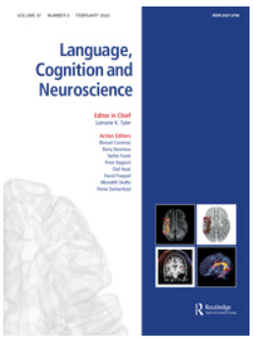

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Eyetracking while reading passives: an event structure account of difficulty

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ABSTRACT

Among existing accounts of passivisation difficulty, some argue it depends on the predicate semantics (i.e. passives are more difficult with subject-experiencer than agent-patient verbs). Inconsistent with the accounts that predict passive difficulty, Paolazzi et al. (2019) found that passives were read faster than actives at the verb and object by-phrase in a series of self-paced reading experiments, with no modulation of verb type. However, self-paced reading provides limited direct measurement of late revision/interpretive processing. We used modified stimuli from Paolazzi et al. (2019) to re-examine this issue in two eye-tracking while reading experiments. We found that in late measures, passives with subject-experiencer verbs had longer fixation durations than actives at the verb and two subsequent regions but no difference was observed across agent-patient verbs. Subject-experiencer verbs provide a state, but the passive structure requires an event. Thus, the required eventive interpretation is coerced with subject-experiencers (if possible) and induces difficulty.

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KEYWORDS
Event structure; sentence processing; eye-tracking; passive sentence

1. Introduction

Passives have been at the forefront of many linguistic debates from theoretical syntax to innate rules of acquisition to theories of processing complexity (Ambridge et al., 2016; Borer & Wexler, 1987; Bresnan, 1982; Chomsky, 1981; Ferreira, 2003). These debates have in common the assumption that passives are more complex than actives or at least that passivisation is costly with subject-experiencer predicates (stative predicates, e.g. love, admire). In a recent publication (Paolazzi et al., 2019), we argue against this position. In four self-paced reading experiments in healthy adults, we found that reading times were shorter for passive sentences than their active counterparts in multiple regions (i.e. verb and by-phrase). At no region did we find that passives resulted in longer reading times. Nor did we find this effect to be modulated by predicate type (subject-experiencer vs. agent-patient). Here, we review existing theories and consider a limitation of the self-paced reading paradigm, i.e. the unnaturalness of the task limits its ability to capture late processing effects of re-reading (e.g. revision). We then present two eye-tracking while reading experiments to help overcome this limitation and further assess the effect of passivisation and whether it is modulated by predicate type.

1.1. Theories of passive difficulty

Previous studies using an offline comprehension task have reported that both adults and children are less accurate in comprehending passive than active sentences (Ambridge et al., 2016; Ferreira, 2003; Messenger et al., 2012; Paolazzi et al., 2019). Various accounts have been presented to explain this finding and in the following, we briefly discuss the main proposals offered for the effect in adults.

One perspective, which we will call the syntactic complexity account assumes that the noncanonical argument order of passives is more taxing on the parser. This is either because the passive structure is produced less frequently and hence the required interpretive processes are not as quick and efficient (Johns & Jones, 2015), or because the syntactic processes themselves are more difficult (Borer & Wexler, 1987; Chomsky, 1981).

Alternatively, the Good Enough theory (Ferreira et al., 2001; Ferreira & Patson, 2007; Karimi & Ferreira, 2016) argues that sentence processing occurs via two parallel routes: (1) heuristic and (2) algorithmic. The heuristic route applies quick and easy generalisations about language comprehension, such as the NounVerbNoun (NVN) strategy, where the first noun is assumed to be

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agent (i.e. doer) and the second noun, patient/theme (i.e. acted on), due to the frequency of this order in English. Syntactic parsing algorithms are more precise and time consuming than the heuristics. In passive sentence comprehension, this can either result in the algorithms eventually adjudicating with the heuristics or when processing is limited, such as when attention is diverted or the environment is noisy, people may rely on the heuristic route alone and converge on an inaccurate interpretation.

1.2. Predicate semantics interacts with passivisation

Additional research has led to the argument that the ease of processing passives is dependent on the semantics of the predicate. Based on the observation that certain predicates could not passivise (e.g. "£5 was cost by the book"; Chomsky, 1975), Pinker (1989) introduced the notion of a semantic constraint, where passives need to be defined by both their syntax and semantics. In particular, a passive subject needs to be affected by the passive object via an action or event denoted by the verb. The specific formulation used is presented in (1):

(1) [B] (mapped onto the surface subject [of a passive]) is in a state or circumstance characterised by [A] (mapped onto the by-object or an understood argument) having acted upon it.

In "The tiger [B] was killed by the lion [A]", A affects B and hence Ambridge et al. (2016) summarises this formulation by an affectedness constraint. A verb that does not affect the internal argument will not be passivisable and verbs that are lower in affectedness are more difficult to passivise. In particular, passivisation has been argued to be more difficult for subject-experiencer verbs (e.g. hate) than agent-patient verbs (e.g. stab). Empirically, acceptability judgment data in adults support this account (Ambridge et al., 2016), as there is an interaction between a verb's affectedness and passivization. The lower the affectedness of the verb, the less acceptable it is in the passive.

However, existing evidence from syntactic priming studies in children is inconsistent with this, as priming does not distinguish between subject-experiencers (low affectedness) and agent-patient verbs (high affectedness; Messenger et al., 2012). The finding that priming for the passive does not differ across these predicates was replicated by Bidgood et al. (2020) with an even larger sample of children and adults. However, they did observe fewer productions of the passive sentence and more errors in passive sentence comprehension with subject-experiencer verbs than agent-patient verbs. Collectively, these data seem to suggest an abstract representation of the passive structure that can cut across the verbal semantics in its ability to prime, but that passives with subject-experiencers are more difficult to process.

The affectedness constraint is appealing and the acceptability data cannot be accounted for by standard syntactic accounts alone. However, this term needs a more precise definition to distinguish between grammatical vs. ungrammatical or the degradation in acceptability of passives. The imprecise nature of the term has been acknowledged by linguistic analyses of other structures (e.g. see the literature on the Ba construction in Mandarin; Huang et al., 2009).

An alternative account for the difficulty associated with passivising subject-experiencer verbs takes an event structure approach (representing the syntax-semantics interface uniformly). Gehrke and Grillo (2007; 2009) argue that verbal passives, in English, require an interpretation of a resulting state subsequent to an event. Eventive predicates (specifically accomplishments and achievements, see Dowty, 1979), such as that in (2), easily satisfy this requirement. In (2), a killing event causes the tiger to transition into a non-living state. In the case of some stative predicates, e.g. (3), there is no result state: the book costs £5 or it does not. In the case of subject-experiencer verbs (i.e. stative predicates), the result state can be coerced to occur subsequent to an event. This can be observed indirectly by the acceptability of "Mary became hated" but not "*£5 became cost". Under this account, the eventive interpretation of the stative predicate needs to be coerced and is thus more difficult to process. Indeed, modifying the passive with prepositions that provide a clear semantic context for the event improves their readability (compare (4) to (5)):

(2) The lion killed the tiger. -> The tiger was killed by the lion.
(3) The book costs £5. -> *£5 was cost by the book.
(4) Mary was hated by John.
(5) Mary was hated by John for cheating on him.

Undoubtedly this perspective intersects with the affectedness constraint in that eventive predicates tend to affect the internal argument and stative predicates do not (or less so). Indeed, Ambridge et al. (2016) mention the idea that the event may be more relevant than the lexical semantics in terms of affectedness. Nonetheless, they maintain that it is the affectedness of the event on the subject of the passive that is critical rather than requiring that the state can arise from an event.

One advantage of the event structure-based account over the affectedness account comes from the observation by Gehrke and Grillo (2009) that the same lexical item behaves differently under passivisation when projected as a verb compared to a noun. Consider the contrasts in (6), which show that the same lexical items *hate, fear* can be passivised as a verb but not as a noun:

(6) a. The tiger was killed by the lion. -> The killing of the tiger by the lion.
b. Mary was hated by John. -> *The hating of Mary by John.
c. John was feared by Mary. -> *The fearing of Mary by John[1].

As Gehrke and Grillo argue, the crucial difference between the passivised nominals in (6a) and (6b)/(6c) is that while *kill* is lexically specified with a complex event semantics which involves a transition into a consequent state, pure stative elements like *hate* or *fear* are not. They can only introduce these semantics when combined with additional verbal structure, forming a complex predicate, as they are in verbal passives but not nominal passives. In line with this, nominal passivisation of predicates that are ambiguous between eventive and stative readings is only grammatical under the eventive reading (7b). Consider the example in (7), which contains the predicate *surround*, that is ambiguous between a stative (7c) and eventive reading (7b):

(7) a. The house was surrounded by the army/trees.
b. The surrounding of the house by the army.
c. *The surrounding of the house by (the) trees.

The inability of stative nominals to passivise can be explained by the absence of the necessary syntactic enrichment to achieve a stative interpretation as a consequence of an event. It is not clear if and how an affectedness account could explain this asymmetry, given that affectedness does not vary across the verbal and nominal instantiation of stative predicates like *fear/hate*.

A last consideration for passivised subject-experiencer verbs is that they generate a temporary ambiguity between an adjectival vs. verbal interpretation that is only resolved at the by-phrase. It may be that the adjectival passive is preferred due to its simplicity, despite later requiring revision. This revision, or managing two parses, could increase difficulty, an issue that has featured in the child acquisition literature (Borer & Wexler, 1987).

1.3. Recent evidence against passive difficulty in online measures

While the accounts above vary in their processing assumptions, they commonly assume that passives increase processing difficulty, in the least, in the case of subject-experiencers. Paolazzi et al. (2019) provided a psycholinguistic test of these accounts in a series of four self-paced reading experiments. Across all experiments, they found passives to be read faster than actives, at several regions, but most consistently at the verb and postverbal determiner region. These results are consistent with previous findings reported in the literature (Carrithers, 1989; Traxler et al., 2014). Paolazzi et al. (2019) argued that the faster reading times in passives with respect to actives are compatible with expectation-based (e.g. Levy, 2008) or surprisal-based models (e.g. Hale, 2001). In English, the passive has additional morphological markers (auxiliary, *by*) and these positions are immediately prior to the points where reading times were most often found to be shorter in the passive condition. It was argued that a verb is more likely following an "NP + was" than following an NP alone. Indeed, this was supported by data from a corpus analysis. Likewise, a determiner is more likely following "NP + was + V+by" than "NP + V". That is, surprisal is lower at the verb and object determiner in the passive condition relative to the active condition, because these word categories are more predictable, given the syntactic context.

