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Living in the present – how referent lifetime influences processing of past, present (perfect), and future tenses

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The English present perfect and simple future tenses are felicitous with the living, but not the dead, as a referent must exist at reference time. In contrast, the simple past is odd with living referents in out-of-the-blue statements, as it requires a specified or implied past reference time. We employed eye-tracking during reading (Experiment 1) and self-paced reading (Experiments 2 and 3) in order to explore how (referent) lifetime-tense congruence influences processing across three English tenses. Referent-lifetime contexts (e.g., *Jimi Hendrix was an American musician. He died in London.*) were followed by critical sentences in the present perfect (Experiments 1–3), simple future (Experiments 1 and 2), and the simple past (Experiment 3) (e.g., *He has performed/will perform/performed in numerous music festivals.*). Lifetime-tense congruence effects in reading times and naturalness responses emerged in all three tenses, but with differences in the latency, magnitude, and direction of effects: Longer reading times were elicited by the present perfect (Experiments 1–3) and simple past (Experiment 3) in incongruent (versus congruent) lifetime-tense conditions, with earlier and larger congruence effects in the present perfect. Conversely, the simple future elicited shorter reading times and reaction times in the incongruent condition (Experiments 1 and 2). All incongruent lifetime-tense conditions elicited lower naturalness judgements than congruent conditions, suggesting metalinguistic awareness of the violations, with the largest effect in the simple future condition. Our findings provide the first evidence of processing costs associated with violations of the Perfect Lifetime Effect, and contribute to the existing literature exploring the distribution and processing of (English) tenses.

1. Introduction

The Lifetime Effect refers to the temporal link between verb tense and a referent's lifetime or existence. The link can license inferences about an unknown referent's lifetime, as in (1a) and (1b),[1] or can be violated when prior knowledge is known about the referent, as in (2a) and (2b), where the use of *was from* and *is from* gives rise to the incorrect inferences that Will Smith is dead and David Bowie is alive, respectively.[2]

(1)	a.	Holly is from Tyne Valley.	↝ *Holly is alive*
	b.	Ida was from Lazio.	↝ *Ida is dead*
(2)	a.	Will Smith was from West Philadelphia.	↝ *#Will Smith is dead*
	b.	David Bowie is from London.	↝ *#David Bowie is alive*

Lifetime inferences are a type of temporal inference, whereby verb tense can give rise to inferences about the current state of a situation (e.g., Altshuler & Schwarzschild, 2013; Musan, 1995; Thomas, 2012). Lifetime inferences are licensed in the simple present and past tenses by individual-level predicates, such as *is/was from Tyne Valley*, which refer to properties that hold for the duration of one's existence (e.g., Kratzer, 1989; Meyer-Viol & Jones, 2011; Mittwoch, 2008a; Musan, 1995). Lifetime inferences arise because a referent must exist at reference time (e.g., Anderson, 1973; Musan, 1997). In English, the Lifetime Effect also applies to the present perfect (e.g., *has done*), as it is a present tense which requires the moment of speech (i.e., the present) to be included in reference time. The (English) present perfect is therefore infelicitous with dead referents, thereby licencing the inference that a referent is alive, as in (3a) (e.g., Mittwoch, 2008a). This is in contrast to the present perfect's morphological equivalent in some closely related languages, such as the *Perfekt* in German, which has a distribution more similar to the English simple past (e.g., *did*) and is often translated into English as the simple past, not the present perfect (Dickey, 2000; Klein, 2000; Rothstein, 2006; Schaden, 2009). Sentence (3a) is an example of the existential reading of the present perfect, also aptly referred to as the *experiential* perfect, which refers to a situation that occurred at least once in some past time frame which continues to the present (Comrie, 1976). This requirement for the past time frame to include the present is what triggers the lifetime inference that Holly is alive in Sentence (3a).

In contrast to the present perfect, the English simple past can be used to describe past actions of both the living and the dead, as in (3b).[3] Though the simple past is commonly used with living referents, it requires a past temporal antecedent (such as *last week*), which has been argued

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[1] ↝ is read as 'infers' or 'gives rise to the inference'.

[2] # represents an infelicitous statement or inference, given certain higher-level knowledge, as in *#The Eiffel Tower is a famous landmark in Toronto.*

[3] ↝̸ is read as 'does not infer' or 'does not give rise to the inference'.

to have an anaphoric nature comparable to pronouns (Kratzer, 1989; Partee, 1973, 1984). Out-of-the-blue utterances with the simple past therefore lack a past reference time in which the situation is to have occurred. Such statements have been described as “hanging in the air” (Klein, 1992, p. 543), “anomalous” (Michaelis, 1994, p. 122), or even “not interpretable without some understood past time reference” (Partee, 1984, p. 254). By contrast, Meyer-Viol and Jones (2011) make an explicit claim regarding whether such utterances are linked to referent-lifetime, stating the simple past makes “no claim” regarding a referent’s lifetime at speech time (p. 247, referring to the statement *Einstein visited Princeton, Yukawa did, Friedman did…*). Extending these accounts to lifetime-tense congruence, competing predictions would be made regarding whether lifetime inferences are licensed by the simple past in such utterances. Given that a (known) referent’s lifetime may stand in as reference time in the absence of an explicit or implied (past) reference time, a dead referent’s lifetime should not leave an utterance such as *Einstein visited Princeton* “hanging in the air”, whereas the use of the simple past in the context of a living referent’s lifetime, such as *Chomsky visited Princeton*, would, according to Klein (1992), Kratzer (1989), and Partee (1973, 1984). Conversely, Meyer-Viol and Jones (2011) would predict no differences in the use of the simple past as a function of whether a referent is living or dead.

Unlike the English present perfect and simple past, the simple future does not refer to immutable past truths, but rather asssertions about future events. Future reference, thus, provides a less controversial example of lifetime-tense congruence, as future assertions are possible for the living but not the dead (see (3c)).

(3) a. Holly has visited Tyne Valley. $\rightsquigarrow$ *Holly is alive*
b. Holly visited Tyne Valley. $\rightsquigarrow/\not\rightsquigarrow$ *Holly is dead*
c. Holly will visit Tyne Valley. $\rightsquigarrow$ *Holly is/will be alive*

In cases where a referent’s lifetime is already known, either through prior knowledge (see (4–5)) or discourse contexts, temporal marking on the verb can contradict this referent-lifetime knowledge. Such lifetime-tense incongruence, as in (4b) and (5a), may elicit processing costs, as the referent’s lifetime cannot be resolved with the temporal marking on the verb. The Lifetime Effect thereby presents an opportunity to explore the influence of implied (rather than explicitly stated) temporal constraints determined by a known referent’s lifetime on the processing of temporal verb morphology. Furthermore, the Perfect Lifetime Effect allows for an investigation into the English present perfect in incremental processing.

(4) a. Will Smith has visited the Eiffel Tower. $\rightsquigarrow$ *Will Smith is alive*
b. Will Smith visited the Eiffel Tower. $\rightsquigarrow/\not\rightsquigarrow$ *#Will Smith is dead*

(5) a. David Bowie has visited the Eiffel Tower twice. $\rightsquigarrow$ *#David Bowie is alive*
b. David Bowie visited the Eiffel Tower twice. $\rightsquigarrow/\not\rightsquigarrow$ *David Bowie is dead*

The current study examines the influence of lifetime-tense congruence during processing, with a focus on the English present perfect in comparison to the simple past and future tenses. We employed eye-tracking during reading and self-paced reading to tap into incremental processing, and naturalness judgement tasks to explore metalinguistic awareness of lifetime-tense congruence. We further measured total-sentence reaction times in order to capture any cumulative costs accrued by reading the sentences as a whole, rather than at certain regions. The following section provides an overview of previous investigations into the processing of past, present, and future verb tenses (1.1), followed by a summary of previous literature on the Lifetime Effect (1.2). We then present three reading studies investigating the influence of lifetime-tense (in)congruence during comprehension, and discuss how the results contribute to the state-of-the-art presented.

