences and then describe target pictures which were semantically unrelated to the prime sentences. Prime sentences were either transitive, in active or passive form, or dative sentences with either a prepositional object or double object. When describing the target pictures, participants produced sentences with the same type of syntactic structure as the prime sentences they had been asked to repeat. Hence, when the prime was a passive transitive, participants were more likely to produce a passive transitive construction when describing the target picture. Similarly, if the primes were in active transitive form the participants tended to produce descriptions in active transitive form, and when primes were in prepositional object or double-

object form, participants more often produced sentences with identical syntactic structure to describe the target picture.

Bock's experimental tasks were disguised as tests of memory, wherein subjects were asked to repeat (in the case of the prime sentences) and then produce (in the case of the descriptions of target pictures) otherwise unrelated sentences; they were also asked to indicate whether they had heard the sentences before (the memory component of the task). The findings of this study were interpreted as indicating that structural priming happens automatically and does not depend on the speaker's communicative intention, prime-target relationships, or other discourse factors in order to happen (Bock, 1986).

Bock and others followed up this initial study with further investigations of structural priming in language production (Bock 1989; Bock & Loebell 1990; Bock, Loebell, & Morey 1992). Bock (1989) asked participants to listen to, and then repeat, prime sentences with prepositional object or double-object sentence structures, which included either the preposition *to* or the preposition *for*. Next, participants were asked to describe target pictures that required the production of an object or double-object sentence structure, although due to the nature of these target pictures (and requirements of the target verbs), the prepositional object always required the preposition *to*. Bock (1989) found that prime sentences containing prepositional datives, including the prepositions *to* or *for,* led to production of the same structure by participants – that is, datives with the preposition *to*. The significance of this is that the production of an abstract prepositional phrase structure was primed, rather than the production of particular function words (Bock, 1990; Pickering & Ferreira, 2008). These findings provided the first evidence and support for an autonomous account of syntactic representation, as opposed to a functionalist account (Bock, 1990).

Bock and Loebell (1990) evaluated two other functionalist explanations for structural priming. The first possibility was that structural priming could be due to ordering of thematic roles, conveyed by the arguments of a particular sentence. For instance, in a passive sentence the patient argument (realized as the grammatical subject of a passivized verb) comes before the agent argument (usually realized in an optional by-phrase licensed by a passivized verb). Bock and Loebell (1990) investigated whether this ordering of argument structure was primed rather than the sentential form itself. If this was so, then exposing participants to prime and target sentences that did not permit repetition of thematic role ordering should lead to no priming at all. Bock and Loebell (1990) used prime sentences containing locative prepositional phrases such as *The wealthy widow drove her Mercedes to the church,* and found that these primed the production of sentences with prepositional object phrases even when the targeted phrase was not locative, such as *A rock climber sold some cocaine to an undercover agent*. Additionally they showed that passives with locative by-phrases, such as *The foreigner was loitering by the broken traffic light*, primed participants to produce passive sentences containing non-locative, agentive by-phrases such as *The referee was punched by one of the fans*. Because these findings indicated priming regardless of argument structure, this provided more evidence to discount the functionalist claim of priming thematic or event roles that are realized on the arguments of verbs.

The second alternative explanation and claim investigated by Bock and Loebell (1990) was that perhaps what is primed is really the prosodic rhythms of sentences. That is, an alternative claim could be made that what is primed ultimately is a particular sequence of words which causes the production of a sentence with a distinctive rhythm leading to the repetition of structure (Pickering & Ferreira, 2008). However, contrary to this possible claim, Bock and Loebell (1990) demonstrated that a prime sentence such as *Susan brought the book to Stella*

primed sentences such as *The girl gave a brush to the man,* while the prosodically similar but syntactically different *Susan brought a book to study* did not. This provided further evidence to counter functionalist accounts of structural priming suggesting that the locus of priming could be the prosodic rhythm of a sentence rather than the abstract syntactic structure.

Bock et al. (1992) showed that participants did not appear to rely on reconstructed representations of sentential Deep Structure when they experienced structural priming. In this study participants produced primes such as:

(a) Five people carried the boat (an active sentence with an animate subject (the deep and surface subject are identical), and an inanimate object (the deep and surface object are identical)).

(b) The boat was carried by five people (a passive sentence with an inanimate surface subject, and therefore also an inanimate deep object).

(c) The boat carried five people (an active sentence with an inanimate subject and an animate object).

(d) Five people were carried by the boat (a passive sentence with an animate surface subject, and therefore also an animate deep object).

According to the transformational approach both (b) and (d) are passives wherein the surface subject is the moved deep object and thus must have the same animacy. After participants were primed, they were asked to describe pictures (such as a boy being awakened by an alarm clock) for which they potentially could produce either a passive or active utterance. Note that in the active form the target utterance would have an inanimate subject and an animate object:

(e) The alarm clock awakened the boy (like (a), this is an active sentence with an inanimate subject, and an animate object).

Bock et al. (1992) found an animacy effect whereby participants produced actives like (e) after being primed with sentences that contained inanimate surface subjects (such as (b) and (c)) more often than when primed with sentences that had animate surface subjects (such as (a) and (d)). In other words, the animacy effect could, under some circumstances, override their preference for producing structures with similar syntactic forms to the prime. Bock et al. (1992) interpreted this evidence as disconfirmation of the transformational grammar account of syntactic production, which was an interesting theoretical perspective and contribution however controversial.

1.3 Structural Priming in Language Production

A central issue in the understanding of syntactic representation has to do with whether syntactic knowledge is lexically independent, lexically dependent, or some combination thereof. If the representation of syntax is at least in-part lexically independent it could then be able to be characterized in terms of phrase-structure rules (Gazdar, 1985; Jackendoff, 1972) which are rewrite rules that organize the constituents of a sentence into groups of words or phrases based on their respective parts of speech such as noun (N), verb (V), or preposition (P) and then into their phrasal categories linked to those parts of speech such as noun phrase (NP), verb phrase (VP), or prepositional phrase (PP). Phrase structures are relevant to structural priming in that they are largely construed as lexically independent and therefore structural priming can provide evidence for the existence of phrase structure rules and in doing so suggests a lexical independence of syntactic structure (Pickering & Ferreira, 2008).

Pickering and Ferreira (2008) provide an example involving a prepositional object (PO) structure for *gave the girl a book* which can be rewritten into the rule VP → V NP PP meaning that this verb phrase can consist of the verb *gave* followed by the noun phrase *the book* followed

by the prepositional phrase *to the girl*. They contrast this with the example of the double-object (DO) structure *gave the girl the book* which can be rewritten as the rule VP→ V NP NP, meaning that the verb phrase consists of a verb followed by two noun phrases. Moreover, these same rules apply regardless of lexical content and therefore priming should occur even in the absence of lexical item repetition between prime and target with respect to the inclusion of closed-class (Bock, 1989) or open-class items (Bock, 1986). Priming should also be expected to happen irrespective of thematic differences between prime and target (Pickering & Ferreira, 2008; Bock & Loebell, 1990) because traditional phrase structure rules make no reference to thematic differences. Phrase structure rules relate directly to the ordering of constituents in a given sentence, thus priming should not occur if the order of constituents is altered (Pickering, Branigan, & McLean, 2002). Also, it should be noted that traditional phrase structure rules make no reference to empty categories, thus are consistent with priming from locatives to passives (Bock & Loebell, 1990) and do not undergo transformations thus supporting the direct mapping from semantics to surface structure positions (Bock et al., 1992).

According to Pickering and Ferreira (2008) the most straightforward application of the phrase-structure rule account to language production would be that speakers construct utterances by deciding which phrase-structure rules to utilize while also considering among lexically specific information. Using the example discussed previously, when choosing between the PO or DO structure in *gave the book to the girl* or *gave the girl the book* speakers select one or the other phrase structure rule. In this way, priming would serve to influence that choice based on recent application of either phrase structure rule, therefore increasing the likelihood of that one already used. According to this account, it would not make any difference whether prime and

target differed in terms of other structural aspects. Take the following as an example, sentences (f-h) all use the same rule:

(f) The boy gave the book to the girl.

(g) The boy gave the book that I liked to the girl.

(h) I think that the boy gave the book to the girl.

Tree diagrams for these sentences are shown here:

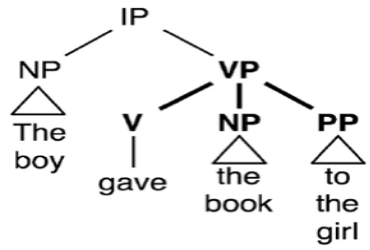

Figure 1: Tree diagram associated with sentence (f) (double object construction).

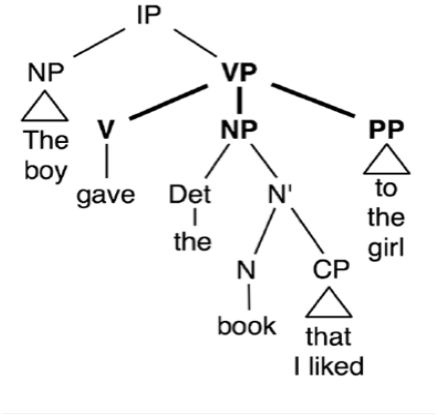

Figure 2: Tree diagram associated with sentence (g) (double object construction with adjunct phrase in direct object).

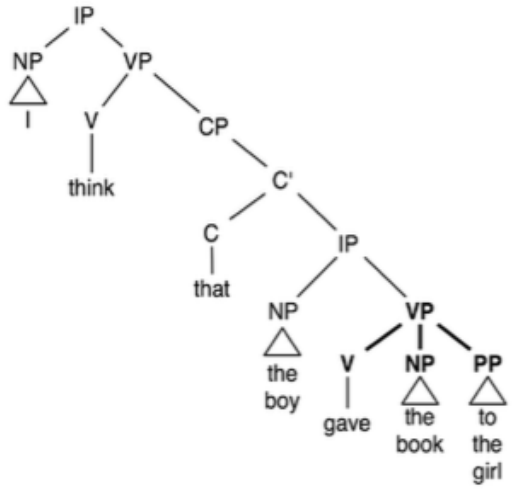

Figure 3: Tree diagram associated with sentence (h) (double object construction in an embedded clause).

In figure 1 the VP forms a portion of the main clause and includes arguments containing simple phrases. In figure 2, the difference is that there is a complex noun phrase consisting of the theme *the book that I liked* which contains a relative clause in addition to a head noun. For this relative clause, additional phrase structure rules are required but the sentence retains the key VP → V NP PP rule. In figure 3 there is a subordinate clause which includes the VP *gave the book to the girl* and as a result the phrase structure rules require additional modification to explain the relationship between the main verb (*think*) and the subordinate clause. Despite this modification, the same rule of VP → V NP PP is retained in the subordinate clause utilizing it as the same local component of the grammatical structure of the sentence, i.e. the same local tree.

If priming includes the activation of specific grammatical rules that determine the local components of the grammatical structure of a sentence then if the prime and target differ in other grammatical aspects, such as the ones just mentioned, this should not matter to achieve the priming effect (Pickering & Ferreira, 2008). Thus, if we want to prime a PO sentence such as *The woman sent the parcel to the man* then our examples (f-h) should serve equally well as

primes. Some research has suggested this to be the case, such as Pickering and Ferreira (2008) who found reliable priming when prime and target sentences contained verb phrases that differed in terms of their internal structure with respect to the complement noun phrases.

However, more relevant to our discussion of PO and DO sentence structures here, Fox Tree and Meijer (1999) had participants produce prime and target sentences that were PO or DO in nature but where one post-verbal argument was sometimes modified by a relative clause such as is the case with the following sentence: *The professor offered his students the theories (that had insulted many people).* Their results demonstrated identical priming effects regardless of whether the prime and target sentences' post-verbal arguments matched in terms of this modification, such as is the case with the inclusion, or exclusion, of *that had insulted many people* in the sentences, and still priming was observed. This provided further evidence for the notion that priming involves using a particular phrase-structure rule from one sentence to the next. In the case of Fox Tree and Meijer's (1999) work it was irrelevant to the priming effect achieved, whether or not an argument was modified by a relative clause, still subjects repeated the crucial VP→ V NP PP or the VP→ V NP NP rules.