Further, in these previous studies, the effect of passivisation on reading times did not differ across predicate type (subject-experiencers vs. agent-patient).

Nonetheless, like previous studies, Paolazzi et al. (2019) found that passives were responded to less accurately than actives in the comprehension task. However, Paolazzi et al. (2021) argue with further data that this effect is due to a task bias – the comprehension questions were always in the active – and, once this is remedied, so too is the overall difficulty of the passive. In the comprehension experiments that balanced the voice of the comprehension question, only the sentences with subject-experiencers resulted in passives being less accurate than the active (Paolazzi et al., 2021). Evidence that theta-role questions demonstrate a passivisation difficulty that is unobserved in other measures is corroborated by additional studies that combined plausibility ratings with comprehension questions (Meng & Bader, 2021).

A limitation of the self-paced reading paradigm is that comprehenders have to read in a strictly left-to-right fashion and cannot re-read earlier parts of the sentence. This differs from reading under natural conditions

whereby we are able to re-read earlier parts of a sentence when encountering a difficult to process segment. This makes self-paced reading well-suited for assessing early processes, such as those that arise from an unexpected word category (i.e. in garden path sentences) or an implausible argument. However, it may be less effective at detecting late processing effects, such as those that could arise from integration difficulty in a region that is otherwise acceptable and plausible. Moreover, if readers adopt a strategy of holding off on integration processes until a dependency (such as that between a verb and its internal argument) is complete, self-paced reading would be less sensitive to these difficulty effects. In the case of the Good Enough model, it may be that the "revision" or "adjudication" of the heuristic process with the algorithmic one is quite late and not localised to the first reading of a particular region. Likewise the difficulty of passivising a state may be a late effect, dependent on the integration of the agent argument with the predicate (interpretation of the VP) in order to "coerce" a state that is a consequence of an event (Belletti & Rizzi, 1988; Gehrke & Grillo, 2007, 2009; Grillo, 2008; Snyder & Hyams, 2015).

Eye-tracking while reading offers a more ecologically valid method to study comprehension processes while reading. As under natural reading conditions, participants can re-read as they wish (e.g. regressions, re-reading), and use visual information in the parafovea or periphery to skip (i.e. not fixate on) short and/or predictable words. Finally, eye-tracking provides a more direct and nuanced measure of processing difficulty, as it is measuring the precise position of the eyes with respect to the text with good temporal resolution, distinguishing between first reading of a word and later re-reading of a word amongst other measures. Thus, eye-tracking provides an ideal method for studying passive sentence processing and particularly any late processing effects. Indeed, the effects postulated to make passives difficult – revision and coercion – have been observed in late measures in previous studies (e.g. regression, re-reading; Boland & Blodgett, 2002; Christianson et al., 2017; Frazier & Rayner, 1982; McElree et al., 2001; Schotter et al., 2014; Traxler et al., 2002).

Previous cross-methodological studies directly comparing self-paced reading and eye-tracking have established eye-tracking's ability to detect late processes where self-paced reading could not. In ambiguity resolution studies, it was found that the late re-analysis effects that were captured by eye-tracking measures could not be observed in self-paced reading (Ferreira & Henderson, 1990; Jackson et al., 2012). Given these considerations, eye-tracking while reading represents the best methodology to study passivisation and any modulation by predicate type (e.g. McElree et al., 2001; Traxler et al., 2002).

1.4. Current study: aim and predictions

The present experiments use eye-tracking while reading to investigate the difficulty of passivisation and whether it is modulated by the predicate semantics (e.g. Belletti & Rizzi, 1988; Gehrke & Grillo, 2009; Grodzinsky, 1995; Maratsos et al., 1985; O'Brien et al., 2006; Volpato et al., 2015). The design follows that of Paolazzi et al. (2019), fully crossing syntax (active, passive) and predicate type (agent-patient, subject-experiencer).

According to mainstream theories of passive processing, there should be an increased processing cost associated with passivisation. Longer fixation durations in the passive condition with respect to their active counterpart should emerge in late processing measures such as re-reading, probability of regression/re-reading and total time. The source of difficulty – revision and/or coercion – has been found to be reflected by late, rather than early, measures of processing and self-paced reading which is very sensitive to early aspects of processing difficulty showed no such effect (Boland & Blodgett, 2002; Frazier & Rayner, 1982; McElree et al., 2001; Traxler et al., 2002). Alternatively, if passives are not any more difficult to process than actives (Paolazzi et al., 2019), then there should be no increased reading times for passives relative to actives even in late eye-tracking measures.

According to the Good Enough account, longer reading times for passives than actives should be observed at the verb, as this is the point where revision would be required (past participle rather than verb and assignment of argument roles). An affectedness account would make a similar prediction at the verb, but with the effect being larger for subject-experiencers than agent-patient predicates. Again, the verb is the point where it becomes clear whether or not the subject would be affected and to what degree. The same prediction is made for ambiguity resolution of the stative predicates in the passive, as it requires reinterpreting an adjective as a verb. The effect, however, may further extend into the following region of the by-phrase where it becomes clear that it is a verbal passive.

In terms of the event structure approach, it predicts the same effect of syntax at the verb, but only for stative predicates not eventive ones, as it is only the stative-passive condition that requires coercion (from a stative predicate to a state subsequent to an event). Under the event structure account, the whole by-

phrase is critical to establishing the event, thus the interaction effect may be observed at other regions of the by-phrase.

In keeping the design similar to the self-paced reading experiments reported in Paolazzi et al. (2019), we will also collect accuracy data, by inserting comprehension questions after each item (experimental or filler) without manipulating the syntax of the comprehension question. Hence, we expect participants' accuracy to be lower for passives than actives, independent of predicate type, as was reported in previous studies on healthy adults (Ferreira, 2003; Paolazzi et al., 2019), which did not control for task characteristics (such as the syntax of the comprehension questions, as discussed).

2. Experiment 1

2.1. Methods and design

2.1.1. Participants

Fifty-eight native British English speakers were recruited to participate in the study (38 females; average age: 24). They were all aged between 18 and 50 and had no visual, hearing or language impairment. Participants were recruited through the UCL Psychology Participant Pool and received either payment or course credits for their participation. All the participants were informed of the aims and procedures of the experiment and provided informed consent, approved by UCL ethics.

2.1.2. Stimuli

A total of 56 experimental item sets were used: 28 eventive and 28 stative, where syntax was manipulated within-subject and predicate type across subjects (see Table 1 for an example and Appendix 1 for the full list). The sentence sets were adapted from Paolazzi et al. (2019) for the following reason. The prepositional phrase (PPs) in the original stative items contained a syntactic dependency that differed across active and passive versions. The implicit subject of the for-clause was dependent on the main clause subject, in the passive version, and the object, in the active version of the sentence (e.g. "Mary was admired by John for singing beautifully" contains a dependency between "Mary" and the subject of "singing", while "Mary admired John for singing beautifully" contains a dependency between "John" and the subject of "singing"). This is not problematic in self-paced reading where reading times on a region of interest are not affected by linguistic material presented after the region, since they are masked. On the contrary, in eye-tracking while reading, sentences are presented in their entirety, thus allowing participants to re-read earlier regions. In this context, any additional difference beyond the pure syntactic difference between active and passive sentences could interact with processing times and confound the data. Hence, we substituted the original sentence completions (locative PPs in eventive items and for-clauses in stative items) with simple temporal PPs. The temporal PPs were always three words long and were introduced by the prepositions "on", "in", "during", "at" in the eventive items, and "throughout", "since", "after", "before" in the stative ones. The eight different prepositions were balanced across the 28 sets (e.g. 7 items contained "on", 7 "in", 7 "during", 7 "at", see Table 1). Given that our experimental items were shortened, the fillers were accordingly shortened as well.

Table 1. Example experimental stimuli.

		Example experimental stimuli
Eventive	Passive	The guitarist was rejected by the attractive and talented singer on Tuesday morning
Eventive	Active	The guitarist rejected the attractive and talented singer on Tuesday morning
Stative	Passive	The guitarist was admired by the attractive and talented singer throughout the tour
Stative	Active	The guitarist admired the attractive and talented singer throughout the tour

2.1.3. Procedure

The items were presented in 11pt Monaco black font on a white background. All sentences were presented on a single line. A comprehension question followed each sentence, but after experimental items, they only targeted theta-roles (e.g. "Did the musician reject the guitarist?"). Given that the present experiment was designed to further investigate online processing, and hence comparability to previous self-paced reading experiments was the most important, we kept comprehension questions in the active form, as in Paolazzi et al. (2019). To avoid creating a bias in attention towards specific parts of the sentence (in this case, the NP-VP-NP part), fillers were followed by questions that targeted other sentential aspects, such as time or location, as in the previous experiments.

The experiment was implemented using EyeTrack, an application developed by the UMass EyeLab to create and run eye-tracking experiments for the SR Research EyeLink trackers. Eye-movements were recorded using an EyeLink 1000 eye tracker (Desktop Mount) with a 2000 Hz infrared camera (SR Research Ltd., Mississauga, Ontario, Canada), interfaced with two computers. Sentences were displayed on an LCD monitor, positioned at a 70 cm distance from the participants' eyes. The tracker was placed at a 55 cm distance from the participants' eyes.

After providing informed consent, the Miles test was performed to determine the subject's dominant eye, which would be tracked during the experiment (Roth et al., 2002).

After the eye-dominance test, participants were seated on a height-adjustable chair with their forehead on a headrest and chin on a chinrest and asked to adjust the chair for their comfort. A nine point calibration and validation were then carried out to ensure precise tracking of eye movements. Participants then read the experiment instructions, which asked them to read each sentence carefully and at their normal speed. There was then a practice session of six trials to familiarise participants with the experimental procedure.

At the start of each trial, a black box would appear on the left side of the screen (positioned at the left edge of where the sentence would appear). A sentence would be presented on the screen as soon as participants' fixation on the box was detected. After reading the sentence, participants would press the centre button on a button-box which was comfortably placed in their hands. Comprehension questions would follow each item, and responses were recorded using the same button-box. After answering the question, a new black box would appear on the screen and start a new trial. Re-calibration was carried out every time the tracker accuracy became unreliable. This could be identified by the inability to trigger a trial's stimulus presentation. Similarly, re-calibration occurred after any break requested by the participant.