1.1 Processing the past, present (perfect), and future

Empirical investigations into the processing of temporal verb morphology have shown that violations of temporal concord between an adverb and verb morphology are rapidly processed during comprehension. Such adverb-tense violations (*Yesterday Giancarlo *goes to the store*) have been shown to elicit processing costs at the onset of an incongruent verb in eye-tracking (Biondo et al., 2019, 2021), self-paced reading (Roberts & Liszka, 2013), and in EEG (Baggio, 2008; Bos et al., 2013; Dillon et al., 2012; Dragoy et al., 2012; Fonteneau et al., 1998; Newman et al., 2007; Steinhauer & Ullman, 2002). In addition, verb tense and aspect marking can modulate anticipatory looks towards a plausible recipient of a described action (Altmann & Kamide, 2007; Knoeferle et al., 2011; Knoeferle & Crocker, 2006; Minor et al., 2022). For instance, Altmann and Kamide (2007), found that, upon hearing the simple future (*The man will drink all of the*…) or present perfect (*The man has drunk all of the*…), more anticipatory looks were directed towards a full beer stein or an empty wine glass, respectively. Likewise, verb aspect (perfective/imperfective, e.g., *Grandma planted/was planting*…) has been shown to influence object and event representation, eliciting more looks towards/selections of a target versus competitor depiction of an event (Madden & Zwaan, 2003; Minor et al., 2022; Zhou et al., 2014), and foregrounding instruments and locations of events (Carreiras et al., 1997; Ferretti et al., 2007). Adverb-aspect and picture-aspect congruence has also been shown to modulate neurophysiological responses (Flecken et al., 2015; Misersky et al., 2021), providing evidence of the rapid availability of the event representation elicited by temporal marking on a verb. Temporal information encoded in a verb's tense/aspect morphology is, thus, rapidly available during processing. In the case of adverb-tense discord, processing costs qualitatively similar to those elicited by other morphosyntactic violations have been reported. However, important differences have been found between the processing of past, present, and future tenses.

The processing of present tenses has reliably elicited processing costs in past-referring temporal contexts (e.g., *Yesterday, Vincent *paints his house*; Baggio, 2008; Bos et al., 2013; Dragoy et al., 2012; Steinhauer & Ullman, 2002). The P600 event related potential (ERP) component, classically associated with morphosyntactic violations and structural reanalysis and repair, has been consistently elicited by such past-present violation conditions cross-linguistically (Dutch: Baggio, 2008; Bos et al., 2013; Dragoy et al., 2012; Newman et al., 2007; English: Steinhauer & Ullman, 2002; Spanish: Biondo et al., 2021), sometimes accompanied by a left-anterior negativity (LAN) typically associated with morphosyntactic anomalies (Baggio, 2008), or the sentence-final negativity (SFN; Dragoy et al., 2012) associated with sustained difficulties (e.g., Hagoort et al., 1993; Osterhout & Mobley, 1995). Meanwhile, in self-paced reading, processing costs associated with a discord between past temporal contexts and present tense have elicited longer reading times in post-verb regions (Chen, 2017; Roberts & Liszka, 2013). These consistent findings of rapid processing costs associated with a present-tense verb in an incongruent past temporal context suggest that adverb-tense relations are rapidly processed during incremental processing.

The processing of past tenses has elicited more mixed results. Studies comparing the processing of adverb-tense violations in present-past conditions (*now…painted*) and past-present conditions (*last week…paints*) have reported an asymmetry in effects elicited by the two conditions (compared to their congruent counterparts). In contrast to the rapid effects typically elicited by past-present violations, adverb-tense violations in the past tense seem to elicit later processing costs, such as the SFN (but not P600) in EEG (Dragoy et al., 2012), or total reading times at the critical verb region in eye-tracking during reading (Biondo et al., 2021). Additionally, Dragoy et al. (2012) found that present-past violation conditions elicited slower responses and fewer rejections (74%) than past-present violation conditions (90%), providing off-line evidence of slower responses and less accurate detection of adverb-tense violations when the past tense is used in present contexts, compared to the reverse. Extant evidence, thus, suggests that present-past (*now…painted*) and past-present (*last week…paints*) violations elicit differing costs in incremental processing, with past-present conditions eliciting immediate effects, and effects elicited by present-past conditions emerging later or only in off-line measures.

The processing of the future tense seems to pattern with the present, in that discord between a past time frame and a future tense verb (*yesterday…will go*) elicits rapid processing costs (P600: Bos et al., 2013; Dillon et al., 2012; Fonteneau et al., 1998; first-pass reading time: Biondo et al., 2021). Future-tense verbs have also been shown to modulate anticipatory looks towards plausible recipients of a future action in the visual world paradigm (Altmann & Kamide, 2007), although a previously depicted event (i.e., a past event) may override this preference, with more looks directed towards the recipient of the past event even when hearing a future-tense verb (Knoeferle et al., 2011; Knoeferle & Crocker, 2007). Together, these findings suggest that the use of the future tense in past contexts elicits rapid disruptions during comprehension, and that the tense can give rise to temporal inferences and guide anticipatory looks towards plausible recipients of a future action. Furthermore, future reference bears modal displacement, in that it links to possible worlds in a similar manner to modal verbs (e.g., neither *I might see him* nor *I will see him* refer to a true event, unlike *I saw him* or *I see him*; Bochnak, 2019). Futhermore, the processing of future reference is associated with less concrete mental representations than reference to concrete past or present events, with the processing of concrete (rather than abstract) events in past- and present-inflected verbs, but not future-inflected verbs, activating neural regions implicated in visual/spatial processing in Hebrew (Gilead et al., 2013). Together, these findings suggest that the future tense elicits anticipatory looks to a recipient of a future action as well as immediate processing costs when used in past temporal contexts, but that its processing is less grounded in visual-spatial processing compared with the past and present verb tenses.

Importantly for the present studies, the English present perfect is a present tense with perfect aspect, which refers to a past situation with some present relevance (Comrie, 1976).[4] The tense, thus, has its foot in both doors, expressing "a relation between present state and past situation" (Comrie, 1976, p. 53). This present relevance requires the tense to be used in temporal contexts that include the present, such as *since last week*. The present perfect has been found to elicit processing costs when preceded by temporal adverbs that do not include the present (*Since last week,/*Last week, Mark has seen the same film three times*), with the incongruent condition (*Last week*) eliciting lower grammaticality judgements and longer self-paced reading times than the congruent condition in post-verb regions (*Since last week*; L1-speaker control group in Roberts & Liszka, 2013). The simple past violation condition (*Last week/*Since last week, Mark saw the same film three times*) was found to likewise elicit lower judgements, with no differences in self-paced reading times found between the conditions. These findings indicate that violations of the present perfect's present-inclusive requirement elicit processing costs, whereas violations of the simple past do not. In addition, the present perfect can elicit anticipatory looks towards a plausible recipient of a past action (more looks to an empty beer stein than a full wine glass upon hearing *The man has drunk all of the…*; Altmann & Kamide, 2007). Taken together with the findings from Dragoy et al. (2012), it seems that present-tense verbs elicit rapid processing costs and lower ratings in past (versus present) referring contexts, whereas past-tense verbs elicit late effects in present (versus past) referring contexts.

The studies above explored how concord between a temporal adverb and a verb's temporal marking influences processing, providing evidence of rapid processing costs when this concord is violated. Although temporal marking on a verb is obligatory in English, temporal adverbs are not. The Lifetime Effect presents the opportunity to explore the processing of temporal concord in the absence of an explicitly mentioned time reference via the lifetime of a referent. If adverb-tense congruence elicits rapid processing costs in the present and future tenses, but more delayed

[4] *Perfect* should not be confused with *perfective*, which denotes a situation "viewed in its entirety" (Comrie, 1976, p. 12) and is often contrasted with the imperfective.

effects in the past tense, does this pattern of results carry over to the processing of lifetime-tense congruence in the Lifetime Effect?

1.2 Processing of the Lifetime Effect

In Chen (2017), English-speaking participants were presented context sentences describing two fictitious characters as either both living (living-living), both dead (dead-dead) or one living and one dead (dead-living).[5] This was followed by a sentence containing an individual-level predicate and a past or present marked verb. Referent-lifetime congruence was found to elicit longer self-paced reading times in sentences containing the simple present (*They are both very handsome*). The emergence of this effect in the present was earlier for the dead-living condition (longer reading times in the predicate region: *very handsome*) than the dead-dead lifetime condition (longer reading times at the spillover sentence-end region). Conversely, the simple past condition elicited no differences in reading times between the lifetime context conditions. In a separate acceptability judgement experiment, higher acceptability ratings were elicited by the fully congruent lifetime contexts (living-living + simple present; dead-dead + simple past) than conditions containing at least one incongruent referent-lifetime. These findings suggest a preference for living referents with the simple present and dead referents with the simple past, but processing costs in incremental processing only when lifetime-tense congruence is violated in the simple present by dead referent(s). This asymmetry mirrors the claim that the present tense elicits stronger lifetime inferences than the past tense (Mittwoch, 2008a), and counters claims that there would be no difference between the two tenses (Kratzer, 1989). This pattern of results is also consistent with adverb-tense congruence effects elicited by the past and present tenses reviewed above, namely, that processing costs are rapidly elicited by the present tense in past (dead) contexts, but only late or off-line effects are elicited by the past tense in present (living) contexts.