The related issue of whether the global grammatical structure of a sentence affects priming was investigated in Branigan, Pickering, McLean, and Stewart (2006). This study provided evidence for reliable priming for dative alternation irrespective of whether prime and target sentences included simple main clauses such as *the girl gave the puppy to the boy* or whether one included a simple main clause, and the other included a complex sentence, wherein the critical structure was embedded. In fact, what was found was that priming occurred when the prime included a subordinate clause such as *John said that the girl gave the puppy to the boy* and the target included a main clause. Priming also occurred when both prime and target involved

subordinate clauses, and also when prime included a main clause and the target included a subordinate clause. Ultimately, this is taken to bolster the idea that when a particular phrase structure rule is repeated, reliable priming is observed, regardless of other phrase structure rules that may be involved (Pickering & Ferreira, 2008).

The research just discussed provides evidence for the idea that subjects can be primed for a choice in phrase structure rule. Other research indicates that the ordering of that choice can also be primed. For example, Scheepers (2003) investigated the production of relative-clause sentences in German such as the German translation for *Someone shot the servant of the actress who was on the balcony*. This type of sentence is ambiguous in English because it may be the case when initially processed that either *the servant* or *the actress* may be on the balcony (Cuetos & Mitchell, 1988). However, the German equivalents are not always ambiguous because the relative pronoun (*who* in the English translation) often agrees with the gender and number of the noun phrase. Scheepers (2003) had German-speaking participants produce primes by completing unambiguous sentence fragments such as *The assistant announced the score [masc, sing] of the candidate [fem, sing] that [fem, sing]…*, where the 'that' could only refer to *candidate*. The subjects then produced targets when presented with an ambiguous sentence fragment such as *The pensioner railed about the author [fem, sing] of the fliers [neut, plur] that…*, where 'that' could refer either to *the author* or *the fliers*. Scheepers (2003) found that when subjects encountered an ambiguous prime that required "high" versus "low" attachment, e.g. whether *score* or *candidate* would be modified by the relative clause, subjects also completed the ambiguous fragments with "high" or "low" attachments, producing a relative-clause that modified *author* or *fliers* respectively. These results did not identify what phrase-structure rule is chosen by the speaker during priming because high and low attachment consist of the same set of rules simply ordered

differently. This study, then, indicates that the order of phrase-structure rules can be primed; further research (e.g., Desmet & Declercq, 2006) has replicated this finding cross-linguistically.

Further research, beginning with Pickering and Branigan (1998), has identified a lexically dependent component to syntactic priming in language production which typically involves the repetition of the verb from prime to target (though in some studies, the noun is repeated). This phenomenon is described as open-class lexical overlap between prime and target sentences and has been labeled the 'lexical boost' in structural priming. Several other studies have confirmed this facet of syntactic priming involving sentence completion (Cleland & Pickering, 2006; Corley & Scheepers, 2002); dialogue (Branigan, Pickering, & Cleland, 2000; Schoonbaert, et al., 2007); and in the production of complex noun phrases with the repetition of the noun from prime to target (Cleland & Pickering, 2003).

Gries (2005) provided further evidence of this 'lexical boost' in corpus studies, thus there is certainly a lexically dependent component to structural priming. However, as was found by Bock (1989) and Fox Tree and Meijer (1999) this lexical dependence has nothing to do at all with content-word, or function-word repetition, such as prepositions or complementizers (Bock, 1989; Fereira, 2003; Fox Tree & Meijer, 1999). In addition, Pickering and Branigan (1998) provided evidence that there is no effect in the form of the verb used from prime to target as in the use of the past tense of the verb *show* (i.e., the use of *showed* or *shows*). Priming is not influenced by this effect. Moreover, no effect on priming was demonstrated when aspect was varied (i.e., such as in *showed* vs. *was showing*) and when number was varied (*shows* vs. *show*). Again, no effects were found. Thus, closed-class morphemes (i.e., *-ed*) and closed-class words (i.e., *to*) are processed similarly.

Hopper and Thompson (1984) discuss a discourse basis for lexical categories from the perspective of Universal Grammar. They describe how both the noun (N) and the verb (V) as lexical categories have been universal to lanuages while other lexical categories have been optional. They also suggest that changes in language have coincided with the formal descriptions of language by grammarians dating back to the antiquity. Furthermore, they suggest the role of morphemes facilitating the building up of N and V creating in turn the syntactic structures that appear to be universal to all languages (Hopper & Thompson, 1984).

N and V are what also create the basis for the theta-grid and as we'll see with the experiment described here that is the principal emprical researh contribution for the present dissertation, theta-grid creates the deep structural component of syntax that gives rise to structural priming. It is not the superficial elements of sentences that are significant; it is the unnderlying verb-argument structure that allows an utterance to conform to grammaticality;-the theta-grid or alternatively the predicate-argument structure. I also believe that these underlying deep structural facets of language are what are inborn, in a nativist sense, and are universal to all human languages.

Discourse analysis and the discovery of how lexical catergories are determined in language use is related to structural priming becuase the deep mental representation of N and V are primable through a residual activation and implicit learning which reduces cogntive load. The use of language involves a reduction in cogntive resources which is the basis for the syntactic repetition or the structural priming observed. That is, this happens ulitmately to reduce cognitive load while simultaneously acheiving communication among interlocutors during production and comprehension of language.

Menenti, Pickering, and Garrod (2012) reviewed the literature on topic alignment in conversational analysis, which is the phenomenon wherein interlocutors prime one another's speech productions at various levels of representation (e.g. from phonological to morphological to syntactic) with the goal of having a conversation about something in the world with the interlocutors jointedly attending (or aligned) to the topic of conversation. They reviewed both the behavioral resaerch from psycholinguistics and the brain imaging research from cognitive neuroscience. They contend that mental states can be primed by interlocutors because they share the same representation between people in a conversation and that those mental states also reveal the fact that brain states are also being primed and shared. The goal of this alignment is simple, that is, it facilitates joint attention and again from a nativist point of view it facilitates socio-biological fitness to the social environment as well.

1.4 (a) Structural Priming in Language Production and the Implications for the Representation of Syntax

Due to the fact that structural priming happens in the absence of the repetition of content-words, and moreover, still happens, and is enhanced by, the repetition of those content-words, seems to indicate that syntactic information is in part abstract, and in part, associated with specific lexical entities. In terms of how this is represented, there have been two possibilities put forth, a two-locus account, and a one-locus account. The two-locus account assumes two distinct mechanisms, or cognitive systems, give way to abstract priming (which is lexically independent in this case) and, also, give way to lexicalized priming (such as is the case with the observed 'lexical boost'). The one-locus account assumes a single mechanism which can explain both abstract and lexicalized priming.

Pickering and Branigan (1998) adopted a one-locus mechanism account of structural priming and the observed 'lexical boost' based on a model proposed by Levelt, Roelofs, and Meyer (1999). Levelt et al. (1999) made the assumption that syntactic information is encoded within the lemma stratum, wherein lemmas (corresponding to the base forms of words) are tied to syntactic information. Pickering and Branigan (1998) added to this account such that specific lemmas are linked to combinatorial nodes that activate when the speaker produces a particular construction of an utterance. Accordingly, what follows from this account is that priming is due to a residual activation of the lemma, and the combinatorial nodes, as well as the links between them. Specifically, residual activation of a particular combinatorial node happens during lexically independent priming. Syntactic priming of prime and target sentences sharing the same verb happens, instead, by the residual activation of the pre-activated lemma node, and, additionally, by the combinatorial node itself, as in the case with lexically independent priming.

The priming effect is typically observed to be smaller in magnitude when the verb used is different in the subsequent target sentences following the prime because it happens solely because of the residual activation of the combinatorial node. It makes no difference, however, whether the target sentences contain the same or different verbs, because the same lemma node is activated in both cases. On this account there is only one locus in both lexically independent structural priming, and the 'lexical boost' in structural priming, because what underlies the priming effect is one set of processing principles which have the same network of representations. Thus, this is counter to a two-locus account, in which the lexically independent effect and the 'lexical boost' effect are attributed to two distinct cognitive (or memory) systems (Traxler, Tooley, & Pickering, 2014).

In terms of what structural priming can say about syntactic knowledge, it appears that on the one hand, this knowledge is not fully abstract, as is made evident by the 'lexical boost' that has been observed (Pickering & Branigan, 1998; Traxler et al., 2014), and, also, by the observed semantic boost (Cleland & Pickering, 2003). On the other hand, structural priming is observed regardless of lexical content, therefore syntactic knowledge is not full lexicalized. There appears to be a lexical-syntactic interactionism which can be represented with combinatorial nodes when it comes to structural priming, whereby syntactic knowledge is represented independently of lexical knowledge, however, can be influenced by the ongoing lexical processing that happens when language is used (Pickering & Ferreira, 2008). This is the case for language production and is applicable to the issues of concern in comprehension as well.

1.5 Structural Priming in Language Comprehension

Branigan and Pickering (2016) suggested that structural priming as an experimental paradigm could provide a useful alternative to the use of acceptability judgements as a way to determine the grammaticality of an utterance. This is because a construction that is more likely to be produced, or that is comprehended more rapidly, may be somehow cognitively "privileged", in the sense that it may require fewer cognitive resources. Hence, priming effects could reveal aspects of the participants' underlying knowledge of the structures of their language but based again on implicit psychological processes rather than subjective preference. Acceptability judgements, on the other hand, can be unreliable because asking someone explicitly to evaluate the well-formedness of some construction is susceptible to possible confounds (for example, participants may try to determine what the experimenter would like them to say). This makes structural priming not simply an invaluable psycholinguistics phenomenon to be studied in its

own right but a helpful experimental paradigm to investigate language processing and aspects of linguistic representation.

Until recently, there has been less empirical and theoretical work on priming in comprehension. There are several reasons for this; for instance theories of comprehension focus less on the representational aspects of language than do theories of language production, instead focusing on processes such as syntactic ambiguity resolution; the time course of comprehension; whether the processor can consider more than one analysis simultaneously; and how syntactic processing can be affected by semantic processing (Pickering & Ferreira, 2008). This section provides a review of the literature on structural priming in comprehension and describes how this research has been informative about language comprehension.

If we consider how priming research may impact an understanding of language comprehension, we would expect it to illuminate an understanding for how people construct structural representations. The questions we might propose, then, might include the following: do people construct one, or more than one, level of representation? Are those representations constructed in terms of grammatical relations, thematic roles, or both? Structural priming in language comprehension is of particular interest to linguists and psycholinguists because it may provide a means to investigate how such structural representations develop over the life-course in ways that the research in priming in language production has not been able to do. These issues, among others, will be considered below.

According to Pickering and Ferreira (2008) in the psycholinguistics literature, there are considerably more studies on comprehension than on production, which is why it may be surprising that there is less priming literature on comprehension, as compared to production. For the first ten or so years of structural priming research there has been a complete dearth of studies

that looked at whether a target sentence is more easily processed if preceded by an exemplar with the same syntactic structure during language comprehension. Pickering and Ferreira (2008) claim that the lack of research into the impact of structural priming on language comprehension is interesting because such studies would be modeled on the prior priming research that has been done in production, such as the original study, in Bock (1986), and on other comprehension research that has preceded it, such as Meyer and Schvaneveldt (1971).

Still more, the research on priming from one modality to the other, as in from comprehension to production (e.g. Branigan, Pickering, & Cleland, 2000; Levelt & Kelter, 1982; Potter & Lombardi, 1998) predates, and provides an impetus and direct evidence for, priming in comprehension. Since the early 2000s, studies have begun to demonstrate that structural priming can occur in language comprehension; that is to say, reading a particular prime sentence can ease the processing of reading a subsequent target sentence if they both instantiate the same syntactic structure (Pickering & Traxler, 2004; Branigan, Pickering, & McLean; 2005; Arai, van Gompel, & Scheepers, 2007; Ledoux, Traxler, & Swaab, 2007; Weber & Indefrey, 2009). These studies, however, have revealed more of a lexical dependency in structural priming of comprehension, requiring lexical repetition from prime to target in order to achieve the priming effect. Pickering and Traxler (2004) required participants to read difficult garden-path sentences presented in prime-target pairs such as the following, while having their eye movements or EEG recorded:

(i) Prime: The man *watched* by the woman was tall and handsome.

(j) Target: The child *cleaned* by the girl was covered in chocolate.

These examples share the same syntax, but Pickering and Traxler found that reading this prime *did not* facilitate reading of this target. If the prime and target share the matrix verb as well as the same syntax, however, then priming is observed such as in the following sentences:

(k) Prime: The man *watched* by the woman was tall and handsome.

(l) Target: The mouse *watched* by the cat was hiding under the table.

Under these conditions priming was observed in naturalistic reading using eye-tracking (Pickering & Traxler, 2004; Traxler & Tooley, 2008); and EEG studies targeting the P600 ERP response to the disambiguating portion of reduced-relative sentences also revealed an attenuated brain response to this manipulation (Ledoux et al., 2007; Tooley et al., 2009).