The task lasted approximately 45 min and was administered in a soundproof room.

2.1.4. Data analysis

Ten participants were excluded from the final analysis due to the following reasons: one participant scored low on filler accuracy (75%); eight participants had more than 50% of trials from any one condition eliminated due to track loss occurring on the critical region (inclusive of verb to object NP). Track loss included blinks or long saccades (>80 ms) going into or out of the region (see Keung and Staub, 2018 for a similar practice); one participant was excluded due to a clear lack of reading (short and few fixations that span long parts of text). Data from 48 participants were analysed.

Comprehension accuracy data were analysed using a mixed effects logistic regression including syntax and predicate type along with their interaction as fixed effects, and both subjects and items as random effects (including intercepts and slopes for syntax). The contrasts were passive vs. active [−0.5, 0.5] and eventive vs. stative [−0.5, 0.5]. During the discussion of the results, modifications of the random effects structure due to convergence failure or singularity will be indicated.

Eye movements were initially pre-processed to exclude trials based on: (1) track loss in the critical region or (2) more than 15 blinks overall within the whole trial (including the stage before the sentence was triggered). Overall, 13.16% of trials were excluded after pre-processing. Eye fixations less than 80 ms were combined with preceding or proceeding fixations, if within a character distance. Fixations less than 40 ms or greater than 1000 were excluded.

The most comparable measure in eye-tracking to self-paced reading times is captured by *gaze duration* (see below for a detailed definition). In addition to gaze duration times, eye-tracking while reading provides measures of go-past time, probability of regression out, probability of re-reading, re-reading duration and total reading duration (see below for all relevant definitions), amongst others:

- Gaze duration (GD): sum of all fixation durations in a region before it is exited leftward or right-ward;
- Go-past (GP) time: sum of all fixation durations in a region before it is exited to the right; it does not include the time spent in other regions during regressions.[2]
- Probability of regression (PR): 1 if the region was exited to the left on first pass, 0 otherwise.
- Probability of re-reading (PRR): 1 if the region was re-read, 0 otherwise.
- Re-reading (RR) time: sum of all fixation durations in a region after it is exited to either right or left; It is NA when there are no regressions into the region[3].
- Total time (TT): sum of all fixation durations in a region.
- Skipping: 1 if region is skipped on first pass.

Gaze duration commonly reflects initial reading stages, while go-past time, re-reading, probability of re-reading and regressions and total time are associated with later or second pass stages (Rayner, 1998).

Eye movements were then analysed in RStudio (https://www.rstudio.com/). Each eye-movement measure (gaze duration; regression path; re-reading time; probability of re-reading, probability of regression, total time) was analysed within each of the critical sub-regions (region 1, containing only the verb; region 2, containing both the determiner and the first adjective; region 3, containing both the coordinator and the second adjective; region 4, containing the postverbal noun; see an example in (8)). The data were analysed with a linear mixed effects model including syntax and

predicate type along with their interaction as fixed effects, and both subjects and items as random effects (including both intercepts and slopes for syntax). However, since this model would not always converge, the maximal model that would allow for consistency across measures and regions was used, this included random intercepts only. The contrasts used were passive vs. active [−0.5, 0.5] and eventive vs. stative [−0.5, 0.5]. *p*-values were determined through treating the *t*-value as a *z*-statistic (Barr et al., 2013). Interactions were broken down with a model that included *Predicate/Syntax* as fixed effect to examine the effect of syntax on each level of the predicate:

(8) a. The guitarist was/ rejected/ by/ the attractive/ and talented/ singer/ on Tuesday morning.
b. The guitarist/ rejected/ the attractive/ and talented/ singer/ on Tuesday morning.

2.2. Results

2.2.1. Accuracy data

In the comprehension task, there was a significant main effect of syntax, due to the fact that accuracy was lower on passives (84.5%) than on actives (93.5%; $\beta = -1.05$, SE = 0.21, $z = -5.06$, $p < .001$[4]; see Table 2). The effect of passivisation (difference between passives and actives) was twice as large for stative predicates (11.3) than eventive predicates (5.95), despite this difference, the interaction was not significant.

Table 2. Response accuracy (and standard error) to comprehension questions in Experiment 1.

	Syntax	
Predicate	Passive	Active
Eventive	88.99% (1.71)	94.94% (1.19)
Stative	80.65% (2.16)	91.96% (1.49)

2.2.2. Eye-tracking data

We will discuss results for the following measures: gaze duration, go-past time, re-reading time, probability of regression, probability of re-reading and total time. These will be considered for each of the four critical regions analysed: (1) verb, (2) determiner and first adjective, (3) conjunction and second adjective, (4) postverbal noun.

In order to be succinct, we will only describe significant results that are of interest to the hypotheses laid out (i.e. main effect of Syntax and Syntax*Predicate interaction). Appendix 2 reports all statistics from the analyses (of both Experiments 1 and 2) and hence any main effect of Predicate type can be found there. It is hard to interpret an effect of predicate, given that predicate type was manipulated between items. Further, a post-hoc analysis, run on data taken from SUBTLEX-UK (which contains word frequencies based on subtitles of British television programmes; Van Heuven et al., 2014), revealed that our eventive verbs are twice as frequent as our stative ones (eventives Zipf frequency: 4.65; statives Zipf frequency: 2.48).

Verb Region: At the verb, there was no significant effect in gaze duration, but there was a significant effect of syntax in go-past time (Figure 1(A); $\beta = -23.37$, SE = 11.15, $t = -2.09$, $p = .04$) and probability of re-reading (Figure 1(B); $\beta = -0.45$, SE = 0.14, $t = -3.10$, $p < .01$), whereby active sentences had higher probability of re-reading than passive sentences. The syntax effect in probability of re-reading was qualified by an interaction with predicate type ($\beta = 0.72$, SE = 0.29, $t = 2.48$, $p = .01$). When broken down, a higher probability of re-reading in the eventive-active condition than the eventive-passive condition ($\beta = -0.80$, SE = 0.19, $t = -4.14$, $p < .01$) was observed alongside no difference with the stative predicates. There was also an interaction between predicate and syntax in total time ($\beta = 187.00$, SE = 52.15, $t = 3.59$, $p < .01$). The interaction in

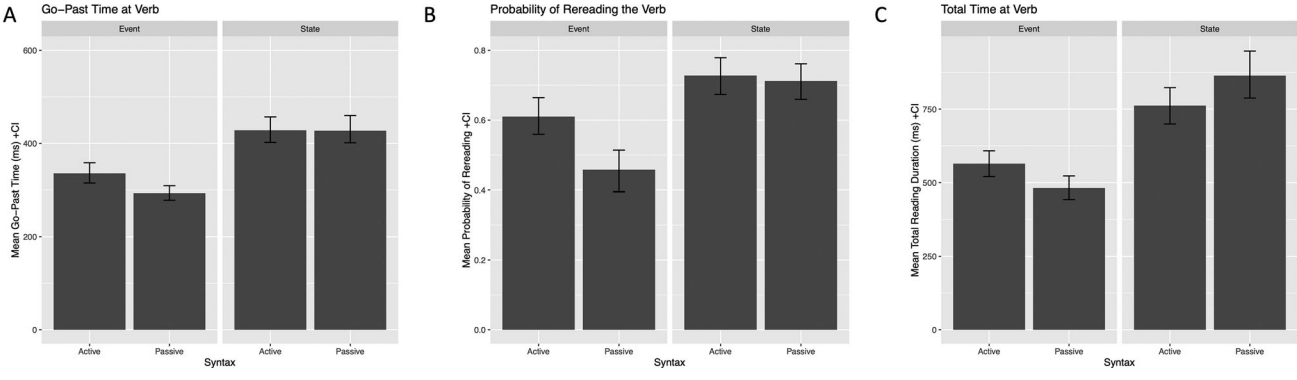

Figure 1. Mean eye-tracking measures at the verb with 95% confidence intervals (CI). (A) Go-past time. (B) Probability of re-reading. (C) Total reading duration.

total time revealed a significant effect of syntax for both predicate types, but, crucially, in opposite directions (see Figure 1(C); Table 3): passives were processed faster than actives with eventive predicates (β = −88.10, SE = 37.06, t = −2.38, p = .02), but slower than actives with stative predicates (β = 98.90, SE = 36.70, t = 2.69, p = .01). These data indicate that at the verb, passivising a stative predicate is more difficult than passivising an eventive predicate. Moreover, reading an eventive predicate in a passive structure is facilitated relative to an active structure. No other effect was observed across the measures.

First adjective region: At the second region, which comprised both determiner and first adjective, we found a significant effect of syntax (β = 30.61, SE = 11.39, t = 2.69, p = .01; see Figure 2(A)) in gaze duration (Figure 2(A)) due to longer fixations in the passive condition with respect to the active one. The same effect was observed in total time (Figure 2(C); β = 66.50, SE = 24.68, t = 2.70, p = .01). However, there was also a significant interaction between syntax and predicate in total time (Figure 2(C)) as well as re-reading (Figure 2(B); re-reading: β = 125.99, SE = 61.96, t = 2.03, p = .04; total time: β = 100.22, SE = 49.37, t = 2.03, p = .04). In both cases, passives with stative predicates had longer reading times than actives with stative predicates (re-reading: β = 86.55, SE = 40.04, t = 2.16, p = .03; total time: β = 116.61, SE = 34.91, t = 3.34, p < .01) and there was no difference across passivisation with eventive predicates. No other effect or interaction was observed across the measures.

Second adjective region: The third analysed region was composed of the conjunction "and" and the second adjective. We did not observe any significant effect or interaction across any of the eye-tracking measures.

Postverbal noun: The final region only contained the postverbal noun. No significant effect or interaction emerged in gaze duration, go-past time or re-reading times. However, a significant interaction was observed in probability of re-reading (Figure 3(A); β = 0.54, SE = 0.26, t = 2.07, p = .04) and total time (Figure 3(B); β = 98.83, SE = 38.73, t = 2.55, p = .01; see Figure 3). When broken down, neither simple main effects were significant in probability of re-reading, but total time revealed a significant effect of syntax in the stative condition (β = 73.74, SE = 27.39, t = 2.69, p = .01), due to passives having longer reading times than actives, while no difference was found in the eventive condition. No other effect or interaction was observed across the measures.