Alternatively, the distribution of the present perfect and simple past has been argued to involve pragmatic competition between the two tenses, which can account for the asymmetry in cross-linguistic distributions of present perfects and simple pasts, i.e., the constrained distribution of the present perfect in languages like English and Swedish, and of the simple past in languages like German and French (Schaden, 2009; Yoon, 2012). Based on Gricean pragmatics, this view suggests the use of the default, or unmarked, form does not require any justification, whereas use of the marked form triggers a “pragmatic reasoning process” (Schaden, 2009, p. 133). In this view, the use of the English simple past does not require any justification, as it is the default past-marked tense, whereas the use of the present perfect triggers a reasoning process to account for the use of the marked competitor. This can account for findings of processing costs for violations

[5] While Chen (2017) compared lifetime-tense effects in English and Mandarin, we refer here to the results from the English-language experiment.

in the present perfect, but not the simple past, in English (as in Roberts & Liszka, 2013), and would predict such a pattern in lifetime-tense congruence effects for the two tenses.

We extend the findings of adverb-tense and lifetime-tense effects to contexts in which only one referent and their lifetime is described, and when this referent's lifetime is presumably already known to participants. In addition, we explore the influence of referent-lifetime knowledge on the processing of the present perfect in contrast with the simple future and simple past. Given previous findings of processing costs associated with the use of the present perfect (Roberts & Liszka, 2013) and simple future (Biondo et al., 2022; Bos et al., 2013; Dillon et al., 2012; Fonteneau et al., 1998) in past temporal contexts, both tenses are expected to elicit processing costs in past (dead) referent-lifetime contexts. The finding of absent (Chen, 2017) or later effects (on-line: Dragoy et al., 2012; off-line: Roberts & Liszka, 2013) for the use of the simple past in present contexts leads to the expectation of later effects in on-line processing and/or effects in off-line measures. We employed eye-tracking during reading and cumulative self-paced reading which provide information on *when* processing costs occur, thereby providing information on the nature of the mechanism at play in the processing of the Lifetime Effect, and shedding light on any discrepancies in the latency of effects across tenses. The findings will thereby provide insight into how referent-lifetime context modulates incremental language comprehension, as well as the incremental processing of the English present perfect in incongruent past-temporal contexts in contrast with the simple future and simple past.

2. Current study

In three reading experiments, we investigated the incremental processing of temporal morphology when preceded by referent-lifetime contexts using eye-tracking (Experiment 1) and self-paced reading (Experiments 2 and 3). Whereas previous empirical investigations into the processing of temporal concord have explored local morphosyntactic relations between temporal phrases and temporal verb morphology, investigations into lifetime-tense congruence allow for the investigation of implicit temporal constraints linked to a referent's lifetime on the processing of verb morphology. The current study thereby builds on previous studies exploring adverb-tense congruence more broadly by replacing explicitly mentioned temporal constraints (temporal adverbs) with implied temporal constraints (a referent's lifetime). More broadly, investigations of implied temporal constraints provided by a referent's lifetime allow for an exploration of world knowledge on the processing of temporal constraints, similar to the findings in Altmann and Kamide (2007) whereby one's general higher-level world knowledge (e.g., what is or is not a likely recipient of a future or past action based on its current visually-depicted state) guided anticipatory eye movements to plausible recipients of a future or past action. Along this stream, our study investigates how and when higher-level knowledge about what is or is not possible for living and dead referents is available during processing. While Chen (2017) investigated the processing of lifetime-tense congruence effects in self-paced reading of individual-level predicates in the simple past and present tenses, the current study extends these effects to eye-tracking during reading, as well as self-paced reading, and predicates describing achievements in the present perfect, simple future, and simple past. The inclusion of eye-tracking during reading provides a more temporally fine-grained investigation into incremental processing, providing information on the time-course of lifetime-tense congruence effects in incremental processing.

In all three experiments, referent-lifetime knowledge was established via lifetime-context sentences defining a well-known cultural figure and explicitly stating their lifetime status (*Amy Winehouse was an English singer. She died in London.*). An ensuing sentence referred to an accomplishment of the cultural figure in one of the three verb tenses which was either congruent or incongruent given the preceding referent-lifetime context sentences (*She has performed/will perform/performed on many stages*). With the findings from Altmann and Kamide (2007) in mind, both Experiments 1 and 2 contrasted the English present perfect with the simple future. For both tenses, a preceding dead context would therefore be incongruent, as the referent does not/will not exist at reference time (the present or the future). This would follow similar findings of early effects of adverb-tense congruence in each tense (present perfect: Roberts & Liszka, 2013; simple future: Biondo et al., 2022 (Spanish); Bos et al., 2013 (Dutch); Dillon et al., 2012 (Hindi), Fonteneau et al., 1998 (French)). Experiment 3 contrasts the English present perfect with its common competitor, the simple past, which elicits an anomalous reading when following a living context in the absence of a defined past time reference (Klein, 1992; Michaelis, 1994; Partee, 1973, 1984). Experiment 3 thereby extends the findings of adverb-tense congruence effects for the present perfect in Roberts and Liszka (2013) to lifetime-tense congruence, and builds on previous investigations into the processing of past-tense verbs in non-past temporal contexts (e.g., Baggio, 2008; Dragoy et al., 2012). In addition to reading times (eye-tracking or self-paced), which were taken to reflect incremental processing, total-sentence reaction times were recorded in order to capture any cumulative processing costs not captured in the by-region reading times. Naturalness judgements were collected in each experiment in order to capture any discrepancies between the tenses in metalinguistic awareness of lifetime-tense congruence (Chen, 2017; as in Dragoy et al., 2012; Roberts & Liszka, 2013). An overview of critical manipulations across experiments is provided in **Table 1**.

Taking into account the extant research on the role of temporal concord and lifetime-tense congruence in comprehension, we addressed three overarching research questions across experiments: (i) (How) is incremental processing of temporal verb morphology modulated by preceding lifetime contexts of real-world referents? (ii) Are there differences in the processing of lifetime violations between the tenses? (iii) How are any differences between the tenses borne out, and, specifically, what are the implications for the English present perfect and the Perfect Lifetime Effect?

3. Eye-tracking during reading (Experiment 1)

3.1 Methods

3.1.1 Participants

Twenty-four native English speakers (aged 18–31, 21 female) participated in the study and were compensated 16 Euro. The whole procedure lasted approximately 90 minutes. Participants were all right-handed and had learned no other language before the age of six. The number of participants was based on power analyses run on pilot data from 8 participants (`powerCurve()` function in `simr` R package, Green & MacLeod, 2016; see supplementary materials on the OSF repository (https://osf.io/6sra7) for Experiment 1 pilot results and power analysis). Data collection was conducted in Berlin, Germany.

3.1.2 Materials and design

Critical items ($n = 80$) contained two lifetime-tense contexts, one for a living and one for a dead cultural figure (see (6)), and two critical sentences describing a common accomplishment of these cultural figures in either the present perfect (PP) or simple future (SF) (see 7)). Ten accomplishment/achievement verbs were used with plural objects (e.g., *win important elections*, *receive prestigious music awards*, *release well-received bestsellers*, *appear in numerous blockbusters*, *sell popular screenplays*, *work with well-known directors*, *star in critically acclaimed musicals*, *perform in numerous packed stadiums*, *write popular cookbooks*, *play notable iconic roles*). This resulted in an *existential/experiential* reading in the present perfect condition, triggering the Lifetime Effect.

(6) a. Beyoncé is an American performer. She lives in California. (*living*)
b. Whitney Houston was an American performer. She died in California. (*dead*)

(7) a. She <u>*has performed*</u> in many arenas in the past, apparently. (*PP*)
b. She <u>*will perform*</u> in many arenas in the future, apparently. (*SF*)

The critical stimuli contained two two-level factors (*lifetime*: dead or alive, *verb tense*: present perfect (PP) or simple future (SF)). Each item contributed four possible sentence combinations, corresponding to four conditions (see **Table 1** for distribution of conditions across experiments), resulting in 320 total sentence pairs. The four sentence pairs within each item were distributed across four experimental lists in a Latin Square design, resulting in 80 stimuli (20 per condition) in each list. The stimuli were fully counterbalanced, in that each item contributed equally to each condition, thus eliminating effects of verb form frequency and length, for example, from our effect of interest (i.e., lifetime-tense congruence).

Lifetime-context sentences for critical items (see (6)) had identical structure (*NAME is/was a(n) NATIONALITY + OCCUPATION. S/he lives/died in LOCATION*), with the information relevant to each cultural figure extracted from Wikipedia. The lifetime information of the cultural figures was explicitly mentioned in order to ensure the relevant lifetime knowledge was present.

Table 1: Distribution of conditions (Experiments 1–3).