Other studies examining comprehension priming have tried to match task paradigms and stimuli from the production research. Arai, et al. (2007) used ditransitive sentences similar to those used in production research as in Bock (1986) which took either the DO (double-object) or PO (prepositional object) structure. Some examples of sentences from Bock (1986) were the DO form of the sentence *The lifeguard tossed the child a rope* and the prepositional object dative like *The lifeguard tossed a rope to the child*. Arai et al. (2007) showed participants pictures depicting the subject, the theme object, and the recipient object of each sentence and fixations to these pictures were recorded using eye-tracking. Following the reading of a DO prime sentence, participants made the assumption that the NP after the verb would be the same in the target sentence as it had been in the prime, so they fixated longer when this was different (Arai et al., 2007; Tooley & Traxler, 2010). Again, this priming was observed within the context of verb repetition, leading Arai et al. (2007) to claim that structural priming in comprehension differs from priming of production, in that the former is entirely lexically dependent.

However, some studies have found structural priming of comprehension in the absence of verb repetition. Thothathiri and Snedecker (2008a) utilized eye-tracking and a task similar to Arai et al. (2007) except that the 3-4 year old participants heard two prime sentences before acting out the targets with toy representations of the recipients and objects. Thothathiri and

Snedecker interpreted their findings as suggesting that young children show evidence of structural priming, hence (at least at certain ages) priming in comprehension can happen without verb repetition. The studies that did not observe this may not have been as sensitive as the others and simply were unable to detect it; or it may be that structural priming in comprehension is only observable at certain developmental stages. Perhaps this is related to critical periods in language development because some studies like Arai et al. (2007) recruited undergraduate students as subjects, Thothathiri and Snedecker (2008a) worked with young children who hadn't learned to read yet and so used a different method to demonstrate their understanding, while Thothathiri and Snedecker's (2008b) were adults. Overall, structural priming effects observed in comprehension appear to be greater in magnitude with verb repetition than without, which has also been the finding in structural priming in language production.

Branigan et al. (2005) presented participants with sentences such as the following:

(m) The policeman prodded the doctor with the gun.

This expression can be taken to mean, in the verb attachment analysis, that the policeman used the gun to prod the doctor; or, in the noun attachment analysis, that the policeman prodded the doctor who had the gun. Having read the primes, participants were presented with two pictures, one that corresponded to one or the other interpretation and one that did not. Then participants were presented with another set of structurally similar targets and two more pictures, with each picture matching a possible interpretation. When the verb was repeated from prime to target, participants more frequently chose the picture that corresponded to the analysis assigned to the prime. Priming was stronger when there was verb repetition than when there was not; and in the absence of lexical repetition, this tendency was not reliably observed. These findings are very similar to Pickering and Branigan's (1998) results, wherein the same- verb experiments showed

significant priming effects but the different-verb conditions did not. These experiments elucidate what leads participants towards a final choice analysis; however, they are less informative about the processes underlying these interpretations (Traxler & Tooley, 2007).

Pickering and Traxler (2008) investigated the comprehension of reduced-relative clause sentences in six eye-tracking experiments, including sentences such as

(n) The speaker proposed by the group would work perfectly for the program.

One of their findings was that, initially, participants tended to assume that the NP *the speaker* was the agent of *proposed*. When participants then encountered the phrase *by the group*, the original analysis caused a processing difficulty (Ferreira & Clifton, 1986; Trueswell et al., 1994). At this point, the participant would reinterpret the sentence as a reduced-relative construction. The difficulty was reduced when the reduced-relative target was preceded by a reduced-relative prime, but only when there was a repetition of the lexical item (i.e. the verb) in prime and target sentences. The other experiments in this paper showed that this effect also held for relative, short-relative, and passive constructions.

Pickering and Ferreira (2008) suggested that all these syntactic constructions share a level of representation during comprehension. For example, all the constructions that involve a reduced-relative clause involve an initial patient/theme argument, so one possibility is that the binding of the first noun phrase, as the patient of the verb, is the site of priming, and thus suggests that priming affects the early stages of comprehension. Moreover, structural priming in online comprehension appears to transfer *between* related constructions (Kaschak, 2006) while in language production priming appears to transfer *across* constructions (Bock & Loebell, 1990).

Traxler (2008) showed that structural priming of instrumental phrases was greater when the prime contained an instrumental prepositional phrase than when it contained an agentive

prepositional phrase. Pickering and Ferreira (2008) suggest that this kind of priming may be sensitive to a level of representation wherein the different types of prepositional phrases are distinguished, or that 'semantic relatedness' facilitates the priming observed. Ledoux, Traxler, and Swaab (2007) conducted a similar study using ERPs, and found that the P600 component, a positivity related to syntactic ambiguity resolution, was attenuated following a prime that also contained a reduced relative construction. This was taken as evidence that this priming is syntactic in nature (Pickering & Ferreira, 2008).

Traxler and Tooley (2008) argued against a 'strategic interpretation' of syntactic priming in comprehension, suggesting that verb repetition is essential for any structural priming to occur. However, in a study on the resolution of prepositional phrase attachment ambiguities, Traxler (2008) did find priming in the absence of verb repetition. These studies, and others like them, seem to indicate, at the very least, that verb repetition certainly enhances priming in comprehension but it is unclear when verb repetition is not essential for priming (Pickering & Ferreira, 2008).

1.6 The Mechanistic Accounts of Syntactic Priming in Language Comprehension and the Implications for the Representation of Syntax

Tooley and Traxler (2010) presented some potential reasons why there is a need for verb repetition for priming to happen during comprehension, but not in language production. In the Paradigm/Stimuli Differences Account, the observed need for verb repetition in comprehension priming, compared to the mostly lexically independent priming of production, relates to the differences in the paradigms and stimuli that are used in the two areas of study. For example, they point out that the DO (double object) and PO (prepositional object) stimuli used in many of the production experiments are more common constructions than the reduced-relative clause

constructions used in comprehension research. Moreover, production studies tend to use behavioral measures like picture-description tasks while the comprehension studies have used online measures such as ERP and eye-tracking. Thus, it is difficult to compare the results in the two areas because of the different paradigms used. This discrepancy has led to a false conclusion that production is more sensitive to structural priming effects than comprehension. The small effect sizes observed in both areas support this claim and make it particularly difficult to detect priming in the comprehension research.

The second possibility discussed by Tooley and Traxler (2010) is the Processing Differences Account. In this account production and comprehension are seen as being two different processes, because they happen in reverse order to one another. In production, processing happens first by selecting an appropriate syntax, then the relevant lexical items are selected, and then phonological information is activated to produce the message.

Comprehension, on the other hand, works in reverse order. Processing begins with the phonological input, which is used to build lexical and finally syntactic representations. In both modalities, however, there are sub-processes at work, and the ordering of these differs subtly between the two modalities (Bock, 1990; Levelt, 1989; Levelt et al., 1999). When a person plans an utterance, they begin with an idea which is immediately constrained by syntactic choices (Bock, 1990). In contrast, in comprehension the order of words constrains the choice of possible syntax, an observation that is especially true of verbs, because they constrain both syntax and thematic relations. It is not surprising then that there is such a dependency on verb repetition for structural priming in comprehension.

The third possibility outlined by Tooley and Traxler (2010) is referred to as the Different Mechanisms Account. In this account, assumptions are made that 1) lexically dependent priming

effects exist only in comprehension and that 2) lexically dependent and lexically independent priming effects are due to different underlying mechanisms. This is a strict interpretation of the literature that may seem somewhat controversial; however, it illuminates the debate that exists between the Residual Activation Account (Pickering & Branigian, 1998; Pickering & Traxler, 2004) and the Implicit Learning Account (Bock & Griffin, 2000; Chang et al., 2006).

Within the Residual Activation Account the mechanism for syntactic priming observed in language production involves a residual activation for syntactic structures during priming in production processing. Pickering and Branigan (1998) describe this mechanism based on Levelt's model of speech production (Levelt, 1989) and Roelofs' lemma stratum (Roelofs, 1992; 1993). According to this account words are represented and activated at an initial conceptual level, then activation spreads to a lemma stratum, where the combination of linguistic categories and possible syntactic structures (i.e. combinatorial nodes) exist. Then activation spreads to a level where phonological and morphological information is activated, at a word-form level; this activation can in turn lead to the representation and production of speech sounds. When a prime sentence is processed, there is a residual activation affecting that structure's combinatorial nodes. This residual activation is retained for a short period of time and can spread to other verbs that take the same structure specified by those combinatorial nodes, leading to an increased probability that the structure will be reproduced in subsequent speech production (Tooley & Traxler, 2010).

The residual activation account is supported by findings of both lexically independent and lexically dependent priming in language production. The model suggests that when syntax has been recently produced, there is a residual activation for that syntax, which implies that lexically independent priming should be observed because the shared combinatorial node retains

activation regardless of what lemma will be produced in the target. More residual activation exists for lexically dependent priming (i.e. the effect of lexically independent priming plus a 'lexical boost'; Traxler, Tooley, & Pickering, 2014). Bock and Griffin (2000) found that lexically independent priming of an utterance decays relatively slowly, in one case it lasted for ten intervening filler sentences beyond the prime. This indicated that that the mechanisms giving rise to priming are less transient than a residual activation account allows, leading Bock and Griffin to posit an implicit learning account of structural priming instead.

According to the implicit learning account (Bock & Griffin, 2000) there are longer term implicit learning effects observed in structural priming. Implicit learning is viewed as the unconscious acquisition of abstract information processing routines over time (Tooley & Traxler, 2010). This approach has been implemented as a computational model wherein repeated exposure to a particular syntactic construction strengthens connections between elements of that structure in a simulated neural network. There are certain criteria that must be met in order for implicit learning to happen: 1) the learning must be abstract and rule-based; 2) the rules learned are not explicit; 3) learning is gained by the coincidence of the cognitive processing of information involved in the task; and 4) this kind of learning is preserved in amnesiacs (Seger, 1994).

Bock and Griffin (2000) claim that the implicit learning mechanism can give rise to structural priming, which reflects enhancing strengths of connections between representational units of the network that supports the syntactic structure. In support of this view, Bock and Griffin (2000) demonstrate long-lasting effects of structural priming in production lasting for over ten subsequent filler sentences between trials of prime and target pairs. These longer-term effects cannot be accounted for by residual activation, which predicts short-lived effects that

degrade quickly (Carminati & van Gompel, 2009; Pickering, McLean, & Branigan, 2013). In this way, lexically-dependent priming and the so called 'lexical boost' (Traxler, Tooley, & Pickering, 2014) that has been observed do not result from the residual activation of lemmas, but from an implicit learning of the verb that is repeated. This verb provides a cue for the processor to repeat the structure that was uttered in the prime sentence, leading to the boost effect. Chang et al. (2006) and Gries (2005) found further support for implicit learning in structural priming, using a connectionist recurrent network and linear models of corpus data respectively. Thus, results from this body of research indicate that a longer-term mechanism involving implicit learning is responsible for the facilitation of syntactic structure.

The two mechanistic accounts just described are put together in what is referred to as a Dual Mechanism Account, which may provide the most comprehensive account for the empirical observations and their theoretical implications. According to the Dual Mechanism Account, lexically independent priming effects are due to implicit learning, while lexically dependent priming effects are due to residual activation. Hartsuiker, Bernolet, Schoonbaert, Spreybroeck, and Vanderelst (2008) provide evidence for this account, showing that in both spoken and written production tasks priming persisted for up to six intervening sentences. However, in verb repetition conditions, the magnitude of the priming effects did not persist within any of the intervening structures. This suggests that while the persistence of structural priming in production is relatively long-lived for lexically-independent stimuli, lexically dependent priming effects are more transient in comparison. This implies that the two forms of priming, lexically independent and lexically dependent priming, are modulated by two different underlying mechanisms.

The Dual Mechanism Account predicts verb-specific priming effects like those observed in the comprehension literature. Moreover, this account would predict that the lexically dependent priming effects observed in comprehension are due to residual activation rather than to implicit learning, and Carminati and van Gompel's (2009) finding that syntactic priming effects appear to persist for only two intervening sentences supports this position. The Dual Mechanism Account appears to provide the best mechanistic account for the structural priming effects observed in comprehension (Tooley & Traxler, 2010).