2.3. Discussion

The results support the hypothesis that passivisation is costly for stative predicates (specifically, subject-

Table 3. Mean (and standard error) for each reading time measure across regions in experiment 1 and 2.

		Gaze duration (ms)		Go-past (ms)		Probability of regression out		Probability of rereading		Rereading duration (ms)		Total reading duration (ms)	
Syntax	Predicate	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2	Exp1	Exp2
Verb													
Active	Event	299.87 (8.05)	300.38 (8.26)	335.64 (11.12)	332.69 (10.17)	0.13 (0.02)	0.17 (0.02)	0.61 (0.03)	0.63 (0.03)	439.14 (28.26)	444.67 (27.34)	564.35 (23.30)	564.48 (23.84)
	State	366.85 (13.17)	333.34 (12.20)	428.31 (14.68)	379.11 (15.00)	0.20 (0.02)	0.15 (0.02)	0.73 (0.03)	0.68 (0.03)	559.36 (29.28)	478.67 (23.30)	762.01 (30.50)	639.87 (23.60)
Passive	Event	277.00 (7.33)	296.26 (7.36)	293.56 (8.04)	322.92 (9.60)	0.11 (0.02)	0.14 (0.02)	0.46 (0.03)	0.58 (0.03)	455.57 (27.96)	392.55 (22.90)	481.66 (20.55)	497.92 (19.25)
	State	377.76 (14.08)	317.24 (9.87)	427.39 (15.14)	348.94 (11.89)	0.22 (0.03)	0.17 (0.02)	0.71 (0.03)	0.69 (0.03)	705.64 (50.41)	490.30 (26.17)	864.10 (42.81)	643.06 (25.63)
First Adjective													
Active	Event	370.05 (11.96)	350.59 (9.40)	414.47 (13.04)	392.48 (11.93)	0.16 (0.02)	0.14 (0.02)	0.55 (0.03)	0.62 (0.03)	487.16 (28.60)	478.69 (27.27)	634.85 (24.00)	641.16 (24.08)
	State	398.26 (11.81)	356.07 (10.00)	473.19 (19.16)	398.53 (12.04)	0.20 (0.02)	0.14 (0.02)	0.73 (0.03)	0.67 (0.03)	553.24 (31.60)	499.95 (28.35)	796.90 (29.44)	683.59 (25.64)
Passive	Event	408.85 (14.43)	357.60 (9.26)	444.52 (15.82)	385.05 (10.49)	0.14 (0.02)	0.13 (0.02)	0.54 (0.03)	0.56 (0.03)	455.02 (30.49)	453.83 (27.97)	656.62 (26.27)	602.34 (24.18)
	State	423.86 (14.38)	356.16 (9.92)	502.96 (19.72)	414.90 (12.18)	0.24 (0.03)	0.20 (0.02)	0.76 (0.03)	0.65 (0.03)	649.56 (37.38)	501.29 (26.88)	916.50 (36.71)	682.03 (24.32)
Second Adjective													
Active	Event	384.49 (12.44)	345.38 (9.43)	418.68 (13.23)	387.82 (13.07)	0.11 (0.02)	0.12 (0.02)	0.55 (0.03)	0.60 (0.03)	429.56 (23.64)	472.77 (26.48)	622.15 (21.27)	622.70 (23.36)
	State	382.99 (11.71)	361.55 (11.65)	424.68 (14.94)	394.48 (13.18)	0.11 (0.02)	0.12 (0.02)	0.68 (0.03)	0.65 (0.03)	536.20 (30.61)	472.86 (26.58)	747.44 (28.07)	622.48 (24.79)
Passive	Event	376.33 (11.52)	357.78 (9.88)	411.77 (13.02)	374.76 (10.76)	0.11 (0.02)	0.07 (0.02)	0.53 (0.03)	0.57 (0.03)	426.95 (25.67)	471.99 (27.00)	601.58 (22.08)	620.40 (23.61)
	State	391.32 (12.36)	354.69 (10.17)	437.78 (14.61)	374.56 (11.31)	0.12 (0.02)	0.08 (0.02)	0.72 (0.03)	0.60 (0.03)	588.63 (32.59)	492.88 (25.87)	805.27 (31.13)	647.27 (23.91)
Postverbal Noun													
Active	Event	330.42 (10.60)	313.04 (8.64)	355.59 (12.62)	331.94 (9.57)	0.13 (0.02)	0.15 (0.02)	0.52 (0.03)	0.50 (0.03)	387.72 (23.23)	400.07 (26.81)	524.46 (20.07)	511.87 (20.67)
	State	304.20 (7.84)	334.29 (12.30)	345.71 (11.45)	366.84 (13.99)	0.18 (0.02)	0.20 (0.02)	0.58 (0.03)	0.54 (0.03)	448.58 (24.32)	385.27 (23.21)	557.87 (21.97)	532.67 (20.71)
Passive	Event	315.04 (10.69)	311.42 (8.89)	337.14 (12.16)	336.99 (9.49)	0.12 (0.02)	0.15 (0.02)	0.45 (0.03)	0.52 (0.03)	399.44 (26.46)	388.68 (22.75)	496.73 (21.07)	505.30 (19.27)
	State	314.60 (9.70)	315.32 (7.77)	352.72 (13.26)	356.90 (10.86)	0.16 (0.02)	0.18 (0.02)	0.63 (0.03)	0.53 (0.03)	509.24 (34.14)	469.86 (26.05)	633.55 (28.79)	566.97 (22.21)

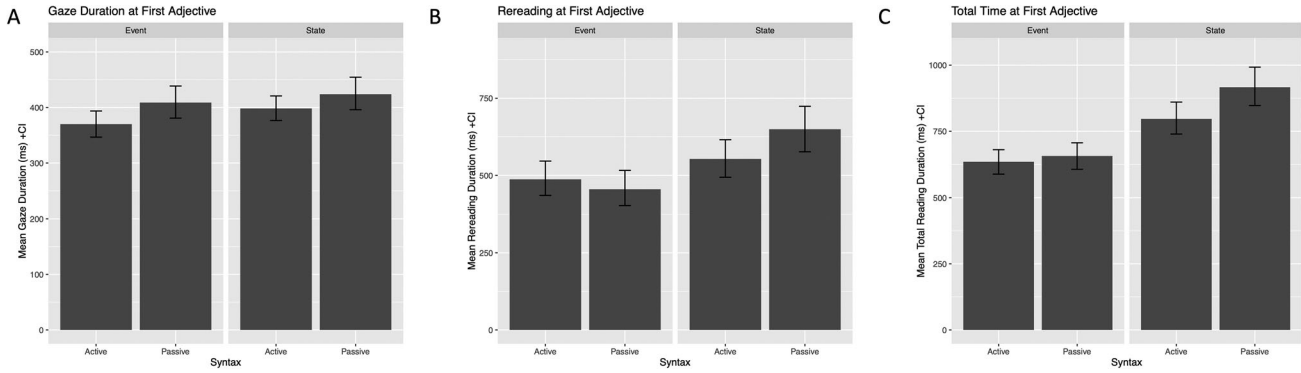

Figure 2. Mean eye-tracking measures at the first adjective region with 95% confidence intervals (CI). (A) Gaze duration. (B) Re-reading duration. (C) Total reading duration.

experiencers) but not eventive predicates. These effects were observed at the verb, first adjective, and the following noun. This interaction effect was not observed in early measures (i.e. gaze duration) but in late measures, as (probability of) re-reading and total time.

There was, however, a main effect of syntax in gaze duration at the first adjective region whereby passives resulted in longer reading times than actives. This is unexpected based on the previous self-paced reading data. This suggests that differences between the methodologies (self-paced reading vs. eye-tracking) may underlie this discrepancy. Indeed, a well-known, investigated phenomenon in natural reading is word skipping. Short words that have a high frequency and that can be easily predicted from context are skipped 70% to 80% of the time (Schotter et al., 2012). Skipping words allows readers to be more efficient, without losing information required to build an overall interpretation of the sentence. However, the time required to fully access and integrate these skipped words must be redistributed across adjacent regions. In particular, orthographic processing of skipped words is thought to take place in the region preceding the skipped word, while syntactic and semantic processing likely occur in the region following it. Hence, syntactic and semantic processing of skipped words should likely cause longer fixation durations on the region following the skipped word, all else being equal (Angele & Rayner, 2013).

Crucially, passivisation is signalled by short and highly frequent words, such as the auxiliary "was" and the preposition "by", which are not present in the active version of the sentence. If these words are skipped, then their processing and integration will be redistributed across adjacent regions, possibly causing longer fixations on and regressions out of the right-ward region to access and integrate the skipped word(s) for reasons

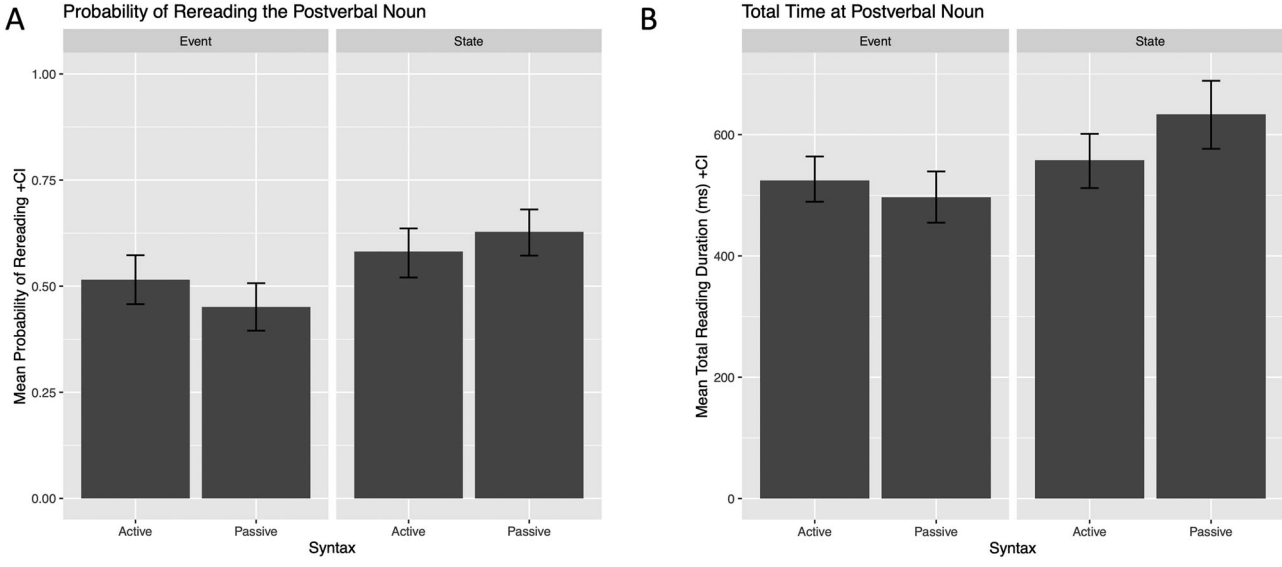

Figure 3. Mean eye-tracking measures at the postverbal noun with 95% confidence intervals (CI). (A) Probability of re-reading. (B) Total reading duration.

independent of passivisation difficulty. If "by" is skipped in the passive (9), we would expect to find longer reading times on the post-by region (i.e. "the girl") in the passive than the active version of the sentence (10). Hence, interpreting a longer gaze duration for the passive is complicated by word skipping:

(9) The boy was pushed by the girl.
(10) The boy pushed the girl.