Tense	Congruence	Lifetime	Context	Critical	Experiment
Present Perfect	+CON –CON	living dead	*Beyoncé…* *Whitney Houston…*	*…has performed…* *…*has performed…*	1, 2, 3
Simple Future	+CON –CON	living dead	*Beyoncé…* *Whitney Houston…*	*…will perform…* *…*will perform…*	1, 2
Simple Past	+CON –CON	dead living	*Whitney Houston…* *Beyoncé…*	*…performed…* *…*performed…*	3

Critical sentences (see (7)) had identical structure across items (*S/he* VERB ADJECTIVE/QUANTIFIER PLURAL-OBJECT *in the past/future,* SPILLOVER), and were identical for congruent and incongruent conditions for both the living and dead. The region containing *in the past/future* was always congruent with the verb tense (i.e., *has performed…in the past/will perform…in the future*). Crucially, there were no local violations in the stimuli. Rather, lifetime-tense violations could only be detected if the critical sentence was read in the context of the preceding referent-lifetime sentence. Therefore, any differences in reading times between the two lifetime-tense congruence conditions within either level of verb tense (e.g., *dead-* versus *living-PP*) could be attributed to difficulties integrating the verb tense with the preceding context.

Filler items ($n = 124$) consisted of sentence pairs that described fictional cultural figures and their professional and personal accomplishments. In 50% of filler items, the critical sentence unambiguously conflicted with information in the context sentences (e.g., mismatching gender, nationality, or job status). Similar to the critical items, filler mismatches could only be detected when the critical sentence was considered in the context of the preceding sentence context. Critical and filler stimuli are available on the OSF repository for this article.

3.1.3 Procedure

After determining the participant's dominant eye, the participant was seated at the experiment display, and adjusted their seat so they could comfortably place their head on a desk-mounted head rest. Eye-movements were recorded using an EyeLink 1000 desktop tracker (SR Research, Missisauga, Ontario, Canada). The experiment instructions were explained to the participant first orally, and then presented in text on the screen. A 9-point calibration preceded the experiment, with additional re-calibrations carried out after breaks ($n = 3$) or when required. Each trial was initiated by the experimenter after the participant fixated on a fixation dot on the screen. The experiment began after five practice trials.

Context sentences were presented on the screen in their entirety. Once participants had fully read and understood these sentences, they clicked the computer mouse to continue. A fixation box appeared for 500 ms, aligned with the beginning of the critical sentence. The critical sentence then appeared on the screen in its entirety. Participants again left-clicked once they had fully read and understood the sentence, at which point they were presented with a 7-point Likert scale. They were instructed to rate the naturalness of the critical sentence given the preceding context on a scale of 1 (*definitely wrong*) to 7 (*perfectly fine*), using the mouse to point and click. This procedure is demonstrated in **Figure 1**, which was presented on-screen to participants after they had read a full-length instructions text.

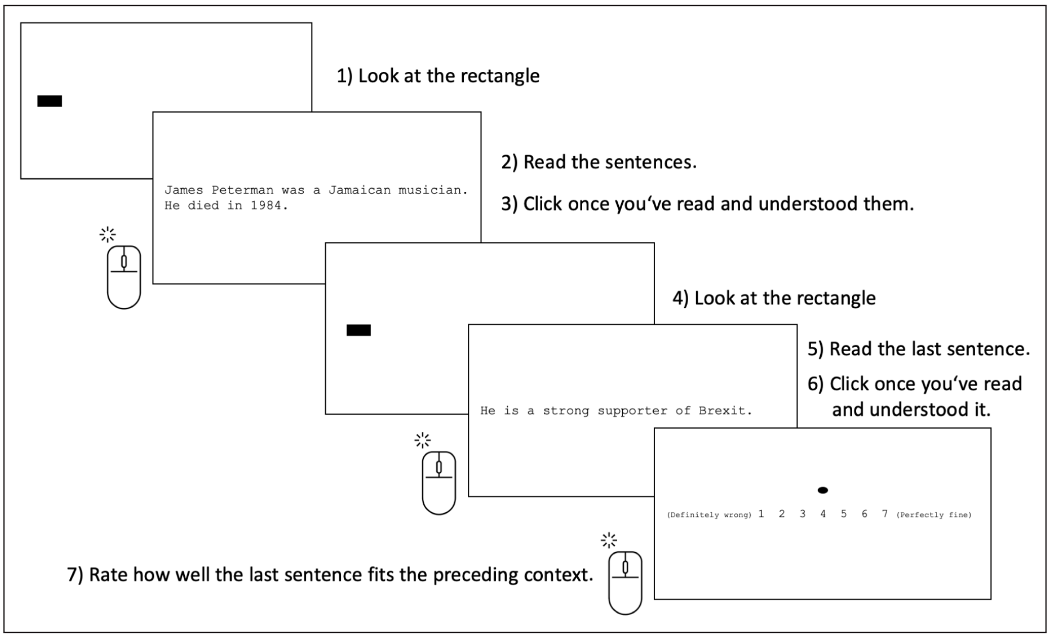

Figure 1: Procedure for Experiment 1 (eye-tracking during reading).

Critical trials never appeared in succession. Trials (n = 204) were divided into four blocks (n each = 51). The total experiment took approximately one hour. Unambiguously incorrect filler items were used as exclusion criteria, with participants who on average rated such items as *3* or higher being excluded from further analyses.

3.1.4 Predictions

We expected to find evidence of the Lifetime Effect in naturalness responses, reading times, and reaction times to the critical screen (duration from critical sentence presentation until mouse click). Comprehension processes modulated by the Lifetime Effect were expected to be exhibited in reading measures at the verb region, namely first-pass reading time (sum of fixation durations in a region before exiting the region in any direction), regression path duration (sum of fixation durations in the critical region, plus the duration of fixations to regions to the left and re-fixations in the critical region, before exiting to the right), and total reading time (sum of all fixation durations in a given region during sentence presentation), as well as in reaction times to the critical screen (reflecting total sentence reading times). Comparatively longer durations for these measures were taken to reflect processing costs. Rating scores were taken to reflect explicit awareness of a violation (i.e., metalinguistic awareness).

Naturalness judgements

Metalinguistic awareness of lifetime-tense congruence was taken to be reflected in the post-trial 7-point naturalness Likert ratings. An effect of lifetime-tense congruence was expected, with lower naturalness ratings for the incongruent (dead) conditions than congruent (living) conditions. Larger nested congruence effects were predicted for the simple future condition compared to the present perfect, reflecting the severity of the dead-simple future violation compared to the dead-present perfect violation.

Total sentence reaction times

Difficulties consolidating lifetime-tense incongruence were expected to result in cumulative and/or later processing costs. Such difficulties were expected to elicit longer total sentence reaction times (duration from critical-sentence presentation until button-press to continue to the naturalness rating), reflecting a delay in lifetime-tense consolidation. Larger nested congruence effects were predicted for the simple future condition compared to the present perfect, reflecting the severity of the dead-simple future violation compared to the dead-present perfect violation.

Eye-tracking reading times

Lifetime-tense congruence was expected to influence incremental processing, reflected in longer reading times for incongruent (dead) than congruent (living) conditions in eye-tracking during reading measures at the verb region. Such a pattern of effects in first-pass reading time and/or regression path duration would be taken to reflect processing costs associated with lifetime-tense incongruence and the rapid availability of referent-lifetime information during the processing of verb tense. An effect in total reading time at the verb region would be taken to reflect late and/or cumulative processing costs (e.g., Vasishth et al., 2013). Due to the subtlety of violations in the dead-present perfect compared to dead-simple future, stronger effects in on-line processing were expected in reading times for the simple future condition than the present perfect condition.

3.1.5 Data analysis

Sequential fixations shorter than 80 milliseconds were merged prior to analysis. Fixations shorter than 80 milliseconds or longer than 800 milliseconds were excluded. Critical sentences were divided into six regions. The regions for an example critical sentence are shown in **Table 2** for all three experiments, with Experiment 1 regions in the first row.

Table 2: Sentence regions across Experiments 1–3.

Experiment	verb-1	verb	verb + 1	verb + 2	verb + 3	verb + 4
1, 2	*She*	*has performed* *will perform*	*in prestigious*	*arenas*	*in the past,* *in the future,*	*apparently.*
3	*She*	*has performed* *performed*	*in prestigious*	*arenas,*	*according to*	*Wikipedia.*

The critical region of interest contained the auxiliary and main verb. First-pass reading time, regression path duration, and total reading time were computed using Data Viewer (SR Research). First-pass reading time is considered an early measure reflecting early, automatic processing, while total reading time is considered to reflect later, controlled processing effects (Conklin et al., 2018; Liversedge et al., 1998; Rayner, 1998), and/or cumulative processing effects (Vasishth et al., 2013). Regression-path duration has been defined as an intermediate measure (Conklin et al., 2018), as regressions reflect difficulties in initial integration as well as costs in reconciling these difficulties (Clifton et al., 2007). Post-trial naturalness ratings and reaction times (i.e., duration from critical sentence onset until participants clicked the mouse to continue to the rating) were also recorded.