2. Methods

2.1 Introduction to the Experiment

In this dissertation for the empirical study, I used eye- tracking methodology to look at online sentence processing and to examine parsing and priming effects in Passive sentences with two types of *by*-phrase constructions: the agentive *by*-phrase and the temporal *by*-phrase. For example, I used sentences like (o) and (p) below:

(o) *The deliveryman was expected by the secretary but he arrived too late.* (agentive *by*-phrase)

(p) *The student was expected by the afternoon and she passed with flying colors.* (temporal *by*-phrase)

These constructions are of interest because the agentive *by*-phrases assign thematic role to the main verb while the temporal *by*-phrases do not. By contrasting these, we can examine the level at which structural priming is more influenced by thematic roles or by lexical identity. That is to say we can determine whether there is priming of event structure as with the temporal *by*-phrase or priming of argument structure as with the agentive *by*-phrase.

The goal of this study is to provide an empirical contribution to an understanding of the structural priming of prepositional phrases and to say something about how they are processed and represented. In particular, I am interested in whether priming occurs at a relatively superficial level whereby similar structures prime each other regardless of deeper properties like thematic role assignment, or if priming operates over more grammatically complex mental representations.

This study makes use of eyetracking as an empirical method to evaluate processing time by measuring eye fixations and regression to specific areas of interest (AOIs) in a written sentence. The study offers a way to evaluate three alternative hypotheses about how priming is effective in parsing of these passives and how that relates to the nature of representation. The hypotheses specifically relate to processing of passive constructions, specifically the by-phrase. I later describe analyses based on processing in other regions of the passive sentences for the fixations in those regions as well as gaze regression analyses in all of the AOIs.

2.2 Hypotheses and Predictions

Hypothesis 1: Surface Priming

The first observation one would expect of the passive sentences is that priming would occur across-the-board based on superficial similarity of syntactic constructions, without regard to whether the *by*-phrase assigns thematic roles (as in the case of the Agent *by*-phrase), or not.

Predictions. Based on Hypothesis 1, I predict that priming of *by*-phrases will occur across-the-board. Agentive *by*-phrases will prime themselves; temporal *by*-phrases will prime themselves; agentive *by*-phrases will prime temporal *by*-phrases, and temporal *by*-phrases will prime agentive *by*-phrases.

Hypothesis 2: Selective Priming by Phrase Type

The second hypothesis is that representation of phrase types is differentiated in terms of the functional role that they play in the sentence; for example, whether or not they assign thematic roles such as agent, or if they are more adjunct-like in merely indicating the temporal contours of the event.

Predictions. Based on the second hypothesis, I predict that priming will occur within construction types, but not across construction types. Agentive *by*-phrases will prime agentive *by*-phrases and temporal *by*-phrases will prime temporal *by*-phrases, but there will be no cross-priming between them.

Hypothesis 3: Priming by Verb Argument Role Assignment

The third hypothesis is that priming only occurs in cases where the by-phrase assigns a thematic role, in this case the role of Agent to the underlying subject of the passivized verb. In other words, priming will selectively affect these structures.

Predictions. Based on the third hypothesis, it can be predicted that only the agent by-phrase will be subject to priming. Temporal *by*-phrases are too "light" in this sense and are not amenable to effects of priming. Given that the Agentive *by*-phrases are primable, the question arises "by what?" Clearly Agentive *by*-phrases will be primed by similar *by*-phrase constructions, but there is an open question as to whether Agentive *by*-phrases can be primed by temporal *by*-phrase primes. While not specifically predicted by this hypothesis, cross-priming in this case cannot be ruled out.

2.3 Participants

11 participants from William Paterson University in Wayne, NJ participated in the experiment for course credit. All of the participants were Native-English speakers (some bilingual-5 participants) with normal (or corrected to normal) vision and hearing. There were 6

females and 5 males ranging in age from 18-25 years. The average age was 20 years (*SD* = 2.41 years). They all had normal vision or corrected to normal vision (none wore contact lenses, 3 wore eye-glasses). They were of middles class backgrounds with approximately an educational level of a second year college student.

2.4 Methods and Materials

See complete list of experimental stimuli in Appendix 1. Participants were told that they were to be assessed on a brief memory task (see Appendix 2 for instructions given to participants). Items in the memory test were based on comprehension of the prime and target stimuli that were presented as well as the filler items. Post-study items, that tested comprehension of the presented sentences, were given after the experiment, aloud, in the form of true and false questions (see Appendix 2). The experiment consisted of presenting 24 pairs of prime and target sentences, each pair separated by 3 filler sentences. The prime and target pairs were all passives and contained either an agentive prepositional *by*-phrase or a temporal prepositional *by*-phrase. All sentences were presented on-screen for 5 seconds each with an ITI of 1 second. In all the experiment lasted about 7 minutes for each participant. Prime-target pairs were of four types: agentive prepositional phrase (PP) primes with temporal PP targets; agentive PP primes with agentive PP targets; temporal PP primes with agentive PP targets; and temporal PP primes with temporal PP targets. For example, the conditions looked something like the following to the participant (P = Prime, G = Target, and F = Filler):

P1 (Passive w/agentive by-phrase) The deliveryman was expected by the secretary but he arrived too late.

G1 (Passive w/temporal by-phrase) The student was expected by the afternoon and she passed with flying colors.

F1 (filler) The corrupt inspector offered a deal to the bar owner.

F2 (filler) The secretary is baking a cake for her boss.

F3 (filler) The lifeguard tossed a rope to the struggling child.

and so on until the 12th prime-target pair and then they were presented in reverse order for the total of 24 pairs altogether for control by way of counterbalancing. In this way each passive sentence appeared once as a prime, and once as a target of priming. Half of the trials involved a matched prime-target pairing (i.e., AGENT PRIME + AGENT TARGET or TEMPORAL PRIME + TEMPORAL TARGET) meaning they the prime and the target 'matched' on type of syntactic structure. The other half of the stimuli involved a mismatched prime-target pairing (i.e., AGENT PRIME + TEMPORAL TARGET or TEMPORAL PRIME + AGENT TARGET) mean the prime target pair mismatched on syntactic structure. In this way, it was possible to test whether priming was stronger in matched conditions vs mismatched conditions. Thus, the control was established by organizing the presentation of the stimuli as well as the design and data analysis so that target sentence duration of fixation was compared with prime sentence duration of fixation which compared different syntactic constructions to the alternative construction.

2.5 Measuring Priming Effects

Given that each passive sentence appeared once as a prime and once as a target, these were segregated by MATCH vs. MISMATCH priming conditions. That is, if a passive sentence was used as a prime in a *match* (wherein sentences matched on syntactic structure) condition, it would appear as a target in a *mismatch* (wherein sentences mismatched on syntactic structure) condition and vice versa for all conditions. Given this design constraint, we were able to test for precise priming effects based on fixation times for the exact same sentences. For example, if an agent passive was presented as a prime in the *match* condition (i.e., Agent Prime + Agent Target), then fixation times would be compared with that same sentence in Target position in a *mismatch* condition (Temporal Prime + Agent Target), and so on for each of the conditions. In

this way, comparing fixation times between primes and targets involved the same sets of sentences, in distinct prime-target pairings. This has to do with the nature of the counterbalancing I used to control in the experiment and to measure priming effects.

2.6 Apparatus

The apparatus for the experiment consisted of a portable data acquisition computer (Apple MacBook Pro 2018) and 15" Lenovo Monitor. The eye-tracker used was a Gazepoint eye-tracker connected into the data acquisition computer via USB drive. All participants were seated approximately 18" away from the Gazepoint System before the eye-tracker was calibrated. Here are some images of what the system looked like:

Figure 4: GazePoint Eye-Tracking System.

The stimuli consisted of .pdf files with the experimental stimuli centered on them in landscape orientation in Times New Roman font (size 22 pt.). Figures 5 and 6 below provide examples of the stimuli with AOIs drawn over the agentive prepositional *by*-phrase (blue rectangle), the NP (det N) (red rectangle), and the VP (aux V) (yellow rectangle) in Figure 5 and the temporal *by*-phrase stimuli (blue rectangle), the NP (det N) (orange rectangle) and the VP (aux V) (pink rectangle) in Figure 6.

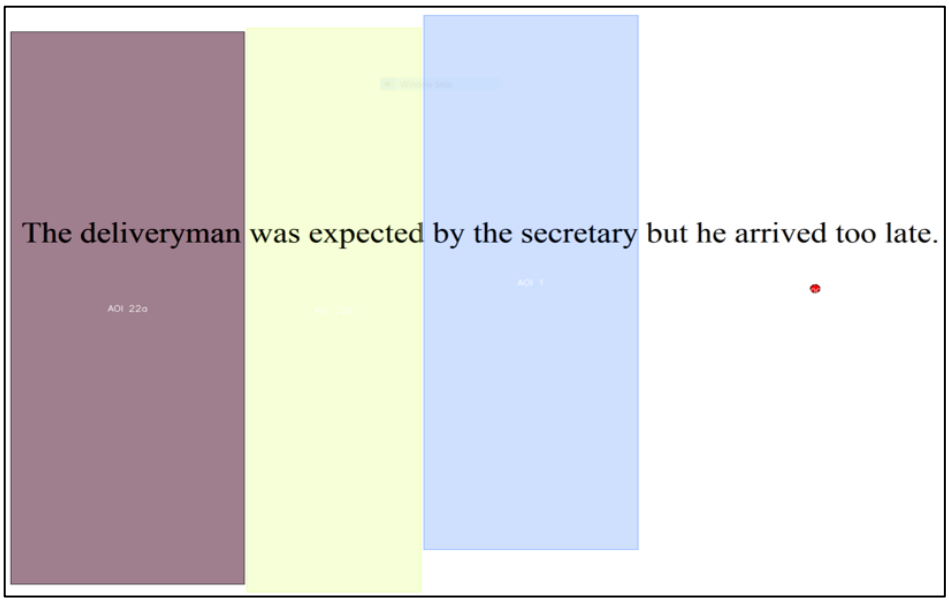

Figure 5: Example of how AOIs were drawn on the agentive *by*-phrase stimuli.

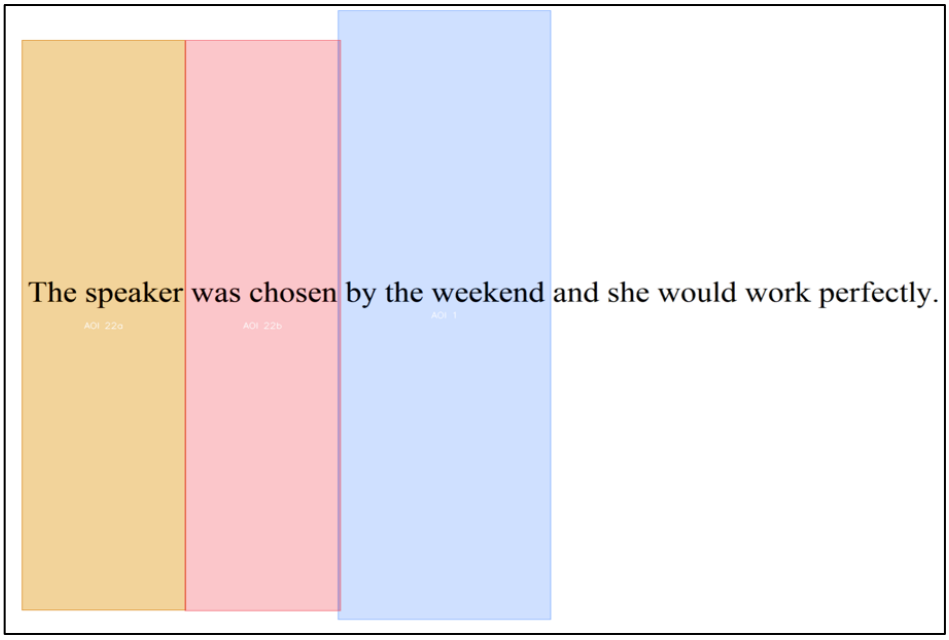

Figure 6: Examples of how the AOIs were drawn over the temporal by-phrase stimuli.