Nonetheless the interaction effects do clearly support a modulation of passivisation difficulty by the predicate semantics. Before further interpreting the data, it is worth noting that the predicate type was manipulated between participants in the present experiment. Thus, it would be prudent to replicate these findings in a within-subject design. In addition to minimising random noise, a within-subject design will determine whether the presence of passive sentences with eventive predicates can eliminate (some of) the difficulty observed for passives with stative predicates. In particular, the eventive-passive condition may encourage a verbal passive interpretation. This would be in line with recent syntactic adaptation studies, where repeated exposure to a particular construction can lead to a facilitation in processing the construction over the course of the experiment (Fine & Jaeger, 2016; Yan & Jaeger, 2020). Thus, a within-participants design may facilitate the verbal passive interpretation and thereby limit the effects of the temporary ambiguity (verbal vs. adjectival) in the stative-passive condition, which is what Experiment 2 will test.

3. Experiment 2

3.1. Methods and design

3.1.1. Participants

Fifty-two native British English speakers were recruited to participate in the study (35 females; average age: 24.4). The same recruitment criteria and procedures were used as in Experiment 1.

3.1.2. Stimuli

The 28 experimental sentence sets were identical to those in Experiment 1. Six fillers were replaced with adjectival passives to ensure that the adjectival interpretation remained available. The experiment had a within-participants design: every participant was tested on all conditions but saw each item only once.

3.1.3. Procedure

See Experiment 1.

3.1.4. Data analysis

Four participants were excluded due to having excessive data loss (>60% trials) from any one condition due to track loss occurring on the critical region. Data from 48 participants were analysed. Overall, 13.84% of trials were excluded after pre-processing. See Experiment 1 for further details.

3.2. Results

As predicate type was manipulated between items, its main effects are not interpretable/of interest. Hence, we will only describe significant results of Syntax and the Syntax*Predicate interaction, as they are of interest to the hypotheses laid out. Appendix 2 reports all statistics from the analyses and hence any main effect of Predicate type can be found there.

3.2.1. Accuracy data

Again, the difference in accuracy between passive and active sentences for the stative predicates (11%) was almost twice that for the eventive predicates (6%). However, there was only a significant main effect of syntax[5] ($B = -1.07$, SE = 0.31, $t = -3.43$, $p < .001$) that did not interact with the predicate manipulation.

3.2.2. Eye-tracking data

Verb region: Unlike Experiment 1, there were no significant effects or interactions in this region[6].

First adjective: Unlike in Experiment 1, there were no significant effects in this region.

Second adjective: The only significant effect was a main effect of Syntax on probability of regression ($\beta = -0.55$, SE = 0.22, $t = -2.57$, $p = .01$), whereby actives had a higher probability of regressions out than passives.

Postverbal noun: An interaction emerged at the postverbal noun in re-reading (Figure 4; $\beta = 96.53$, SE = 44.98, $t = 2.15$, $p = .03$), whereby re-reading times were longer in the passive condition than the active condition for stative predicates ($\beta = 82.24$, SE = 31.49, $t = 2.61$, $p = .01$) and there was no difference between passives and actives for eventive predicates. No other relevant effects were significant in this region.

3.3. Discussion

Experiments 1 and 2 were identical other than the predicate manipulation was between subjects in Experiment 1 and within subjects in Experiment 2. Across experiments, the results show similarities, but also some differences. Both experiments reveal an

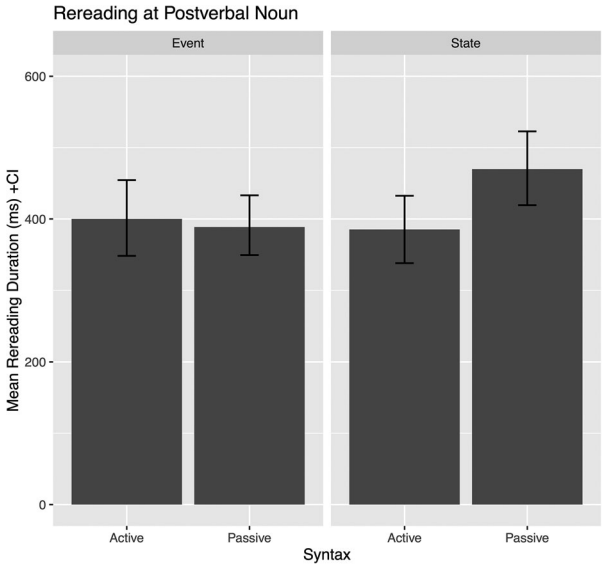

Figure 4. Mean re-reading duration at the postverbal noun with 95% confidence intervals (CI).

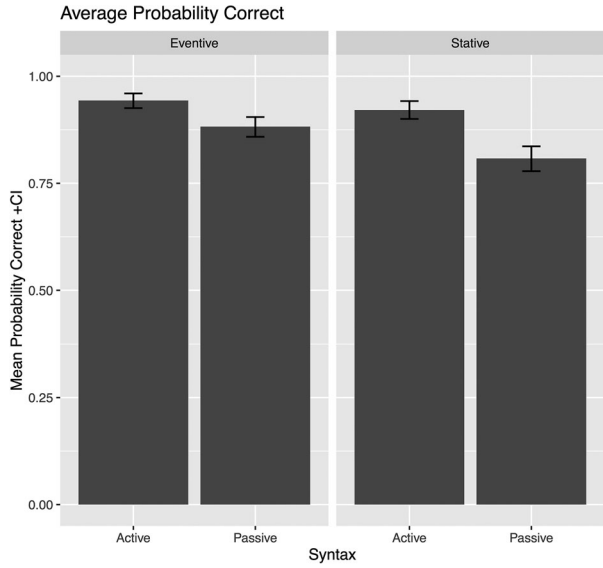

Figure 5. Mean probability correct answer with 95% confidence intervals (CI).

interaction between syntax and predicate at the postverbal noun region. The interaction between predicate and syntax in the verbal region in Experiment 1 showed a similar pattern in Experiment 2 but did not reach significance. The measure in which an interaction effect was most often found across experiments was re-reading and total time – late measures of processing difficulty. Likewise, across experiments we found go-past times at the verb region to be longer in the active than the passive condition although it did not reach significance in Experiment 2 (p = .06). This is consistent with the self-paced reading data. A similar effect was also observed in probability of regression within the second adjective region in Experiment 2, only. While there was an interaction in the first adjective region both in re-reading and total time in Experiment 1, neither were observed in Experiment 2. This might be due to the presence of eventive passives encouraging a verbal passive and thereby reducing the adjectival interpretation of stative passives and hence the required revision initiated at the "by-phrase". More puzzling is the difference across Experiments in terms of the effect of syntax on gaze duration measures in the first adjective region. In Experiment 1, we saw longer reading times in the Passive than Active condition at the adjective, but no effect was observed in Experiment 2. Since in both experiments syntax was manipulated within participants, these different results should not be attributable to the methodological difference across experiments. However, differences in significance may not be significantly different. In order to assess whether they are and also increase the power of our analysis, we pooled the data from Experiments 1 and 2 and included Experiment as a fixed effect.

4. Pooled data across experiment 1 and experiment 2

4.1. Accuracy data

The accuracy data demonstrated a significant main effect of syntax (β = −1.02, SE = 0.20, Z = −5.08, p < .01), with passive sentences being responded to less accurately than active ones (see Figure 5). Numerically, the difference in accuracy between actives and passives was much larger for the stative predicates (11.31%) than the eventive predicates (6.1%). Nonetheless, the interaction was not significant and there was no significant difference across the two experiments.