Following visual inspection and a BoxCox test (`boxcox()` function in the `MASS` package (v.7.3.60.2); Venables & Ripley, 2002) on the reading and reaction time data, the data were log-transformed to achieve normality of the residuals in the subsequent models (Box & Cox, 1964). A linear mixed-effects model was run on the log-transformed reading time data for the verb region and total-sentence reaction time data (`lmer()` function from the `lmerTest` package (v.3.1.3)); Kuznetsova et al., 2017). A cumulative link mixed-effects model was run on the naturalness ratings (`clmm()` function in the `ordinal` package (v.2023.12.4); Christensen, 2019). Fixed effects were the two factors (congruence and tense) and their interaction, with trial order as a covariate. Participant and item were included as random effects, with main and interaction effects of congruence and tense as random slopes. Sum contrasts were used to investigate main effects and their interactions, with the levels congruent and *PP* coded as `-0.5`, and incongruent and *SF* as `+0.5`. Where interaction effects of congruence and tense emerged, follow-up nested contrasts were used to investigate lifetime-tense congruence effects within each tense (Brehm & Alday, 2022; Schad et al., 2020). Model estimates are provided in **Tables 3–5**. Model predictions (with 95% confidence intervals) were produced with the `ggpredict()` function from the `ggeffects` package (v.1.5.2; Lüdecke, 2018) in order to produce visualisations and supplementary tables (available on the OSF repository).

Model selection was carried out in order to determine the most parsimonious model given the observed data, following Bates, Kliegl, et al. (2015). This began with the maximal model justified by the experimental design, including all random slopes and intercepts described above

(Barr et al., 2013). For each model run, a random effects principal component analysis was run (`summary(rePCA(model))` from the `lme4` package (v.1.1-35); Bates, Mächler, et al., 2015) and variance-covariance matrices examined (`VarCorr(model)` from the `lme4` package (v.1.1-35); Bates, Mächler, et al., 2015) in order to determine whether/how to reduce the random effects structure until the model converged (Bates, Kliegl, et al., 2015). Random slopes that had correlation values close to 0 or 1 and/or that explained the least amount of variance were removed step-wise, as indicated by the model's variance-covariance matrix. If a model converged but was overfit (indicated by the random effects principal components analysis), the model was further simplified using the same method as a non-converging model. In such cases, model comparisons were run on converging models with varying random effects structures using `anova(model1, model2)` in order to confirm whether the final model was the best fit to the data based on the Akaike information criterion (AIC). Only once the most parsimonious (and final) model was selected were the fixed-effect estimates inspected (`summary(model)` function). Data and code are available in the supplementary materials (OSF).

Reported *p*-values for eye-tracking reading measures were Bonferroni-corrected for three multiple comparisons (reported *p*-values multiplied by 3), as three measures were analysed in the critical region (first-pass reading time, regression path duration, and total reading times; von der Malsburg & Angele, 2017). As Bonferroni adjustments have been argued to be "slightly too conservative" (von der Malsburg & Angele, 2017, p. 130) and result in a loss of statistical power (Type II error), and in the interest of transparency, the *t*-value and uncorrected *p*-value will be provided in cases where an effect was statistically significant before, but not after, Bonferroni corrections. However, such effects will not be interpreted or included in the discussion, and interaction effects that are not significant post-Bonferroni correction were not explored through models with nested contrasts.

3.2 Results

Two participants were excluded from analyses based on the pre-determined exclusion criteria explained above. Analyses were run on the remaining 22 participants. Model formulae are provided on the OSF in the supplementary materials. Model estimates are presented in-text with 95% confidence intervals, test statistics (*z*- or *t*-value), and *p*-values. Naturalness rating estimates and confidence intervals are in log-odds. Reading and reaction time estimates and confidence intervals are back-transformed to milliseconds.

3.2.1 Naturalness ratings

The distribution of naturalness rating responses per condition is visualised in **Figure 2A**, where white indicates a neutral rating (4), blue represents a positive rating (5–7), and red/pink represents a negative rating (1–3). Model predictions for the probability of a given rating (1–7) per condition are visualised in **Figure 2B**, and provided with mean responses in the supplementary materials on the OSF. Model summaries are given in **Table 3** (estimates are in log-odds).

A main effect of tense was found ($\hat{\beta}$ = –4.9 [–5.6, –4.2], z = –13.63, p < .001), in which the present perfect elicited higher ratings than the simple future. A main effect of (lifetime-tense) congruence was found ($\hat{\beta}$ = –4.5 [–5.3, –3.7], z = –11.17, p < .001), with congruent conditions eliciting higher ratings than the incongruent conditions. An interaction effect of congruence and tense was found ($\hat{\beta}$ = –7 [–8.3, –5.7], z = –10.52, p < .001). No effect of trial order was found ($\hat{\beta}$ = 0.00029 [–0.0017, 0.0022], t = 0.29, p = 0.772).

An additional model with nested contrast coding was run to investigate the interaction effect: Effects of lifetime-tense congruence were present in both the present perfect ($\hat{\beta}$ = –1 [–1.7, –0.32], z = –2.87, p < .01) and simple future ($\hat{\beta}$ = –8 [–9.3, –6.7], z = –12.32, p < .001), with a larger effect of congruence in the simple future. The negative slope for both tenses indicates lower ratings for incongruent conditions than congruent. These results reflect the high proportion of low ratings for the incongruent (dead) simple future condition compared to the incongruent (dead) present perfect condition, in relation to the respective congruent (living) conditions (**Figure 2**).

3.2.2 Total sentence times

Mean total-sentence reading times (from onset of critical-sentence presentation until button press to continue to the rating task) are shown in **Figure 3** and provided with raw mean reaction times in the supplementary materials on the OSF. Model summaries are given in **Table 4**.

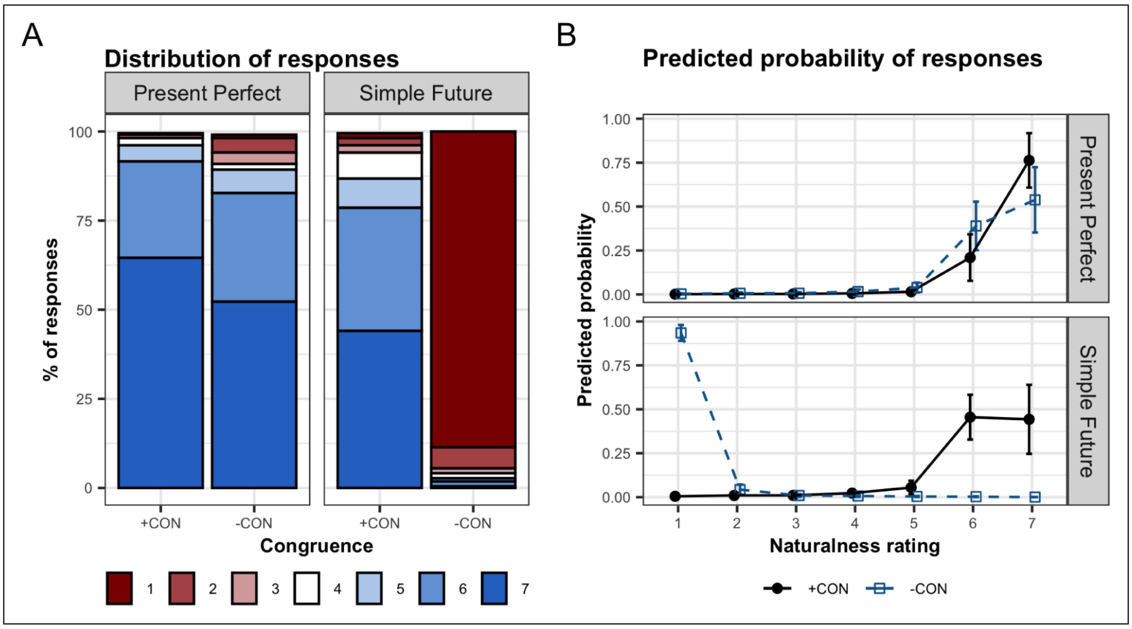

Figure 2: Naturalness judgement ratings for Experiment 1 (definitely wrong 1–7 perfectly fine). **A:** Distribution of observed responses per condition; **B:** Model predictions for the probability of each rating per condition (with 95% confidence intervals).

Table 3: Model summaries for naturalness ratings in Experiment 1 (estimates are in log odds).