Figure 7 below provides details of the set-up for the apparatus and how the participants were seated at it:

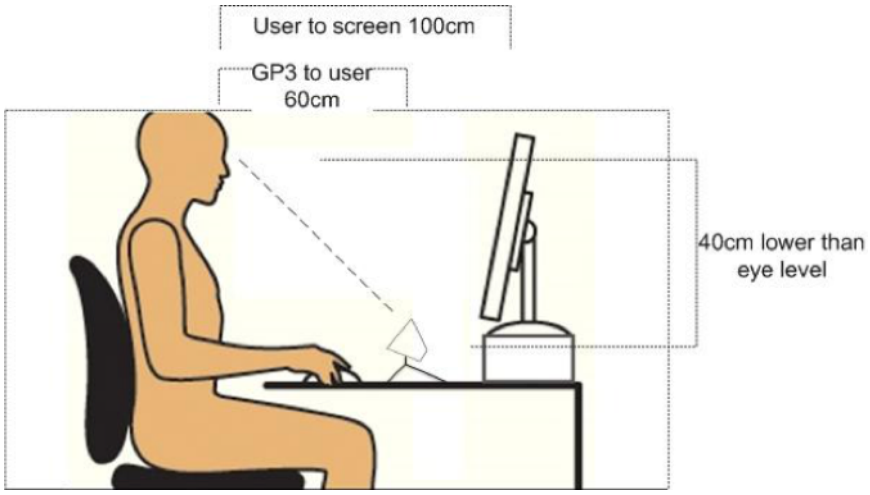

Figure 7: Schematic showing how Participants were Seated at the System.

3. Results

3.1 Fixation Duration Data Analyses for the Prepositional by-Phrase (PP), NP (det N), and VP (aux V) AOIs

As outlined in the Methods section, each passive sentence appeared once as a prime and once as a target. If the sentence was a prime in a match condition (Prime-Target = Agentive-Agentive or Temporal-Temporal), then it appeared as a target in a mismatch condition (Agentive-Temporal or Temporal-Agentive). In order to assess the effects of priming, fixation times were compared for the same sentences in both prime and target roles. Significant differences in these comparisons indicate effects of priming, while offering maximal control for other sentence properties such as sentence length, word frequency and so on.

Fixation times were recorded in eight conditions. These are designated here by 3-letter combinations representing the kind of Prime (T or A for Temporal or Agentive), the Target (again T or A for Temporal or Agentive), and finally whether the fixation time relates to the Prime (P) or the Target (G) presentation. Priming effects were evaluated for the target conditions

(XYG) by comparing them to the same sentences in the priming condition (YXP). If fixation times were significantly shorter when a sentence is in the target position (G) than in the priming position (P), this was considered to provide evidence for a priming effect for the Target condition. Within the target conditions, prime and target were either matched (AAG, TTG) or mismatched (ATG, TAG).

This labeling schema provides distinct labels for eight conditions, as follows; an example of prime-target pairs for each condition are also provided:

AAP: The review was chosen by the author and it was impressive.
The speaker was chosen by the chairperson and she would work perfectly.

AAG: The speaker was chosen by the chairperson and she would work perfectly.
The review was chosen by the author and it was impressive.

TTP: The author was chosen by the late evening and he was impressive.
The speaker was chosen by the weekend and she would work perfectly.

TTG: The defendant was sent by the afternoon but he arrived late.
The referee was sent by the afternoon and he had excellent vision.

ATP: The student was accepted by the dean and she was very pleased.

The student was accepted by the end of the afternoon and she had a mole on her lip.

ATG: The thief was recognized by the victim and was held for questioning.

The victim was recognized by the morning but he was in bad shape.

TAP: The manager was terminated by the end of the day because he was not a good fit with the firm's needs.

The accountant was terminated by the businessman because he wasn't qualified.

TAG: The referee was sent by the afternoon and he had excellent vision.

The student was accepted by the dean and she was very pleased.

The following pairs of conditions were therefore compared to evaluate priming effects:

1. ATP vs. AAG = priming of agent targets in the match condition (priming was observed)

Ex. Prime (ATP) The student was accepted **by the dean** and she was very pleased.

Ex. Target (AAG) The review was chosen **by the author** and it was impressive.

2. AAP vs TAG = priming of agent targets in mismatch condition (priming was not observed)

Ex. Prime The review was chosen **by the author** and it was impressive.

Ex. Target The student was accepted **by the dean** and she was very pleased.

3. TAP vs. TTG = priming of temporal targets in match condition (priming was not observed)

4. TTP vs. ATG = priming of temporal targets in mismatch condition (priming was not observed)

Here we want to compare the fixation duration of the by phrase in the first sentence in 1. to the agentive by phrase in the second sentence in. second example in 2. Paired samples t-tests

were conducted to compare mean fixation times between primes and targets in the matched and mismatched conditions. Alpha level for significance was set at $p \leq .0125$, which is the value corrected for post hoc type I error, using the Bonferroni correction for 4 comparisons (0.05/4 = .0125). The effect size used was Cohen's d (Cohen, 1992), a commonly used effect size when there is a need to compare the difference between means as in the t-tests used in the data analysis here. According to Cohen (1992) Cohen's d ranges from d = 0.2 which considered to be ‘'small' effect size to d=0.5 which would be considered to be a 'medium' effect size to d=0.8 which is considered a 'large' effect size. The main area of interest that is predicted to show priming effects is within the PP, which could be either agentive or temporal. The regions prior to the PP (NP and VP) were not predicted to show any priming effects. The hypotheses outlined above permit prediction of the following effects for PP priming:

Hypothesis 1 Surface Priming Priming effects should occur across the board for Agentive and Temporal conditions, both Matched and Mismatched.

Hypothesis 2 Priming by phrase type Priming effects should occur only in matched conditions for both Agentive and Temporal passives.

Hypothesis 3 Selective priming by Role assignment: Priming should only occur in conditions where there are major functional role assignment processes. In this case, priming is only predicted in the Agentive passives for matched conditions.

3.2 Priming Effects for by-phrase (PP) region

Data from the experiment for the PP segment are shown in Table 1 and Figure 8 below. All figures here show mean fixation times in seconds for the specified AOI (NP, VP, PP) with standard error bars indicated for each column. Bars are shown in pairs where the first bar represents fixation for the prime condition and the second bar for the target condition. As noted

previously, differences between two bars represent differences in fixation times to the same sentences in their prime and target conditions. Within the PP, there was only one significant priming effect, which was for the Agentive by-phrase in the Matched condition (mean fixation times: ATP = 0.93s, AAG = 0.71s, t (10) = 5.044, p = 0.003, d =.65).

The effect observed for ATP_AAG wherein an agentive prime actually primed the agentive target was robust and with a medium effect size. This observation allows us to understand that in language comprehension, or in the language processing that goes on during comprehension, there is, at least in the case of a passive agentive by-phrase a facilitation made by the mental representation of that syntactic structure for processing. I earlier described how this could happen, namely through a combination of implicit learning and residual activation for those structure as was described in section 1.6 earlier. The fact that significant effects were not found for the other combinations in this study may have something to do with the limitations of the design and analysis, or that there is something significant about the mental representation of agentive versus temporal by-phrases.

None of the other comparisons were either significant or approached significance. This pattern of effects supports hypothesis 3, that priming only occurs with matched priming in the AGENT by-phrase condition. Moreover, in this situation priming only occurs in cases where the *by*-phrase assigns a thematic role, in this case the role of Agent to the underlying subject of the passivized verb. In other words, priming will selectively affect these structures. This was the only significant finding of all the paired samples t-tests performed; however, it was a rather robust finding as indicated by the effect size d=0.65. However, this observation should be read cautisouly given the low sample size (which was n=11), the relatively arbitrary threshold for

statistical signficane stemming from the Bonferroni correction, and potentially misleading analyses based on aggregate data.

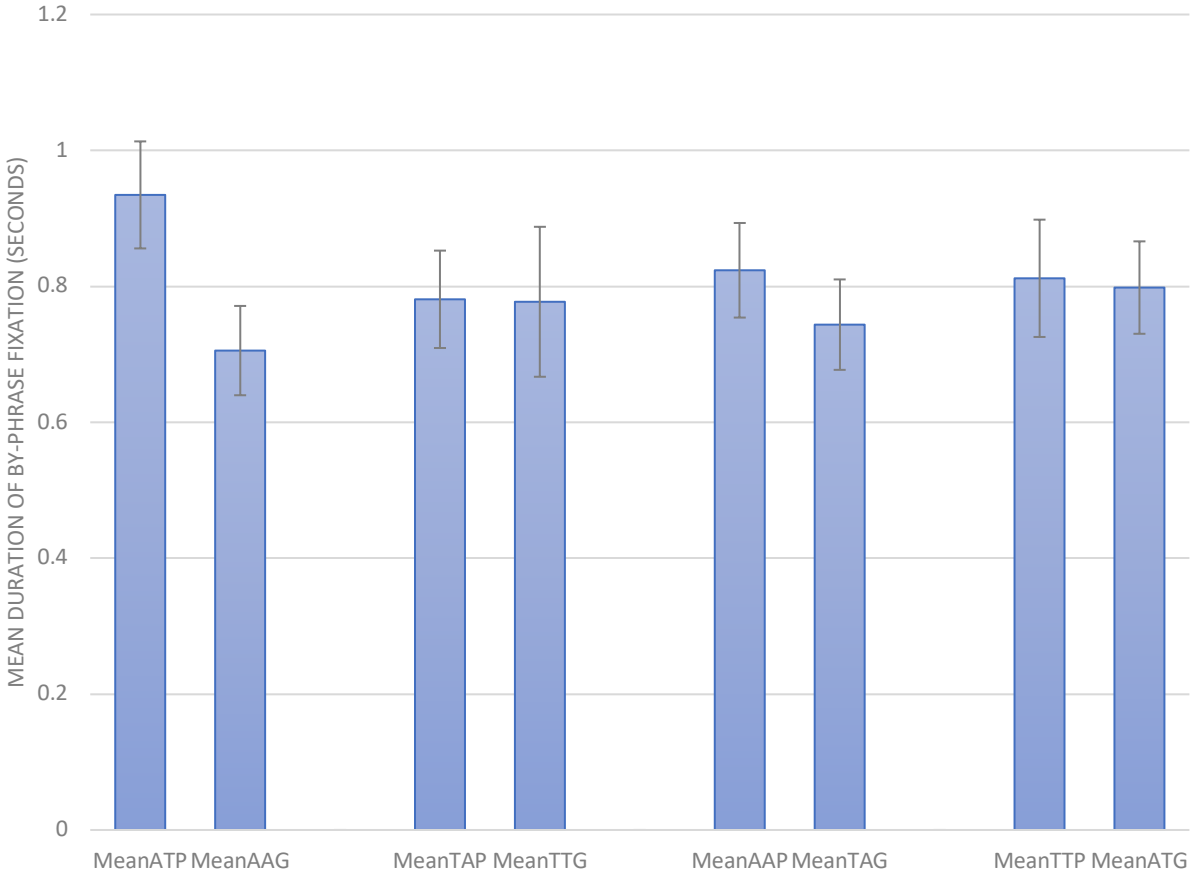

Figure 8: Mean by-phrase fixation times

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). Error bars indicate standard error of the mean.

Table 1: Comparisons for by-Phrase Fixation Times (ms) between conditions

Comparison*	ATP_AAG	TAP_TTG	AAP_TAG	TTP_ATG
Mean fixation time in seconds (SD)	ATP = .93 (.26) AAG = .71 (.22)	TAP = .78 (.24) TTG = .78 (.37)	AAP = .82 (.23) TAG = .74 (.22)	TTP = .81 (.29) ATG = .80 (.23)
t (df)	5.044 (10)	.049 (10)	1.052 (10)	.252 (10)
p (alpha ≥.0125), *d*	.003, .65	.481, 0	.159, .25	.400, .03

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). *d* = Cohen's d.

3.3 Priming Effect Analysis in the NP and VP regions

For the NP (det N) AOIs, one would not expect priming effects in terms of reduction in fixation on this AOI because this is the first phrase in the sentence where structural properties of predicates have yet to be generated. Looking at NP fixation times provides a control case that

contrasts with the analysis of the *by*-phrase. The lack of priming effects within the NP region assures us that such effects only occur within the critical region where temporal and agentive passives are disambiguated and processed. For the aux-Verb (VP) AOIs, one might expect some reduction in fixation on these AOIs due to priming of the general passive structure within this region. However, we would not expect there to be differences in priming between conditions because all passives in this condition are primed by either matched or mismatched primes that are not yet disambiguated within this region.