4.2. Eye-tracking data

Verb: There were no effects in gaze duration. In go-past time times there was a main effect of syntax (Figure 6(A); β = −21.48, SE = 7.83, t = −2.74, p = .01). Both eventive and stative verbs had longer fixation durations in the active than the passive condition. There was a similar main effect of Syntax in probability of re-reading (Figure 6(B); β = −0.28, SE = 0.10, t = −2.80, p < .01), qualified by an interaction with predicate (β = 0.51, SE = 0.20, t = 2.58, p < .01). The eventive-active condition had a higher probability of re-reading (β = −0.53, SE = 0.13, t = −3.95, p < .01) than the eventive-passive condition and there was no effect of syntax in the stative condition. An interaction between experiment and

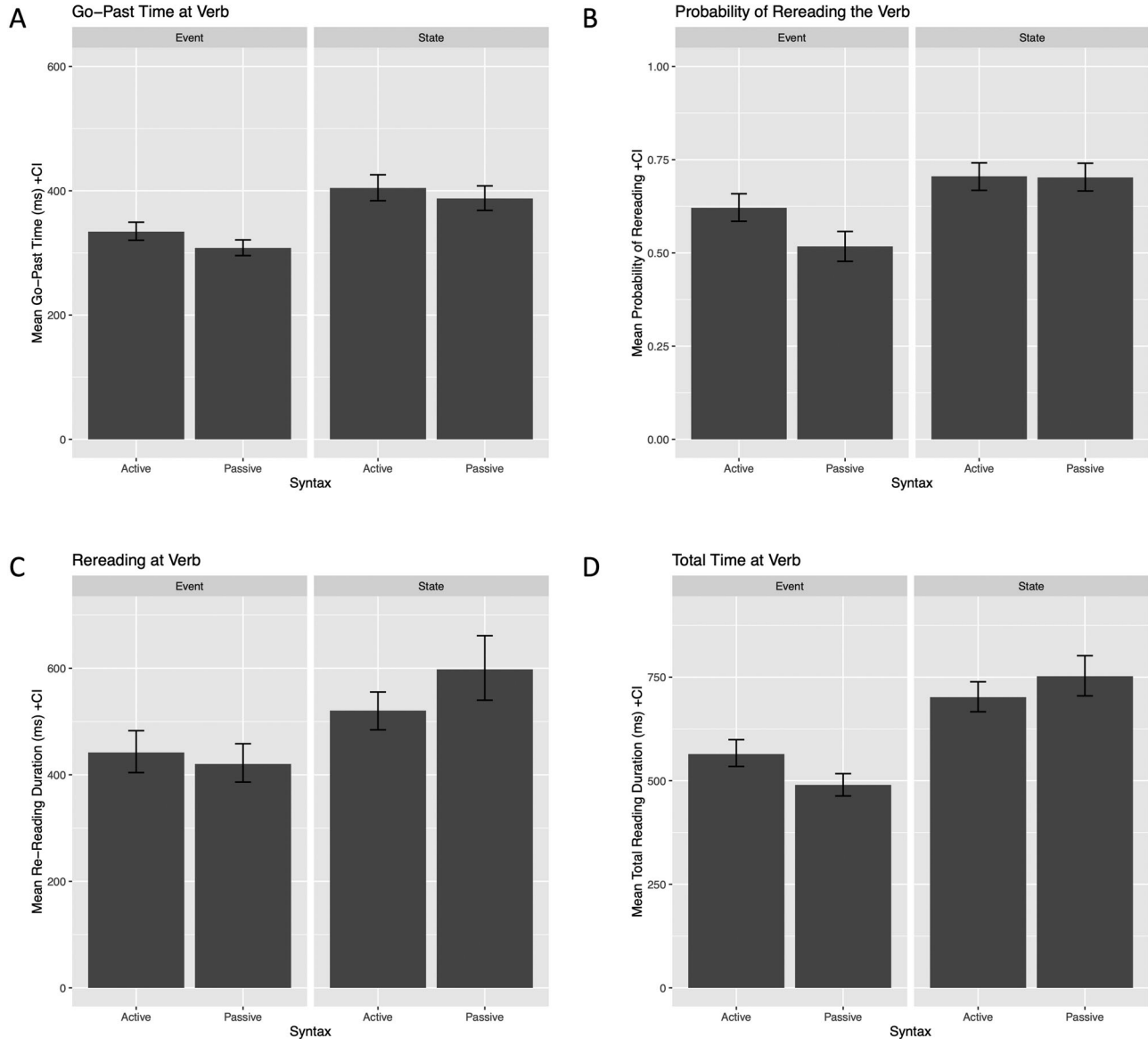

Figure 6. Mean eye-tracking measures at the verb with 95% confidence intervals (CI). (A) Go-past time. (B) Probability of re-reading. (C) Re-reading duration. (D) Total reading duration.

syntax was observed in re-reading (Figure 6(C); β = −90.46, SE = 41.65, t = −2.17, p = .03), with a significant syntax effect in Experiment 1 (passive > active) but not in Experiment 2. There was also an interaction between syntax and predicate type in re-reading (β = 103.33, SE = 41.65, t = 2.48, p = .01), such that the stative-passive condition resulted in more re-reading (β = 73.23, SE = 27.60, t = 2.65, p = .01) than the stative-active condition, however there was no difference between the eventive-passive and eventive-active conditions. An interaction also emerged in total time (Figure 6(D); β = 131.74, SE = 33.45, t = 3.94, p < .01), where again the stative-passive condition had longer fixation durations than the stative-active condition (β = 52.39, SE = 23.57, t = 2.22, p = .03) and the effect went in the opposite direction for eventive predicates (β = −78.75, SE = 23.78, t = −3.31, p < .01). See Table 4 for all fixed effect statistics from the Pooled data analysis.

First adjective: There was an effect of syntax in gaze duration (Figure 7(C); β = 17.31, SE = 7.10, t = 2.44, p = .01), whereby passives had longer fixation durations than actives. In total time, the syntax effect was qualified by a significant interaction with experiment (Figure 7(C); β = −87.71, SE = 32.90, t = −2.67, p = .01). The syntax effect (passive > active) appeared in Experiment 1 but not 2. There was an interaction between syntax and predicate in probability of regression (Figure 7(B); β = 0.50, SE = 0.24, t = 2.10, p = .04). This was due to the probability of regressions out of the region being greater for the stative-passive condition

Table 4. Statistical results for each eye-tracking measure and region from the pooled data analysis.

	Gaze duration				Go past				Probability of regression out			
Fixed effect	*B*	SE	*t*-value	*p*-value	*B*	SE	*t*-value	*p*-value	*B*	SE	*t*-value	*p*-value
Verb												
Syntax	−9.03	6.87	−1.32	0.19	−21.48	7.83	−2.74	**0.01**	−0.03	0.13	−0.26	0.79
Predicate	56.27	10.88	5.17	**<0.01**	75.52	14.15	5.34	**<0.01**	0.38	0.18	2.11	**0.04**
Exp	−19.92	13.77	−1.45	0.15	−29.31	18.41	−1.59	0.11	−0.01	0.22	−0.05	0.96
Syntax:Predicate	12.65	13.72	0.92	0.36	12.04	15.66	0.77	0.44	0.35	0.25	1.38	0.17
Syntax:Exp	−1.82	13.72	−0.13	0.89	2.69	15.66	0.17	0.86	−0.13	0.25	−0.52	0.60
Predicate:Exp	−56.11	21.75	−2.58	**0.01**	−76.40	28.28	−2.70	**0.01**	−0.69	0.36	−1.91	0.06
Syntax:Predicate:Exp	−42.60	27.48	−1.55	0.12	−54.84	31.36	−1.75	0.08	0.17	0.51	0.33	0.74
First Adjective												
Syntax	17.31	7.10	2.44	**0.01**	14.56	8.75	1.66	0.10	0.11	0.12	0.93	0.36
Predicate	13.23	14.35	0.92	0.36	42.55	19.48	2.18	**0.03**	0.43	0.17	2.56	**0.01**
Exp	−48.34	19.01	−2.54	**0.01**	−67.43	26.12	−2.58	**0.01**	−0.27	0.20	−1.32	0.19
Syntax:Predicate	−7.72	14.19	−0.54	0.59	12.84	17.49	0.73	0.46	0.50	0.24	2.10	**0.04**
Syntax:Exp	−28.27	14.20	−1.99	*0.05*	−25.41	17.50	−1.45	0.15	0.11	0.24	0.48	0.63
Predicate:Exp	−24.08	28.70	−0.84	0.40	−50.80	38.96	−1.30	0.19	−0.21	0.33	−0.61	0.54
Syntax:Predicate:Exp	7.35	28.39	0.26	0.80	31.55	34.98	0.90	0.37	0.12	0.47	0.25	0.80
Second Adjective												
Syntax	1.06	6.99	0.15	0.88	−7.68	7.86	−0.98	0.33	−0.25	0.14	−1.78	0.08
Predicate	7.75	12.99	0.60	0.55	13.55	17.02	0.80	0.43	0.09	0.19	0.49	0.62
Exp	−29.03	16.97	−1.71	0.09	−41.95	22.75	−1.84	0.07	−0.16	0.22	−0.73	0.47
Syntax:Predicate	−1.17	13.98	−0.08	0.93	6.46	15.71	0.41	0.68	0.19	0.28	0.67	0.50
Syntax:Exp	6.48	13.99	0.46	0.64	−14.90	15.72	−0.95	0.34	−0.63	0.28	−2.21	**0.03**
Predicate:Exp	0.00	25.97	0.00	1.00	−17.34	34.04	−0.51	0.61	−0.13	0.37	−0.34	0.74
Syntax:Predicate:Exp	−30.23	28.00	−1.08	0.28	−17.38	31.46	−0.55	0.58	−0.04	0.57	−0.08	0.94
Postverbal Noun												
Syntax	−5.53	6.12	−0.90	0.37	−3.26	7.47	−0.44	0.66	−0.08	0.12	−0.67	0.51
Predicate	0.07	9.59	0.01	0.99	15.22	11.33	1.34	0.18	0.36	0.15	2.41	**0.02**
Exp	1.26	12.11	0.10	0.92	−0.75	14.18	−0.05	0.96	0.15	0.17	0.91	0.36
Syntax:Predicate	4.85	12.25	0.40	0.69	7.22	14.94	0.48	0.63	−0.07	0.25	−0.29	0.78
Syntax:Exp	−8.54	12.26	−0.70	0.49	4.98	14.95	0.33	0.74	0.14	0.25	0.56	0.58
Predicate:Exp	24.92	19.18	1.30	0.19	23.11	22.66	1.02	0.31	−0.15	0.30	−0.52	0.61
Syntax:Predicate:Exp	−44.86	24.52	−1.83	0.07	−44.54	29.90	−1.49	0.14	−0.12	0.50	−0.23	0.82