Term	$\hat{\beta}$	**SE**	z	p
Trial order	0.00	0.00	0.29	0.772
Tense	–4.89	0.36	–13.63	< .001
Congruence	–4.51	0.40	–11.17	< .001
Congruence × Tense	–6.99	0.67	–10.52	< .001
Nested effects				
PP: Congruence	–1.02	0.35	–2.87	< .01
SF: Congruence	–8.01	0.65	–12.32	< .001

Table 4: Model summaries for reaction times in Experiment 1 (log-transformed).

Term	$\hat{\beta}$	**SE**	t	**df**	p
Intercept	7.95	0.04	186.44	32.12	< .001
Trial order	0.00	0.00	–17.59	1662.01	< .001
Tense	–0.12	0.03	–4.93	20.48	< .001
Congruence	–0.03	0.02	–1.59	20.38	0.127
Congruence × Tense	–0.27	0.05	–4.98	20.62	< .001
Nested effects					
PP: Congruence	0.10	0.03	3.57	19.28	< .01
SF: Congruence	–0.17	0.04	–4.15	20.35	< .001

A main effect of tense was found in critical sentence reaction times ($\hat{\beta}$ = –355 ms [–505, –205], t = –4.93, p < .001), with the present perfect eliciting longer reaction times than the simple future. An effect of lifetime-tense congruence was not found in reaction times ($\hat{\beta}$ = –99 ms [–229, 31], t = –1.59). An interaction of tense and lifetime-tense congruence was found in reaction times ($\hat{\beta}$ = –758 ms [–1078, –440], t = –4.98, p < .001). An effect of trial order was found ($\hat{\beta}$ = –6.57 ms [–7.3, –5.84], t = –17.59, p < .001), reflecting shorter total-sentence reaction times for later (versus earlier) trials.

A model with nested contrasts (congruence within either level of tense) was run to explore the observed interaction effect, revealing lifetime-tense congruence effects in both the present perfect ($\hat{\beta}$ = 279 ms [116, 442], t = 3.57, p < .01) and simple future ($\hat{\beta}$ = –478 ms [–718, –238], t = –4.15, p < .001). The positive slope in the present perfect indicates that the incongruent (dead) condition elicited longer reaction times than the congruent (living) condition. The negative slope in the simple future indicates the opposite effect: the incongruent (dead) condition elicited

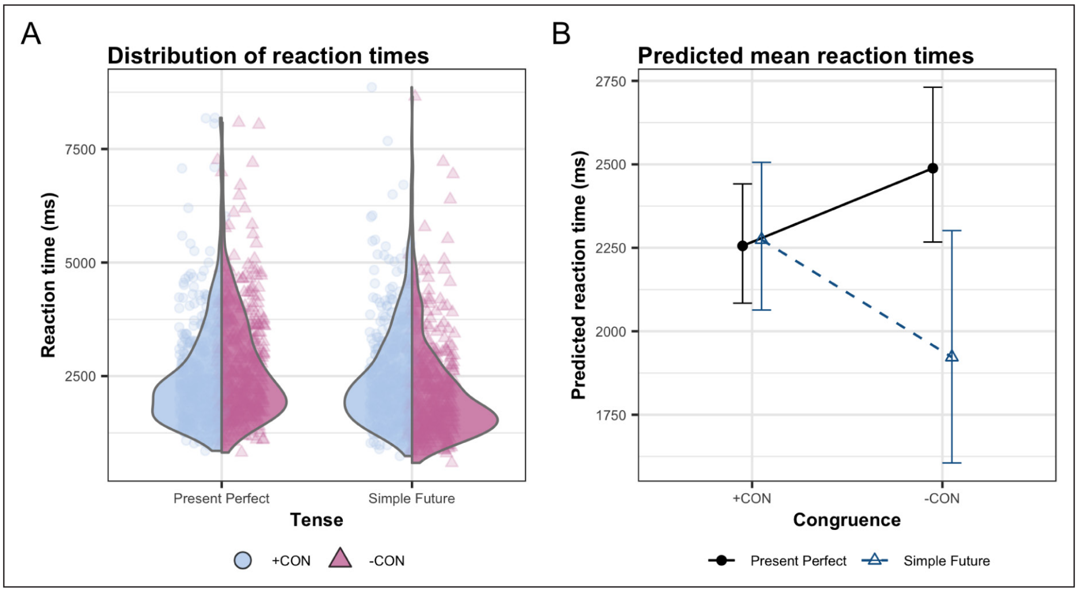

Figure 3: Total-sentence reaction times times for Experiment 1. A: Distribution of raw total-sentence times (milliseconds); B: Back-transformed model predictions for critical-sentence reaction times (with 95% confidence intervals).

shorter reaction times than the congruent (living) condition. The direction of the effect in the present perfect, but not the simple future, follows predictions.

3.2.3 Eye-tracking reading measures

Back-transformed model predictions for eye-tracking reading times at the verb region are visualised in **Figure 4A**, and provided with raw mean reading times in the supplementary materials. Model summaries for all a priori models run on eye-tracking measures for the verb region (sum contrast coding and nested constrast coding) are given in **Table 5**. Reported *p*-values are corrected for multiple comparisons (*p*-values multiplied by three, for each measure analysed), unless otherwise stated.

An effect of trial order was found in total reading time ($\hat{\beta}$ = –0.93 ms [–1.13, –0.72], t = –8.85, $p < .001$), reflecting shorter reading times for later trials. An effect of tense was found in total reading time ($\hat{\beta}$ = –70 ms [–97, –43], t = –5.18, $p < .001$). An effect in regression path duration was no longer significant after Bonferroni corrections ($\hat{\beta}$ = –15 ms [–29, –2], t = –2.25, uncorrected $p = .03$). The negative slope in each measure indicates longer reading times for the present perfect compared to the simple future.

Effects of lifetime-tense congruence were found in first-pass reading time ($\hat{\beta}$ = 19 ms [6, 32], $t = 3$, $p < .05$) and total reading time ($\hat{\beta}$ = 59 ms [24, 94], $t = 3.50$, $p < .01$). An effect emerged in regression path duration, but did not maintain significance after Bonferroni

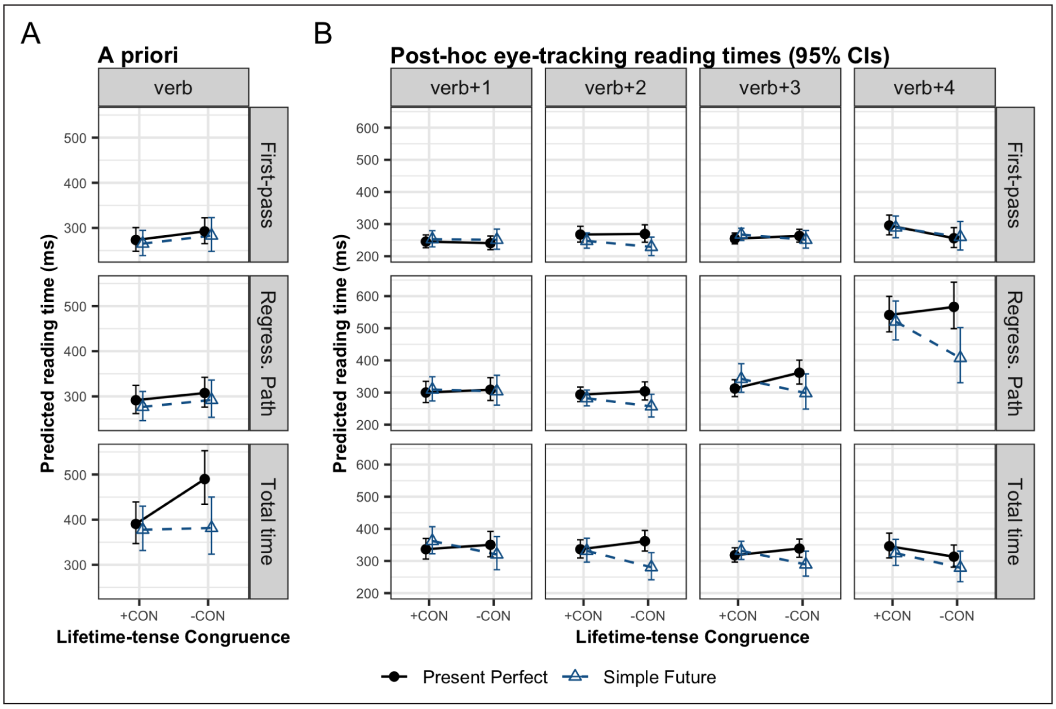

Figure 4: Experiment 1 back-transformed model predictions (with 95% confidence intervals) for the eye-tracking reading measures first-pass reading time (First-pass), regression path duration (Regress. Path), and total reading time (Total time). A priori analyses pertained to the verb region (A), and post-hoc analyses were run on the post-verb regions (B).

corrections ($\hat{\beta}$ = 16 ms [1, 31], t = 2.25, uncorrected p = .03). The positive slope in each measure indicates longer reading times for incongruent (sum coded as +0.5) versus congruent conditions (sum coded as -0.5).