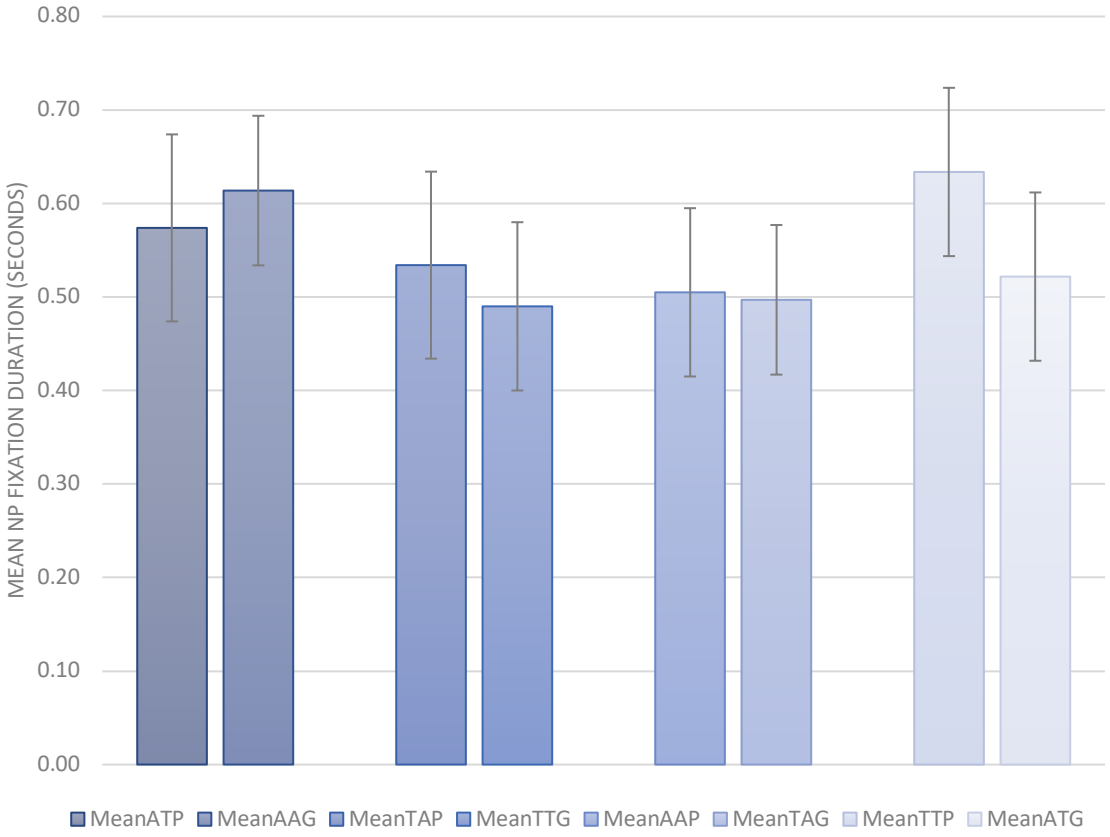

Figure 9: Mean NP fixation times

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with

Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). Error bars indicate standard error of the mean.

Table 2: Comparisons for NP Fixation times (ms) between conditions

Comparison*	ATP_AAG	TAP_TTG	AAP_TAG	TTP_ATG
Mean fixation time in seconds (SD)	MeanATP=.57 (.33) MeanAAG=.61(.32)	MeanTAP=.53 (.37) MeanTTG=.49 (.27)	MeanAAP=.51 (.33) MeanTAG=.50 (.29)	MeanTTP=.63 (.31) MeanATG=.52 (.25)
t (df)	.550 (10)	.383 (10)	.121 (10)	1.525 (10)
p (alpha $\geq$.0125), *d*	0.297, .09	p = .355, .09	p = .453, .02	p = .079, .28

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). *d* = Cohen's d.

The means and paired t-test results for fixation times to the NP (det N) are tabulated in Table 2 and illustrated in Figure 9 above. Table 3 and Figure 10 below show data for the VP (aux V) region. In all of these comparisons, there were no significant findings at the corrected alpha level of .0125. One comparison in the VP comparison for Temporal matched priming was

significant using uncorrected alpha levels ($p = .024$), but did not meet the adjusted alpha criterion ($p \leq .0125$); this finding could be due to post-hoc type I error, especially given the small number of participants in the experiment (alternative possibilities for analyses are described in the Discussion).

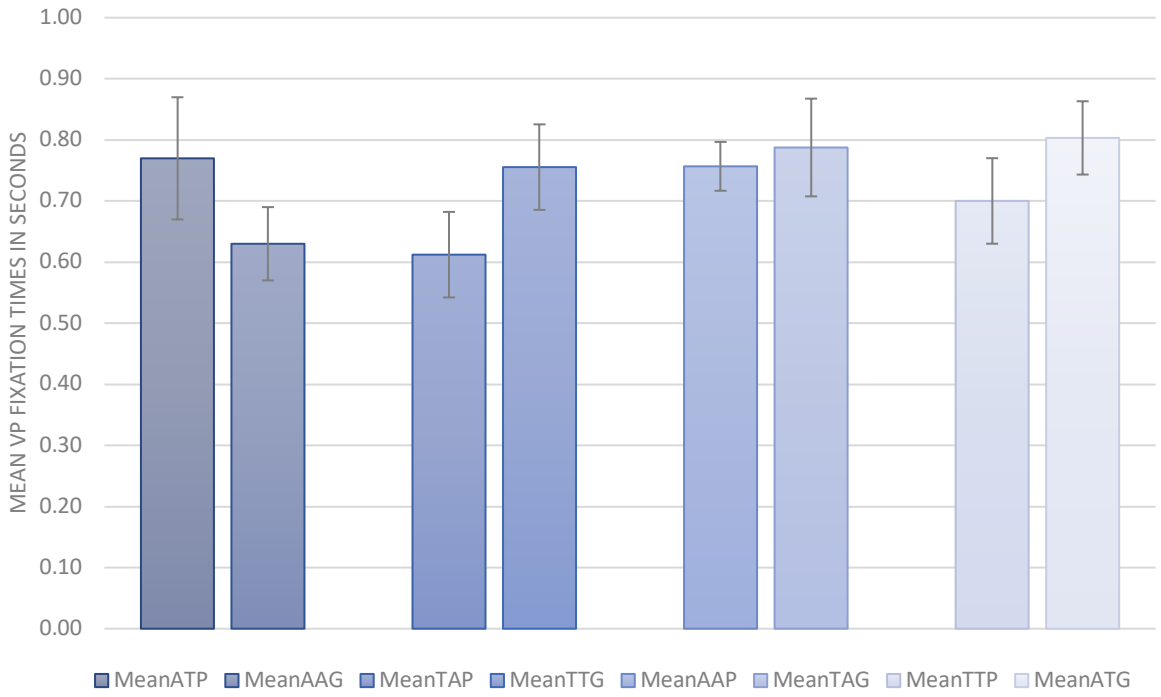

Figure 10: Mean VP fixation times

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). Error bars indicate standard error of the mean.

Table 3: Comparisons for VP Fixation times (ms) between conditions

Comparison*	ATP_AAG	TAP_TTG	AAP_TAG	TTP_ATG
Mean fixation time in seconds (SD)	MeanATP=.77 (.34) MeanAAG=.63 (.21)	MeanTAP=.61 (.23) MeanTTG=.76 (.26)	MeanAAP=.76 (.14) MeanTAG=.79 (.25)	MeanTTP=.70 (.24) MeanATG=.80 (.20)
t (df)	1.367 (10)	2.250 (10)	.429 (10)	1.621 (10)
p (alpha ≥.0125), *d*	.101, .35	.024, .43	.339, .11	.068, .32

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). *d* = Cohen's d.

3.4 Results: Fixation Regression Analyses for the Prepositional by-Phrase (PP), the NP (det N), and the VP (aux V)

The final data analyses examined the numbers of fixation regressions or "revisits" to specific AOIs, which are logged on the Gazepoint eye tracker data output when a fixation occurs, is terminated, and is then refixated again. Such revisits to a region can be used to examine processing of regions that are problematic for parsing. Eye movement regressions have been found where the initial parse might require reanalysis, as in garden path sentences such as *The horse raced past the barn fell* (Bever, 1970). In such constructions, the initial parse typically

favors an intransitive sentence (*the horse raced*) with a directional adjunct (*past the barn*), but reanalysis is triggered when the word "fell" occurs at the end of the sentence. Reanalysis requires the reader to go back to a point of ambiguity, to assign a reduced relative clause structure to the subject of the sentence (*the horse that was raced*). Such reanalysis requires the reader to return to the region where the reduced relative clause must be resolved, and this can be observed as a regression in eyetracking paradigms like this one.

Unlike garden path sentences, the stimuli in the present experiment did not require reanalysis to resolve an anomaly. Therefore, there is no a priori reason to expect regressions to occur in any systematic way. However, it is possible that readers might show some kind of regressions when sentences present some other kind of processing difficulty, such as argument assignment within a prepositional phrase. Hence the analysis of regressions in the current experiment is post hoc, exploratory in nature rather than hypothesis-driven.

As for the fixation time analysis, areas of interest were drawn over the prepositional *by*-phrases (PP) for all experimental stimuli as well as over the sentence-initial NP (det N) and the VP (aux V). Mean numbers of regressions over these three AOIs are shown in Fgures 11-13 below. T-tests were again conducted to compare group means; these are tabulated in tables 4-6 below.

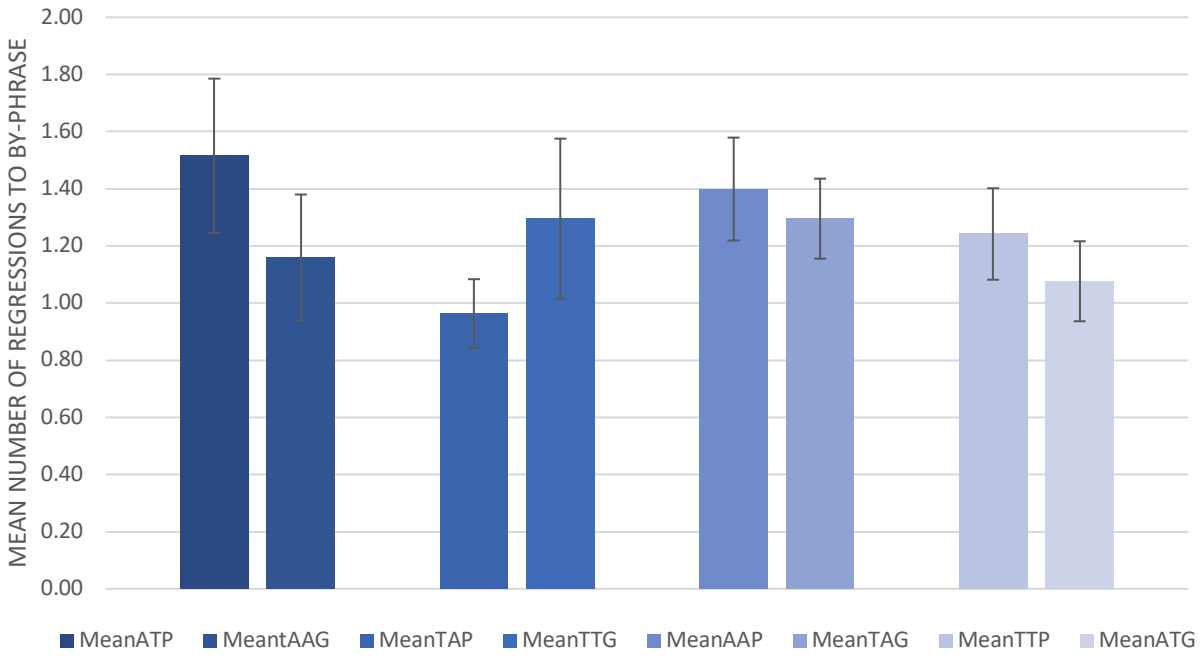

Figure 11: Mean Numbers of Regressions to By-Phrase AOI

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). Error bars indicate standard error of the mean.

Table 4 Comparisons for numbers of by-Phrase Regressions between conditions

Comparison*	ATP_AAG	TAP_TTG	AAP_TAG	TTP_ATG
Mean number of Regressions (SD)	MeanATP=1.52 (.90) MeanAAG=1.16 (.73)	MeanTAP=.96 (.41) MeanTTG=1.30 (.92)	MeanAAP=1.40 (.60) MeanTAG=1.30 (.46)	MeanTTP=1.24 (.52) MeanATG=1.08 (.46)
t (df)	1.473 (10)	1.297 (10)	.463 (10)	2.446 (10)
p (alpha ≥.0125), *d*	.086, .31	.112, .34	.327, .13	.018, .08

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). *d* = Cohen's d.

T-tests for numbers of fixations to the by-phrase AOIs in the prime-target pairs yielded no significant results using the Bonferroni corrected alpha level (p =.0125). Priming for the temporal passive primed by the agent passive approached significance (TTP_ATG: t (df) = 2.446, p = .018). Such a result suggests that a temporal passive that is preceded by an agent passive may lead to fewer regressions than when it follows a filler item. Why this particular configuration of prime-target pairs might lead to a reduction in regressions is not entirely clear, and might not hold up if statistical power was greater.