	Probability of rereading				Rereading duration				Total reading duration			
Fixed effect	*B*	SE	*t*-value	*p*-value	*B*	SE	*t*-value	*p*-value	*B*	SE	*t*-value	*p*-value
Verb												
Syntax	−0.27	0.10	−2.80	**<.01**	20.85	20.84	1.00	0.32	−13.17	16.73	−0.79	0.43
Predicate	0.73	0.19	3.81	**<.01**	123.28	31.93	3.86	**<0.01**	201.61	34.94	5.77	**<.01**
Exp	0.02	0.25	0.07	0.94	−81.02	39.89	−2.03	**0.04**	−85.43	46.49	−1.84	0.07
Syntax:Predicate	0.51	0.20	2.58	**<.01**	103.33	41.65	2.48	**0.01**	131.74	33.45	3.94	**<.01**
Syntax:Exp	0.31	0.20	1.59	0.11	−90.46	41.65	−2.17	**0.03**	−35.27	33.46	−1.05	0.29
Predicate:Exp	−0.58	0.38	−1.52	0.13	−128.15	63.84	−2.01	**0.04**	−186.86	69.88	−2.67	**0.01**
Syntax:Predicate:Exp	−0.35	0.39	−0.88	0.38	−56.66	83.22	−0.68	0.50	−109.00	66.95	−1.63	0.10
First Adjective												
Syntax	−0.04	0.10	−0.43	0.67	3.87	20.26	0.19	0.85	23.52	16.45	1.43	0.15
Predicate	0.72	0.18	4.02	**<0.01**	83.09	30.41	2.73	**0.01**	135.02	35.00	3.86	**<0.01**
Exp	−0.20	0.23	−0.86	0.39	−58.03	37.77	−1.54	0.12	107.68	46.68	−2.31	**0.02**
Syntax:Predicate	0.26	0.19	1.33	0.18	78.84	40.41	1.95	*0.05*	70.54	32.90	2.14	**0.03**
Syntax:Exp	−0.33	0.19	−1.72	0.09	−40.39	40.44	−1.00	0.32	−87.71	32.90	−2.67	**0.01**
Predicate:Exp	−0.77	0.36	−2.14	**0.03**	−119.17	60.76	−1.96	*0.05*	−161.11	70.00	−2.30	**0.02**
Syntax:Predicate:Exp	−0.04	0.39	−0.10	0.92	−85.26	80.88	−1.05	0.29	−50.18	65.82	−0.76	0.45
Second Adjective												
Syntax	−0.06	0.10	−0.62	0.53	11.90	18.44	0.65	0.52	4.69	15.17	0.31	0.76
Predicate	0.48	0.18	2.66	**<0.01**	68.53	27.00	2.54	**0.01**	95.72	32.01	2.99	**<.01**
Exp	−0.14	0.24	−0.61	0.54	−10.26	33.42	−0.31	0.76	−56.76	42.64	−1.33	0.18
Syntax:Predicate	0.11	0.19	0.59	0.56	37.80	36.83	1.03	0.30	34.73	30.33	1.14	0.25
Syntax:Exp	−0.25	0.19	−1.33	0.18	−17.41	36.78	−0.47	0.64	−23.45	30.33	−0.77	0.44
Predicate:Exp	−0.59	0.36	−1.62	0.11	−138.09	53.99	−2.56	**0.01**	−131.09	64.01	−2.05	**0.04**
Syntax:Predicate:Exp	−0.38	0.38	−0.99	0.32	−24.21	73.56	−0.33	0.74	−76.46	60.70	−1.26	0.21
Postverbal Noun												
Syntax	−0.01	0.09	−0.14	0.89	31.57	17.27	1.83	0.07	19.78	13.05	1.52	0.13
Predicate	0.34	0.15	2.22	**0.03**	48.01	23.60	2.03	**0.04**	58.56	24.79	2.36	**0.02**
Exp	−0.13	0.19	−0.65	0.52	−22.65	28.63	−0.79	0.43	−23.77	32.55	−0.73	0.47
Syntax:Predicate	0.22	0.18	1.19	0.24	82.76	34.34	2.41	**0.02**	72.58	26.10	2.78	**0.01**
Syntax:Exp	0.06	0.18	0.33	0.74	5.19	34.41	0.15	0.88	−8.14	26.12	−0.31	0.76
Predicate:Exp	−0.46	0.30	−1.50	0.13	−60.01	47.19	−1.27	0.20	−47.31	49.58	−0.95	0.34
Syntax:Predicate:Exp	−0.66	0.36	−1.80	0.07	25.05	68.64	0.37	0.72	−59.24	52.22	−1.13	0.26

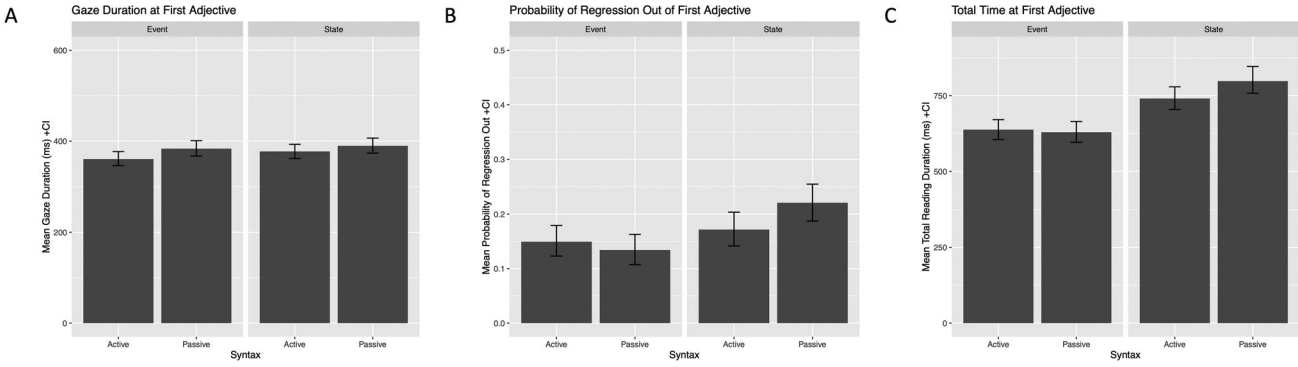

Figure 7. Mean eye-tracking measures at the first adjective with 95% confidence intervals (CI). (A) Gaze duration. (B) Probability of regression out. (C) Total reading duration.

than the stative-active one (β = 0.35, SE = 0.16, t = 2.22, p = .02) and there being no difference across the eventive conditions. There was a similar interaction between syntax and predicate in total time (β = 70.54, SE = 32.90, t = 2.14, p = .03); stative passives had longer reading times than stative actives (β = 58.55, SE = 23.27, t = 2.52, p = .01) but there was no difference across eventive conditions. No other significant effects were observed.

Second adjective: An interaction between syntax and experiment in probability of regression (β = −0.63, SE = 0.29, t = −2.21, p = .03) was observed. This was due to a significant effect of syntax (active > passive) in Experiment 2 but not 1.

Postverbal noun: There were no significant effects in gaze duration or go-past time. An interaction between syntax and predicate was observed in re-reading (Figure 8(A); β = 82.76, SE = 34.34, t = 2.41, p = .02) and total time (Figure 8(B); β = 72.58, SE = 26.10, t = 2.78, p = .01). In both cases, this was due to the stative-passive condition having longer fixation durations than the stative-active condition (re-reading: β = 72.71, SE = 23.32, t = 3.12, p < .01; total: β = 56.02, SE = 18.43, t = 3.04, p < .01), with no difference between eventive-passive and eventive-active conditions.

5. General discussion

The present experiments collected eye-tracking while reading measures to investigate whether and how event structure modulates the difficulty of processing passive sentences relative to active sentences. Here, we will focus our discussion on the most powerful and informative analysis, which combined the data from Experiments 1 and 2. Go-past time at the verb demonstrated a facilitation for passives relative to actives. We

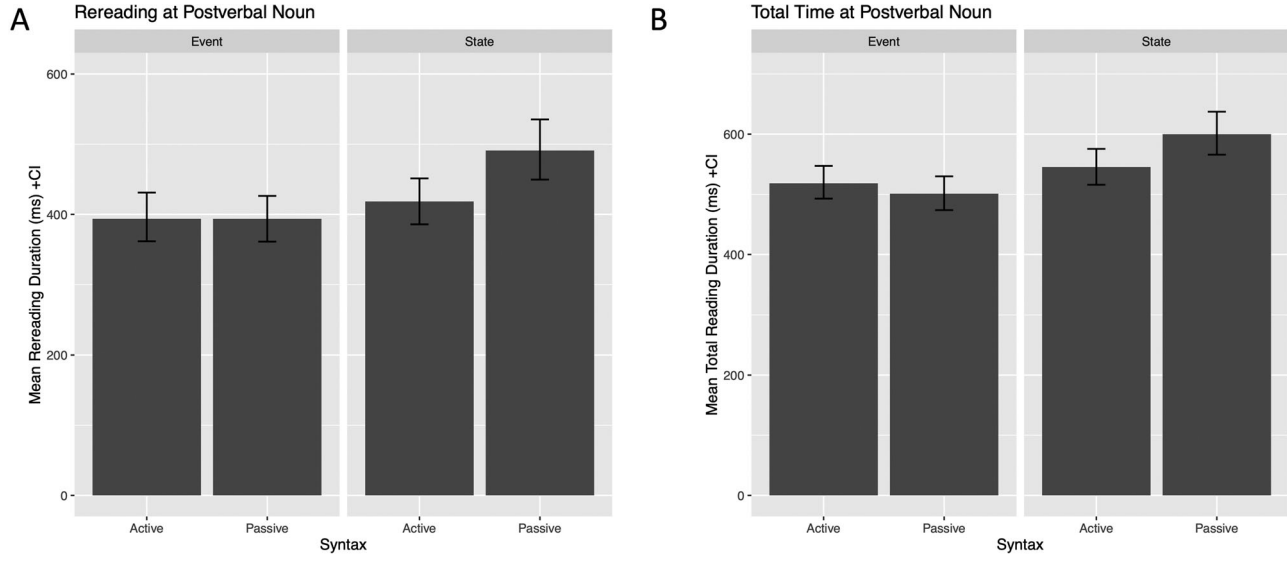

Figure 8. Mean eye-tracking measures at the postverbal noun with 95% confidence intervals (CI). (A) Re-reading duration. (B) Total reading duration.

also found a main effect of passivisation in gaze duration at the first adjective region, due to passives eliciting longer fixation durations than actives. There was no evidence that passivisation was modulated by verb type in gaze duration or go-past time, but syntax interacted with predicate in both re-reading and total reading duration at the verb and postverbal noun phrase and in probability of regression out of and total reading duration, at the first adjective region. Across regions, the interaction effect was always due to passives of statives eliciting longer reading durations or a higher probability of regression out of the region than their active counterparts, while there was no, or the opposite, difference across the eventive predicates.