An interaction effect of tense and lifetime-tense congruence was found in total reading time ($\hat{\beta}$ = –107 ms [–156, –59], t = –4.35, p < .001). In a subsequent model with nested contrasts (congruence within either level of tense at the verb region), an effect of lifetime-tense congruence was found in total reading times in the present perfect ($\hat{\beta}$ = 113 ms [71, 155], t = 5.40, p < .001), but not the simple future ($\hat{\beta}$ = 5 ms [–37, 47], t = 0.25). The present perfect elicited longer total reading times in the incongruent (dead) condition compared to the congruent (living) condition, following predictions. The absence of an effect of lifetime-tense congruence in the simple future condition goes against predictions.

3.2.4 Post-hoc analyses: Reading times in post-verb regions

The a priori predictions pertained to the verb region only, as this region determines lifetime-tense (in)congruence for each trial. Although no effects emerged in the simple future at the verb region in later eye-tracking during reading measures (regression path duration, total reading

Table 5: Model summaries for eye-tracking reading measures at the verb region in Experiment 1 (log-transformed; *p*-values are Bonferroni corrected).

Term	$\hat{\beta}$	SE	*t*	df	p^1	Bonf.sig.[2]
First-pass reading time						
Intercept	5.65	0.05	108.72	27.88	< .001	< .001
Tense	–0.03	0.02	–1.44	77.17	0.154	0.461
Congruence	0.07	0.02	3.00	20.68	< .01	< .05
Congruence × Tense	0.00	0.04	–0.08	1506.35	0.940	2.819
Regression path duration						
Intercept	5.69	0.06	99.79	26.66	< .001	< .001
Tense	–0.05	0.02	–2.25	77.38	< .05	0.083
Congruence	0.05	0.02	2.25	22.93	< .05	0.102
Congruence × Tense	0.00	0.04	0.02	1447.44	0.986	2.957
Total reading time						
Intercept	6.21	0.06	96.99	29.83	< .001	< .001
Tense	–0.14	0.03	–5.18	76.97	< .001	< .001
Congruence	0.12	0.03	3.50	20.04	< .01	< .01
Congruence × Tense	–0.22	0.05	–4.35	1504.87	< .001	< .001
Total reading time: nested effects						
PP: Congruence	0.23	0.04	5.40	47.20	< .001	< .001
SF: Congruence	0.01	0.04	0.25	47.50	0.804	2.413

[1] Pre-Bonferroni corrected *p*-values.

[2] Post-Bonferonni corrections: * < .05; ** < .01; *** < .001.

time), reaction times revealed a speed-up for the incongruent (dead) simple future condition compared to its congruent (living) counterpart. Post-hoc analyses were run on all post-critical sentence regions in order to explore this dissociation of the reaction time effects with the eye-tracking results at the verb region. Only the models that yielded results relevant to interpretation are described below. Subsequent nested contrasts were run on regions that yielded a significant interaction effect. Reported *p*-values were corrected for 12 comparisons (4 regions × 3 measures = *p* multiplied by 12). **Figure 4B** visualises model predictions for eye-tracking reading time measures in post-verb regions back-transformed into milliseconds. Analyses for all regions and measures can be found on the OSF.

An effect of tense was found at the verb + 2 region in first-pass reading times ($\hat{\beta}$ = –30 ms [–39, –21], t = –6.65, p < .001), regression path duration ($\hat{\beta}$ = –29 ms [–44, –14], t = –3.89, p < .01), and total reading times ($\hat{\beta}$ = –49 ms [–78, –19], t = –3.38, p < .05), and in the verb + 4 region in regression path duration ($\hat{\beta}$ = –153 ms [–248, –58], t = –3.35, p < .05), and total reading times ($\hat{\beta}$ = –36 ms [–58, –14], t = –3.18, p < .05). In all cases, the present perfect condition elicited longer reading times than the simple future.

An effect of congruence was found in the verb + 4 region in first-pass reading time ($\hat{\beta}$ = –39 ms [–64, –14], t = –3.28, p < .05) and total sentence reading time ($\hat{\beta}$ = –50 ms [–79, –20], t = –3.51, p < .05). A significant effect of congruence was observed in regression path duration before, but not after, Bonferroni corrections ($\hat{\beta}$ = –83 ms [–159, –7], t = –2.27, uncorrected p = .034).

Interaction effects were found in regression path duration in the verb + 3 ($\hat{\beta}$ = –94 ms [–131, –57], t = –5.01, p < .001) and verb + 4 ($\hat{\beta}$ = –242 ms [–367, –118], t = –3.83, p < .01) regions, and in total reading time in the verb + 1 ($\hat{\beta}$ = –65 ms [–101, –30], t = –3.59, p < .01), verb + 2 ($\hat{\beta}$ = –87 ms [–120, –54], t = –5.15, p < .001), and verb + 3 ($\hat{\beta}$ = –76 ms [–111, –42], t = –4.32, p < .001) regions. Prior to Bonferroni corrections, interaction effects were also found in first-pass reading time in the verb + 2 ($\hat{\beta}$ = –21 ms [–39, –4], t = –2.43, uncorrected p = .015) and verb + 3 ($\hat{\beta}$ = –26 ms [–46, –6], t = –2.57, uncorrected p = .010) regions, and in regression path duration in the verb + 2 ($\hat{\beta}$ = –36 ms [–62, –10], t = –2.75, uncorrected p = .006) region.

Models with nested contrasts were subsequently run to explore the observed interaction effects. Nested effects of lifetime congruence were found in the simple future in regression path duration in the verb + 3 ($\hat{\beta}$ = –46 ms [–72, –19], t = –3.40, p < .01) and verb + 4 ($\hat{\beta}$ = –204 ms [–303, –106], t = –4.15, p < .01) regions, and in total reading time at the verb + 2 ($\hat{\beta}$ = –60 ms [–85, –36], t = –4.79, p < .001) and verb + 3 ($\hat{\beta}$ = –52 ms [–77, –28], t = –4.18, p < .001) regions. An effect was also found prior to Bonferroni corrections in regression path duration at the verb + 2 ($\hat{\beta}$ = –27 ms [–46, –7], t = –2.72, uncorrected p = .008) region and in total reading time at the verb + 1 ($\hat{\beta}$ = –49 ms [–82, –16], t = –3.02, uncorrected p = .005) region. In all cases where nested congruence effects were found in the simple future, the incongruent (dead) condition elicited shorter reading times than the congruent (living) condition.

Nested congruence effects were found in the present perfect in regression path duration at the verb + 3 ($\hat{\beta}$ = 48 ms [22, 75], t = 3.62, p < .01) region, and prior to Bonferroni corrections in the verb + 2 ($\hat{\beta}$ = 26 ms [2, 50], t = 2.11, uncorrected p = .036) region. In all cases where nested congruence effects were found in the present perfect, the incongruent (dead) condition eliciting longer reading times than the congruent (living) condition. The pattern of results of nested congruence effects in each tense in post-critical sentence regions follows the same pattern as that observed in total sentence reaction times: longer reading times for incongruent (versus congruent) conditions in the present perfect, but shorter reading times for incongruent (versus congruent) conditions in the simple future.

3.3 Discussion

The main effect of lifetime-tense congruence at the verb region in first-pass reading time (verb region), total reading time (verb region), total sentence reading times, and naturalness responses indicates that preceding lifetime information modulated sentence comprehension. Importantly, the effect in first-pass reading time suggests referent-lifetime knowledge is rapidly available during processing of ensuing verb tense, eliciting processing costs in cases of lifetime-tense incongruence. In addition, the effect of lifetime-tense congruence differed between the tenses in all measures except first-pass reading time: In the present perfect condition, nested effects of lifetime emerged in total reading times at the verb region, in reaction times, and in naturalness responses, but only in reaction times and naturalness responses in the simple future condition. Furthermore, the incongruent simple future condition elicited shorter reaction times than the congruent condition, against predictions. For both tenses, these nested effects suggest rapid processing costs (first-pass reading times) and lower ratings when referring to accomplishments of congruent (dead) compared to incongruent (living) referents, with differences between the tenses in later processing. These findings were corroborated by the post-hoc analyses of eye-tracking reading measures in post-verb regions, which yielded shorter reading times for the simple future condition in the incongruent (dead) versus congruent (living) condition in regression path duration and total reading time, and longer reading times for the present perfect when preceded by a dead versus living context in regression path duration.