One possibility that Figure 8 and Figure 10 resemble one another is that with a statistical test with increaseed power it might have revealed patterns in the parsing and priming of these

constructions that involve the VP as a theta-assigner and then as a result takes increasing less time to process the targets that follow the primes. Additionally, it may simply be that it is the NP and VP that get primed and measuring regressions to those AOIs allows us to rule that out as a possibility. This makes theoretical sense since their has been evidence that in order for priming to happen in reading comprehension there must be a repetition of the main verb giving the priming effect a 'lexical boost' (Traxler, Tooley, and Pickering, 2014). In this sense it is said that the priming effect is 'structural' and 'lexically-mediated'.

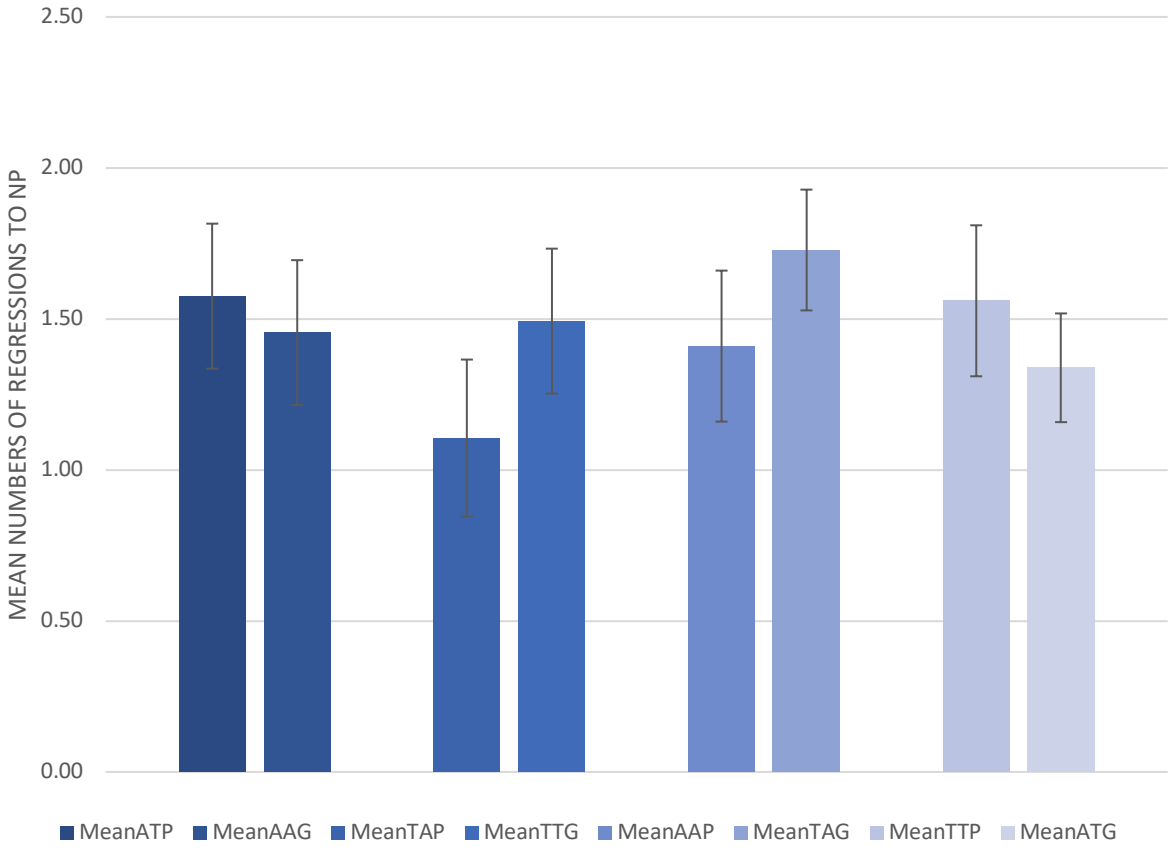

Figure 12: Mean numbers of Regresssions to NP

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). Error bars indicate standard error of the mean.

Table 5: Comparisons for NP Regressions between conditions

Comparison*	ATP_AAG	TAP_TTG	AAP_TAG	TTP_ATG
Mean number of regressions (SD)	MeanATP=1.58 (.81) MeanAAG=1.45 (.80)	MeanTAP=1.11 (.85) MeanTTG=1.49 (.72)	MeanAAP=1.41 (.84) MeanTAG=1.73 (.68)	MeanTTP=1.56 (.83) MeanATG=1.34 (.59)
t (df)	1.37 (10)	2.25 (10)	.43 (10)	2.31 (10)
p (alpha ≥.0125), *d*	.101, .11	.024, d34	.339, .30	.022, .30

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). *d* = Cohen's d.

T-tests were calculated to compare group means for regressions to the NP AOI; means are depicted in Figure 12 above, and *t*-tests are tabulated in Table 5 above. All pairs were non-signicant for the regressions to this AOI although the TTP_ATG comparison (*t* (df) = 2.31, *p* = .022) approached significance as in the previous analysis of PP regressions. Analyses of regressions in the VP region likewise revealed no significant differences that were significant by the corrected alpha level. Although some comparisons approached significance, in these cases the target sentence showed more regressions than its prime rather than fewer. This effect is unlikely to be related to any underlying systematicity in the processing of these conditions, more likely reflecting the unreliability of the data collected from only 11 participants. Mean numbers

of regressions and comparisons between conditions for the VP region are shown in Figure 13 and Table 6 below.

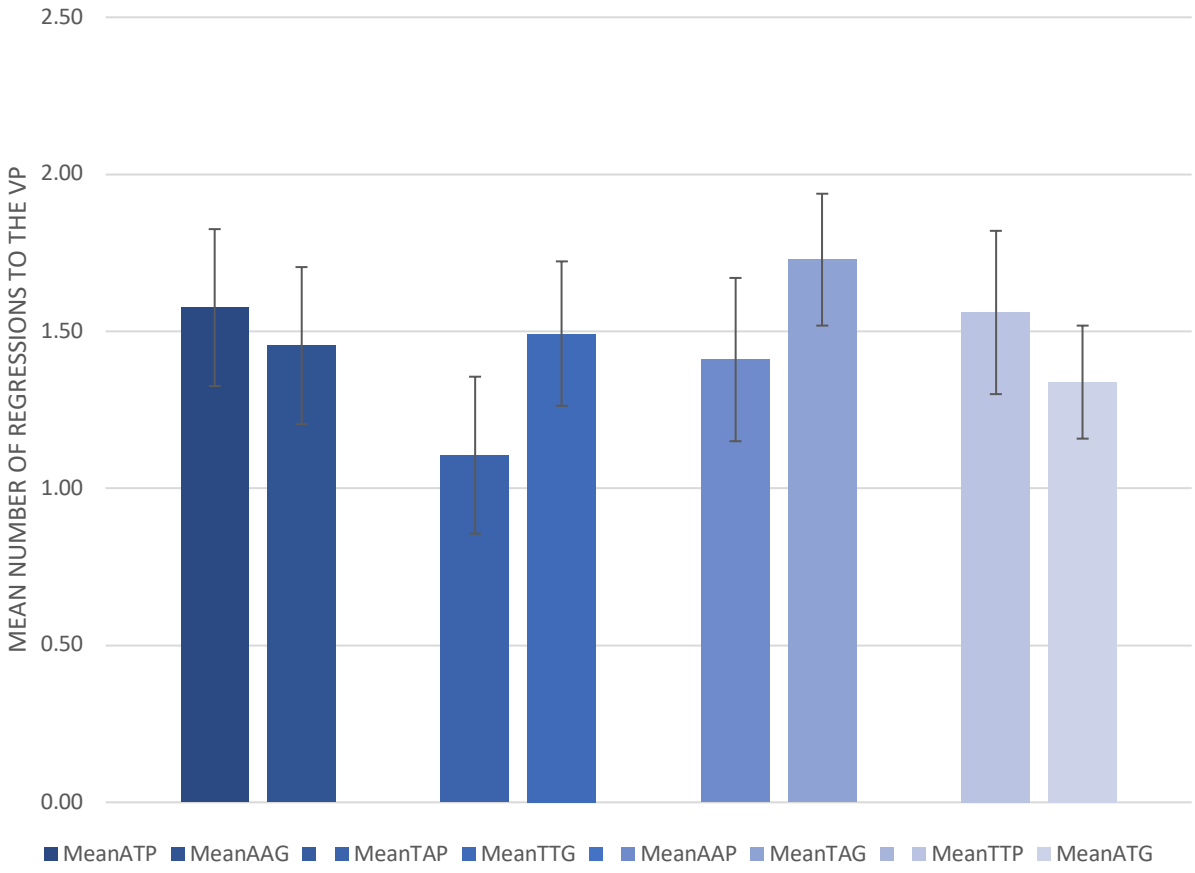

Figure 13: Mean Numbers of Regressions to VP

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). Error bars indicate standard error of the mean.

Table 6: Comparisons for VP Regressions between conditions

Comparison*	ATP_AAG	TAP_TTG	AAP_TAG	TTP_ATG
Mean number of regressions (SD)	MeanATP=1.58 (.81) MeanAAG=1.45 (.80)	MeanTAP=1.11 (.80) MeanTTG=1.49 (.72)	MeanAAP=1.41 (.84) MeanTAG=1.73 (68)	MeanTTP=1.56 (.83) MeanATG=1.34 (.59)
t (df)	.830 (10)	1.88 (10)	1.96 (10)	1.30 (10)
p (alpha $\geq$.0125), *d*	.213, .11	.045, .35	.04, .29	.11, .22

*ATP (Agentive by phrase / prime / with Temporal target); AAG (Agentive by phrase/ prime / with agentive target) TAP (Temporal by phrase / prime / with Agentive target); TTG (Temporal by phrase / prime / with Temporal Target); AAP (Agentive by phrase / prime / with Agentive target); TAG (Temporal by phrase / prime / with Agentive Target); TTP (Temporal by phrase / prime / with Temporal target); ATG (Agentive by phrase / prime / with Temporal Target). *d* = Cohen's d.

4. Discussion

The fixation duration data appear to indicate that agentive *by*-phrases were priming agentive *by*-phrases, with a significantly shorter fixation time for agentive by-phrases in targets that were preceded by primes with the same construction. However, due to the low *n* in this study and the focus on aggregate data in the analyses, there is likely a failure to find significant priming effects with the other combinations of agentive temporal prime target pairings. Revealing significant priming of agentive targets by agentive primes involved comparing the matched vs. the mismatched prime-target pairs. Recall that agentive passives were primes in the match condition (i.e., Agent Prime + Agent Target) and this was compared with the fixation time with that same sentence in the Target position in a mismatch condition (Agentive Prime + Temporal Target).

Comparing fixation times for primes and targets in this way involved the same sets of sentences in distinct prime-target pairings. These findings supported hypothesis number 3 wherein the effects of structural priming for these stimuli (i.e. the agentive by-phrase) indicates something about priming via syntactic structures on a deeper level of representation likely having to do with verb argument structure of the passive construction. Recall that the third hypothesis is that priming only occurs in cases where the by-phrase assigns a thematic role, in this case the role of Agent to the underlying subject of the passivized verb. In other words, the present study offers support for this hypothesis wherein priming selectively affects these structures. Recall that hypothesis 1 predicted that priming should happen in matched conditions for the by-phrases and that hypothesis 2 predicted that there would be priming across matched and mismatched conditions but what we found ultimately was priming only for agentive prime for agentive targets.

For example, concerning the signicant findings that support hypothesis 3 take the following stimuli presentation:

Prime: The delivery man was expected by the secretary but he arrived too late.
Target: The student was graded by the afternoon and would pass with flying colors.

Filler 1-3

Prime: The student was graded by the afternoon and would pass with flying colors.
Target: The student was expected by the professor and she passed with flying colors.

The prime in the first pair is what primed the target in the second pair. Hypothesis 3 predicted that this might happen and that it was due to verb-argument structure. Again all other comparisons failed to reveal significance among the effects; however, we used t-tests and Bonferroni post-hoc comparisons with an arbitrary significance level. It might be possible that the statistics used in the data analysis for this study might have failed to find other priming patterns. I think this is particularly relevant to the temporal by phrase priming other temporal by phrases. Still more there might have been other significant relationships that were overlooked by the tests use here.