The only significant difference across experiments of relevance[7] was in terms of the syntax effect in re-reading at the verb and probability of regression out of the second adjective region. Since syntax was a within-participants manipulation in both experiments, its difference across experiments is likely due to chance. However, all other differences in significance across experiments were not themselves significantly different. Moreover, the observed difficulty of passives with stative predicates was not eliminated by the presence of passives with eventive predicates and is observed at the verb, first adjective, and postverbal noun regions across experiments.

The observed interaction effects will first be discussed with respect to our original predictions, as these are of most interest. The main effect of syntax is of less interest, but we will briefly review these thereafter. Finally, some consideration of the accuracy data in light of results from recent experiments will be discussed.

5.1. Evidence for difficulty with passivising stative predicates (i.e. subject-experiencers)

Our eye-tracking data provide evidence in favour of predicate semantics modulating the difficulty of passivisation in late measures, i.e. probability of regressions out, re-reading and total time. In particular, a significant interaction was observed in three of the four regions: verb, first adjective, and the postverbal noun (e.g. "rejected/admired" and "singer" in (11)). In all regions, the numerical pattern was similar: stative passives demonstrated more re-reading and total reading times than stative actives, whereas eventive predicates demonstrated no difference or a facilitation for passives over actives.

(11) The guitarist was rejected/admired by the attractive and talented singer on Tuesday morning/throughout the tour.

The data are in line with our prediction that passivising stative predicates are more difficult than passivising eventive predicates. According to the relevant literature (Gehrke & Grillo, 2007, 2009; Grillo, 2008; Grodzinsky, 1995; Maratsos et al., 1985; McIntyre, 2013; O'Brien et al., 2006; Snyder & Hyams, 2015; Volpato et al., 2015), affectedness, revision and coercion are considered the underlying causes for the additional difficulty in passivising stative predicates (i.e. subject-experiencers), compared to eventives (Ambridge et al., 2016; Gehrke & Grillo, 2007, 2009; Snyder & Hyams, 2015).

The location of the interaction is perhaps informative to the source of the difficulty. In particular, the interaction emerged at the verb, first adjective and the postverbal noun, particularly in re-reading measures. Re-reading is the sum of all fixation durations for a region after it has been exited to either the right or left, which means after participants went back to re-read previous regions of the sentence or continued reading the following parts of the sentence. If resolving the temporary ambiguity between adjectival versus verbal readings or integrating an unaffected internal argument were the cause of difficulty one would expect the effect to be localised to the verb and/or first adjective rather than involving the postverbal noun. In particular, this should be seen in regressions out of the region and/or in re-reading it. Since the difficulty also emerges at a point where a comprehensive interpretation of the verb phrase has been built – the postverbal noun – it seems plausible to assume that the eventive reading of the stative-passive is driving the difficulty. Coercion of the eventive reading of the verb may require the full interpretation of the VP. Indeed this would be compatible with the definition of an event.

Event Definition (Davidsonian) (Maienborn & Wöllstein, 2005):

> "Events are particular spatiotemporal entities with functionally integrated participants."

That said, it is still possible that the temporary ambiguity and/or affectedness of the verb contributed to the increased re-reading within the verb region and relatedly regressions out of the following region (first adjective). To evaluate these interpretations, it would be of interest to look at the passivisation of object-experiencers that are simultaneously also stative (e.g. "interest", "depress"). If the same difficulty is observed with the object-experiencers as the subject-experiencers where the internal argument *is* the experiencer and clearly affected, then we can be sure that affectedness is not the only source. While previous studies have used object-experiencer predicates in studying passives

(Ambridge et al., 2016; Ferreira, 1994; Messenger et al., 2012) they have not restricted them to stative predicates to adequately test this hypothesis.

These findings are compatible with the absence of an interaction effect in our previously published self-paced reading data (Paolazzi et al., 2019). Here, we did not observe an interaction in early measures (which we argue are more comparable to what we are measuring with SPR), but only in later measures. Hence, the processes may not be captured in SPR times.

Likewise, their inconsistency with syntactic priming studies (Bidgood et al., 2020; Messenger et al., 2012), which do not observe a difference in the priming of passives across agent-patient and subject-experiencer verbs, maybe because the paradigms tap into different costs. Priming may be less sensitive to "late" processing effects. The economy of reusing a syntactic structure may be greater than the difficulty of coercing an eventive reading of a stative predicate.

Finally, the results are generally compatible with Ambridge et al. (2016) which found passivisation reduced acceptability more for subject-experiencer than agent-patient verbs. Ambridge et al. explain this in terms of affectedness, however, those data are also compatible with an event structure interpretation, which allow a unified treatment of the grammatical restrictions on passivisation (e.g. restrictions on nominal passives discussed above) and the higher processing complexity observed with stative passives.

Taken together, the data suggest that the complexity of passivisation depends on the syntactic and semantic properties of the passivised predicates. In particular, passivisation of states is more costly than for events, due to some combination of the following: (1) revision from a simpler adjectival interpretation, (2) coercion of the state as a result of an event, and/or (3) interpretation of a passivised subject that is not directly affected by the predicate.

5.2. Evidence for overall passive facilitation or difficulty?

For both eventive and stative predicates, go-past time time at the verb was shorter for passives than actives. In self-paced reading, we also found shorter reading times for passives compared to actives, independent of predicate type, at the verb. However, in self-paced reading we also saw this facilitation at the postverbal determiner, whereas here, we found the opposite effect in the postverbal region (i.e. the first adjective region), with passives showing longer gaze duration times than actives. Thus, although reading times at the verb were shorter for passives than actives in both studies, the two methods revealed a different pattern of results in the region following the verb.

Interpreting a main effect of passivisation that occurs in a region following either the auxiliary ("was") or the "by" in the passive condition is complicated by the fact that short words are often skipped – 70%–80% of the time – in natural reading (Angele & Rayner, 2013; Schotter et al., 2012). When comparing passives and actives, the skipping phenomenon could introduce a confound, since actives do not contain these two short words. This concern is further strengthened in the region following "by" (the + first adjective), as two short, highly frequent words, "by" and "the" appear in sequence before the most likely first word to be fixated in that region (i.e. the first adjective). Indeed, in the current study "by" was skipped 71% of the time in Experiment 1 and 75% of the time in Experiment 2. Skipping "by" could entail that its lexical access and/or syntactic integration be performed at the following fixated region. Hence, longer fixation durations due to skipping cannot be disentangled from longer fixation durations due to syntactic complexity, which would be observed in the same direction (longer fixation durations on passives with respect to actives). We did not see the same effect in gaze duration at the verb, but there the percentage of trials where "was" was skipped was much lower (51% Experiment 1 and 60% Experiment 2).

It thus seems difficult to meaningfully interpret the observed main effect of passivisation in gaze duration at the first adjective region. In consideration of the fact that this main effect was found in gaze duration, which is the measure most similar to those collected in self-paced reading, but it was nonetheless not observed in four previously published self-paced reading experiments (Paolazzi et al., 2019) using the same stimuli, it is highly likely that it emerged due to the implications that skipping words have on reading times of subsequent words, which is only possible to observe under eye-tracking while reading, not self-paced reading.

Noteworthy, however, is that there was no effect of passivisation (i.e. passives > actives) in late measures, which in conjunction with the self-paced reading data provides further evidence against Syntactic Complexity, Frequency, or Good Enough accounts, which predict that passives are more complex and should have longer reading times than actives.

5.3. Passivisation in offline processing

In our offline comprehension data, we found participants to be less accurate for passives than actives

independent of predicate type. This is compatible with previous results collected in our lab and in the broader literature (Ferreira, 2003; Meng & Bader, 2021), which consistently found passives to be more errorful than actives, independent of predicate type.

Despite the fact that these data would seem compatible with models that predict passives to be inherently more difficult to parse than actives (e.g. the *Good Enough* model, the syntactic complexity approach and the frequentist approach), we and others have previously claimed that the comprehension task can give rise to additional processing demands to make passives appear to be more complex. Specifically, if the task targets post-interpretative processes, as in comprehension questions, the passive may be more demanding on these processes. If the comprehension questions, as in the current experiment, are in the active voice and targeting theta-role assignment this could cause interference in memory for the passive. Alternatively, questions in the active voice could be easier following an active sentence due to syntactic priming. Which of these are at play may vary depending on the participant's strategy and or attentional resources by trial. However, when this confound is eliminated so too is the overall effect of passivisation (Paolazzi et al., 2021). Hence, it is not surprising that passive sentences were found to be more errorful than actives, independent of predicate type. Although it is noteworthy that the accuracy difference across voice in the stative condition was double that in the eventive one.

5.4. Conclusion

Processing passivised states generated more re-reading with respect to their active counterparts, while no difference was found between actives and passives for eventive predicates. We argue this is likely due to the required eventive reading of the stative-passive, as the effect extends to the object noun. Both revision of an adjectival interpretation and difficulty passivising an unaffected internal argument should be localised to the verb and/or first adjective region. Nonetheless, all of these factors could contribute to the observed difficulty at the verb and first adjective region.

Despite there being multiple potential sources for subject-experiencers to render passivisation difficult, the absence of a passivisation effect with eventive verbs distinctively argues against the mainstream models of passive sentence processing – *Good Enough*, *Syntactic Complexity*, and *Production Frequency* – and provides new theoretical avenues to be explored in terms of event structure.

Notes

1. An anonymous reviewer pointed out that "a quick Google search shows that "the hating of … " is clearly acceptable (and therefore presumably considered grammatical by) quite a few people (97,000 results), as is "the fearing of … " (10,000 results)." The argument, however, is not that "the hating/fearing of" is ungrammatical, but that the full passive nominal is ungrammatical. Searching for "the hating of * by" on Google delivers only nine results, none of which is a full passive (in each instance the by-phrase is not part of the nominal and only introduces the author of a song or article which contains the string "the hating of" in the title). Similar search for "the fearing of * by" only delivers two results.
2. An anonymous reviewer asked that the measures "first pass" and "right bound" be renamed "gaze duration" and "go-past".
3. NA values were excluded prior to data analysis
4. The model only converged with intercepts and no slopes in the random effect structure.
5. The model converged appropriately with both intercepts and Syntax slope for subject random effects only
6. The model for total time failed to converge
7. The interactions between predicate and experiment are explicable in terms of the predicate type having a larger effect when manipulated between participants than within participants.

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