In any event, significance was observed for agentive by-phrases priming the same constructions, described above. There are, however, several caveats with the current design. One is the filler items, which were dative constructions containing prepositional phrases (e.g., *The*

waitress took a tray of appetizers to the customer). If it were the case that any prepositional phrase can prime any other prepositional phrase, including a passive by-phrase, then this construction being used as a filler would present a problem. The present results show only limited priming in this paradigm, with only one condition being significant by the Bonferroni-corrected alpha level. If the filler items were having significant effects, it would be expected to see such evidence across the board. Furthermore, since all items contained PPs, then there should have been a cumulative priming across the whole experiment, which was not observed. Therefore, although the choice of PP constructions as filler items may be less than ideal, the possibility that the filler items contaminated the findings seems remote.

I must also acknowledge that there may be ordering effects playing a role in the outcome data. This happens when participants all get stimuli presented in the same order in a within subjects design like the one used in the present study. These are also referred to as carry-over effects and are a potential confounding variable. In the future, data from the start of the session could be compared to data from the end of the session to ensure that there are no differences in responses to items from different times during the session. The present results suggest that structural priming of agentive and temporal by phrases only happens when agentive primes are followed by agentive targets, though the sample size is small and the data analyses reported here related to aggregate data (means and the variance around them). Future analyses could be applied to the individual response data, for example a mixed effects model.

An alternative to the t-tests used in the data analysis for this study I could have used a mixed effects analysis and considered the data at an individual level rather than as aggregates; that is, as 48 data points for each of the 11 participants (albeit correlational data). This could be a way to address the small sample size and a lack of sensitivity of the statistical tests used in the

study, that may have led to a type 2 error for some of the variables measured such as duration of fixation for temporal by-phrases priming temporal by-phrases. A mixed effects analysis could act as an adjunct statistical model allowing us to pursue causal relationships between IVs and DVs (priming relationships essentially) in a future study where we use a larger sample size and perhaps a more powerful statistical test like RM-ANOVA.

The mental representation of the agentive by-phrases has to do with the theta-grid of the underlying subject of the passivized verb. In the case of an agentive by-phrase the thematic relation can be understood as the agentive by-phrase existing as an obligatory adjunct or an entirely theta-roled argument. Still more the predictions I am referring to involve the fact that verb argument structure revolves around the theta-grid of NPs that the verb must take on in order for a clausal construction to achieve grammaticality. In the case of the agentive by-phrases in this study these are the NPs preceding the agentive by-phrase (PP) and the agentive by-phrases (PPs) as obligatory adjuncts.

The data from this study confirm aspects of the hypotheses but leave many questions that still need addressing. In terms of the structural priming involved, the priming itself has revealed to us something about the mental representation of these constructions, since it appears to relate to dual mechanisms of residual activation and implicit learning. If you remember form the earlier in this proposed a model for the mental representation of structural priming involving residual activation of the main verb and the ensuing prepositional by-phrase. This also worked as a dual mechanism with an implicit learning that happens for the syntactic structure.

Beyond the psycholinguistics of experimental psychology linguists have provided a good deal of understanding for how passives are represented and how that revolves around argument structure and this is certainly of interest to the psycholinguist who conducts empirical research

into the processing and representation of passives that I just discussed in the dual-mechanism account. Jaeggli (1986) describes an account of passives as fully modular and whereby there is no single rule for their construction but simply the interaction between morphological and syntactic rules and that only those rules have any theoretical validity. This involves the idea that various lexical entries that make up a passive construction conform to theta-role and that the morphsyntactic structure of those lexical entries determine whether a construction is passive or not;-and in turn whether and how that passive is represented. According to this idea it is a relationship between thematic relation and argument structure that determines how language is represented and processed. The research on structural priming has sought to investigate what role thematic relation (active vs. passive) and argument structure (theta-grid) has on the processing of language.

Grimshaw and Vikner (1993) describe the relationship between obligatory adjuncts and event structure. They suugest that by investigating aspectual elements of sentences we can provide an understanding of grammaticality and identifying what phrases are obligatory. Again, I believe that such an investigation in theoretical linguistics is to identify the relationship of morphology to syntax and to other levels of representation of the structure of language and its use. The attention paid to an understanding of morphosyntax and the identification of grammaticality of language allows us to use an understanding of the mental representation of language whereby we can identify what levels of representation are universal to human language.

Structural priming in language comprehension of reading is enhanced by the repition of the main verb which strcutures the theta-grid. In the experiment described here the repitition of the main verb was examined with the agentive by-phrase and temporal by-phrase contrasted. The results confirmed the hypothesis that the deeper level of representation involving the predicate

argument structure was primable. As I posited earlier this deeper level of representation reveals something about the phylogenetically inherited and universal aspects of human language. However, this was a modest study and such claims need to be further undergirded by additional empirical and theoretical investigations.

Moreover, because this study is one of on-line sentence comprehension and processing it appears that the main verb and its auxiliaries are essential for the priming effect to happen as was evidenced by the regressions to both the prepositional *by*-phrase (PP) *and* the VP (aux V) and the 'lexically-mediated boost' it gives to the priming of the prepositional *by*-phrase. The regressions to VP perhaps being significant if the analyses were handled differently and/or if the power was higher. By 'lexically-mediated boost' according to Pickering, Tooley, and Traxler (2014) that for structural priming to happen optimally during reading comprehension there needs to be a repetition of the main verb in prime and target. That was the design of the stimuli in this experiment; a future study should address this by looking at experimental stimuli of the same constructions but with synonyms for the main verb for prime and target instead of the repetition of the main verb used here to see if the priming is still likely to happen under those conditions.

There are also applied issues that might be better understood with the findings from the present study, particularly those involving sentence processing in aphasia. Zurif, Swinney, Prather, Solomon, and Bushell (1993) showed that people with aphasia have varying degrees of difficulty with comprehending sentences (in reading) when one element of a sentence is needed to comprehend another element. This has been particularly problematic for people with Broca's aphasia when constituent movement and thematic relations are needed to work together in order for the mental represention of the utterance to be constructed. Hence, structural priming can provide further data about how language is represented, and could be valuable in treatment too –

for instance, if priming can remediate delays in processing by facilitating representation of syntax in the ways that we have learned from the experiment described here.

4.1 Conclusions

This study used structural priming as an experimental procedure in a way that appears to have provided some clarity about the processing and representation of agentive prepositional *by*-phrase passives by way of their amenability to structural priming. The priming effect that was achieved was agentive *by*-phrase primes for agentive *by*-phrase targets and this supported one of the three study hypotheses. That hypothesis stated that any priming effect observed would be the result of verb argument role assignment and this was the case, again, because agentive *by*-phrase primes were found to prime agentive *by*-phrase targets.

I considered that priming of passive sentences occurs across-the-board based on superficial similarity of syntactic constructions with hypothesis 2 and without regard to whether the *by*-phrase assigns thematic roles (as in the case of the Agent *by*-phrase). And, hypothesis 1 wherein I considered whether representation of phrase types is differentiated in terms of the functional role that they play in the sentence; for example, whether or not they assign thematic roles such as agent, or if they are more adjunct-like in merely indicating the temporal contours of the event. Both hypotheses 1 and 2 were unsupported by the empirical evidence from this study. It was hypothesis 3 that was confirmed by the experimental evidence wherein the prediction that thematic relation and argument structure facilitate the priming effect. This deeper level of linguistic knowledge is perhaps what exists to facilate the sociobiology of language use and providing an evolutionary advantage to human beings.

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Appendix 1: Example Run for Agentive by-Phrase and Temporal by-Phrase

F1 (filler) The cheerleader saved a seat for her boyfriend.

F2 (filler) The oil tycoon bought a Rolls Royce for his son.

F3 (filler) The waitress took a tray of appetizers to the customer.

P1(Long passive w/agentive) The deliveryman was expected by the secretary but he arrived too late.

T1(temporal by-phrase) The student was expected by the afternoon and she passed with flying colors.

F4(filler) The corrupt inspector offered a deal to the bar owner.

F5(filler) The secretary is baking a cake for her boss.

F6(filler) The lifeguard tossed a rope to the struggling child.

P2(temporal by-phrase) The mailman was expected by the afternoon but he arrived too late.

T2(Long passive w/agentive) The student was expected by the professor and she passed with flying colors.

F7(filler) The governess made a pot of tea for the princess.

F8(filler) The foundation is giving several million dollars to the university.

F9(filler) A rock star sold some cocaine to an undercover agent.

P3(Long passive w/agentive) The review was chosen by the author and it was impressive.

T3(Long passive w/agentive) The speaker was chosen by the chairperson and she would work perfectly.

F10(filler) The legislature is sending a bill legalizing capital punishment to the governor.

F11(filler) The waitress took a tray of appetizers to the customers.

F12(filler) The foundation is giving several million dollars to the university.

P4(temporal by-phrase) The author was chosen by the late evening and he was impressive.

T4(temporal by-phrase) The speaker was chosen by the weekend and she would work perfectly.

F13 (filler) The waitress took a tray of appetizers to the customers.

F14 (filler) The oil sheikh bought a Rolls Royce for his son.

F15 (filler) The cheerleader saved a seat for her boyfriend.

P5(Long passive w/agentive) The manager was hired by the director because he was a good fit with the firm's needs.

T5(temporal by-phrase) The accountant was hired by the weekend and he had a master's degree.

F16(filler) The legislature is sending a bill legalizing capital punishment to the governor.

F17(filler) The foundation is giving several million dollars to the university.

F18(filler) The governess made a pot of tea for the princess.

P6 (temporal by-phrase) The manager was terminated by the end of the day because he was not a good fit with the firm's needs.

T6(Long passive w/agentive) The accountant was terminated by the businessman because he wasn't qualified.

F19(filler) The corrupt inspector offered a deal to the bar owner.

F20(filler) The secretary is baking a cake for her boss.

F21(filler) The lifeguard tossed a rope to the struggling child.

P7(Long passive w/agentive) The defendant had his case heard by the governor but he arrived late.

T7(Long passive w/agentive) The referee was heard by the director and he had excellent vision.

F22(filler) The governess made a pot of tea for the princess.

F23(filler) The foundation is giving several million dollars to the university.

F24(filler) A rock star sold some cocaine to an undercover agent.

P8(temporal by-phrase) The defendant was sent by the afternoon but he arrived late.

T8(temporal by-phrase) The referee was sent by the afternoon and he had excellent vision.

F25(filler) The legislature is sending a bill legalizing capital punishment to the governor.

F26(filler) The waitress took a tray of appetizers to the customers.

F27(filler) The foundation is giving several million dollars to the university.

P9(Long passive w/agentive) The soudent was accepted by the dean and she was very pleased.

T9(temporal by-phrase) The student was accepted by the end of the afternoon and she had a mole on her lip.

F28(filler) The corrupt inspector offered a deal to the bar owner.

F29(filler) The secretary is baking a cake for her boss.

F30(filler) The lifeguard tossed a rope to the struggling child.

P10(temporal by-phrase) The victim was recognized by the morning but he was in bad shape.

T10(Long passive w/agentive) The student was recognized by the painter and she had a mole on her lip.

F31 (filler) The cheerleader saved a seat for her boyfriend.

F32 (filler) The oil tycoon bought a Rolls Royce for his son.

F33 (filler) The waitress took a tray of appetizers to the customer.

P11(Long passive w/agentive) The thief was recognized by the victim and was held for questioning.

T11(Long passive w/agentive) The singer was recognized by the fan but was unable to make it to the concert.

F34(filler) The waitress took a tray of appetizers to the customers.

F35 (filler) The oil tycoon bought a Rolls Royce for his son.

F36 (filler) The cheerleader saved a seat for her boyfriend.

P12(temporal by-phrase) The candidate was prepared by the morning and he would run for governor.

T12(temporal by-phrase) The student was prepared by the morning and she had a mole on her lip.

Appendix 2: Instructions Given to Participants

Instructions: You will be tested on your comprehension of the sentences that appear on the screen so be sure to pay attention. This study is an experiment on reading comprehension. Please do not move about in your seat more than you need to. If you have any questions continue to read the items until the conclusion and then you may ask. You will be given some short true and false questions to answer after the experiment so be sure to pay attention. The study lasts for five minutes of eye-tracking and then three minutes of post study questions.

After the eye-tracking portion:

Are these statements True or False?

Did the cheerleader save a seat for her father?

Did the secretary expect the deliveryman?

Was the review written by the committee?

Did the bar owner offer a deal to the corrupt inspector?

Did the bill get paid by the end of the night?

Was the victim that the doctor recognized in good shape?

Did the referee have bad vision?

Did the pregnant mother deliver early?

Did the waiter take a tray of appetizers to the customer?

Did the accountant have a bachelor's degree?