Taken together, these findings suggest that the dead-simple future violation was detected quickly (longer first-pass reading times at the verb region, followed by shorter regression path duration and total reading times in post-verb regions, and shorter total-sentence reaction times) and reliably rejected (near-basement ratings). The dead-present perfect conversely elicited processing costs (longer first-pass reading times and total reading times at the verb region and regression path duration at the verb + 3 region) and relatively high ratings, but significantly lower ratings than its congruent living-present perfect counterpart. This presumably reflects difficulty consolidating the current relevance requirement for the present perfect with a completed lifetime from the preceding dead context (reading and reaction times), and a preference for living referents with the present perfect. In light of the unexpected findings in the simple future condition, namely shorter post-critical reading times and reaction times for the incongruent condition, and in order to further investigate the incremental processing of the lifetime-tense congruence in the context of the present perfect and simple future, we aimed to replicate these results in two internet-based self-paced reading experiments.

4. Self-paced reading (Experiments 2 and 3)

Experiments 2 and 3 were internet-based cumulative self-paced reading experiments similar in design to Experiment 1. Both experiments were hosted on Ibex (Drummond, 2013) and programmed using PennController for Ibex (PCIbex; Zehr & Schwarz, 2018), an open-source extension of Ibex. The transition to internet-based experiments was necessitated by the COVID-19 pandemic, while the choice of cumulative self-paced reading was motivated by the finding of differences in nested congruence effects between the tenses in eye-tracking during reading measures that include regressions into the region of interest (total reading time) or into earlier sentence regions (regression path duration) in the critical (verb) region and post-critical regions, respectively. Although the moving-window self-paced reading paradigm is more common, it crucially does not allow for regressions into earlier sentence regions, unlike cumulative self-paced reading which can capture delays in button presses which are presumably linked to re-reading of earlier sentence regions. The cumulative self-paced reading paradigm was therefore chosen in an effort to capture the observed differences in congruence effects from Experiment 1.

Experiment 2 aimed to replicate the findings in Experiment 1, while Experiment 3 extended these findings to the comparison between the present perfect and simple past to explore and contrast the role of perfect and perfective aspect in lifetime contexts. Further experiment differences are described below. The methods and design of the two experiments were almost identical, and are presented together with differences explained.

4.1 Methods

4.1.1 Participants

Participants were recruited through Prolific (https://www.prolific.co/), an online research recruitment platform. Participants (n = 160 per experiment, aged 18–31) were right-handed native speakers of British English who indicated in screening questions that they were born and raised in England and resided there at the time the experiments were conducted, and had not learned any other language before the age of six. Renumeration followed standard fees in the laboratory (11 Euro/hour). The number of participants was based on a power analysis of pilot data (n = 96) with a moving-window presentation (see supplementary materials for pilot and power analysis at the OSF repository for this article).

4.1.2 Materials and design

A subset of the critical items from Experiment 1 were used (n = 20) in both Experiments 2 and 3. The shorter experimental duration was in an effort to maintain participants' attention during the remote internet-based experiment. The subset of critical and filler items from Experiment 1 was otherwise unchanged for Experiment 2, with the same conditions and experimental design for the two experiments (**Table 1**).

In Experiment 3, the same stimuli were used as in Experiment 2, but the simple future condition was replaced with the simple past (see (9)). Additionally, the verb + 3 region (e.g., *in the past/future*) was changed, as the phrase *in the past* could potentially license the use of the living-simple past. The spillover region was also replaced with a reference to a source (e.g., *according to Wikipedia*). This new spillover region was split into two sentence chunks (verb + 3 and verb + 4), resulting in the same number of sentence chunks as Experiment 2. The context sentences remained unchanged, and are repeated in (8). Importantly, these changes resulted in the same number of sentence chunks as Experiment 2 ($n = 6$), given in **Table 2**. **Table 1** gives an overview of the conditions across experiments.

(8) a. Beyoncé is an American performer. She lives in California. (*living*)
b. Whitney Houston was an American performer. She died in California. (*dead*)

(9) a. She *has performed* in many arenas, according to Wikipedia. (*present perfect*)
b. She *performed* in many arenas, according to Wikipedia. (*simple past*)

Filler items were altered in Experiment 3 to include sentences about real cultural figures, bands, or sports teams in order to more closely match the critical items. Violations similar to those in Experiments 1 and 2 were used in 50% of the filler items, namely incorrect pronoun gender or number, or contrasting information that can only be detected if the last sentence is considered within the context of the preceding sentence. As in the critical items, prior knowledge of the cultural figures was not required to detect violations, as the necessary information was provided in the context sentences.

4.1.3 Procedure

Context and critical stimuli were presented in cumulative self-paced reading style. The context sentences appeared first in dashed sentence chunks. The first sentence chunk was revealed when the participant pressed the spacebar. The next sentence chunk was revealed when the spacebar was pressed again, and so on. Once a sentence chunk had been revealed, it remained on the screen until the end of the trial. Once the context sentence text was fully revealed, it remained on the screen while the critical sentence appeared in dashed sentence chunks. This differed from Experiment 1, in which the context sentence was removed from the screen prior to critical sentence presentation. Critical sentence chunks were revealed in the same procedure as the context sentence. Critical sentences were divided into the same six sentence regions as in Experiment 1 (**Table 2**).

Once the context sentences and critical sentence were all revealed on the screen, the participant continued to a binary naturalness rating by pressing the spacebar. The 7-point Likert scale in Experiment 1 was replaced with a binary naturalness judgement task in order to limit the variability of buttons used in the internet-based set-up, which required use of a keyboard. Participants were instructed to indicate whether the final sentence fit naturally with the preceding context sentences by pressing the F or J key. Which key corresponded to 'yes' and to 'no' was counterbalanced across participants (50% F = yes, 50% J = yes).

Filler items contained unambiguous contradictions between the context and critical sentences in ten items in both experiments. As in Experiment 1, these items were used as an attention check. Participants needed a minimum accuracy of 75% in these filler items in order to be included in analyses.

4.1.4 Data analysis

A BoxCox transformation was run on reading times prior to analyses, following a Box-Cox test (Box & Cox, 1964; Osborne, 2010). A linear mixed-effects model was fit to the reading time data (`lmer()` function in `lmerTest` package (v.3.1.3); Kuznetsova et al., 2017), and a generalised linear mixed-effects model was fit to the binary naturalness response data (`glmer()` function in `lme4` package (v.1.1-35); Bates, Mächler, et al., 2015). Separate reading time models were run from the verb region onward (total of 5 regions). The same steps from Experiment 1 were taken when the maximal model did not converge. Sum coding and follow-up nested contrasts were identical to those in Experiment 1 (with the simple past condition coded as $+0.5$ in Experiment 3). Reading time results were Bonferroni corrected for five comparisons, one for each model run per experiment.

4.2 Predictions

The findings from the eye-tracking reading measures at the verb region in Experiment 1 form the basis of the predictions for Experiments 2 and 3. The cumulative self-paced reading presentation style allows for participants to make regressive eye-movements to earlier sentence regions, similar to regression path duration in the eye-tracking during reading paradigm. For this reason, the earliest possible effect expected was a main effect of congruence at the verb region, similar to this effect in first-pass reading times found in Experiment 1.

Naturalness judgements

Lifetime-tense violations were expected to elicit fewer acceptances in incongruent versus congruent conditions in both experiments. In the present perfect (Experiments 2 and 3), incongruent (dead) conditions were expected to be rejected more than congruent (living) conditions, but not to elicit a proportionately high rejection rate, reflecting less certainty in the incongruence of a statement like *Heath Ledger…has appeared in acclaimed films*. In the simple future (Experiment 2), a high rejection rate was expected for incongruent (dead) conditions, reflecting metalinguistic awareness of the incongruence of a statement like *Heath Ledger… will appear in acclaimed films*. Two alternative predictions were posited for the simple past (Experiment 3). First, following Roberts and Liszka (2013), incongruent (living) conditions might elicit fewer acceptances than congruent (dead) conditions, reflecting awareness of the lifetime-tense incongruence in a statement like *Meryl Streep…appeared in acclaimed films*. Alternatively, an absence of a congruence effect in the simple past would suggest that the lack of an explicitly mentioned past time frame is deemed acceptable.

Total-reading times

Lifetime-tense congruence effects in total-sentence reading times were expected in all three tenses. In the present perfect (Experiments 2 and 3), longer total-sentence reaction times were expected for incongruent versus congruent conditions, indicating sustained processing costs associated with consolidating the present perfect in the context of a dead referent's lifetime. In the simple future, lifetime-tense incongruence (versus congruence) was expected to elicit a speed-up, reflecting metalinguistic awareness of the obvious violation present in the incongruent dead-simple future condition. An effect in the simple past (Experiment 3) would be taken as evidence of processing costs associated with using the tense with a living referent in the absence of a past temporal adverb, differing from Roberts and Liszka (2013). The absence of such an effect would suggest that such sentences left "hanging in the air" (Klein, 1992, p. 547) do not incur slowdowns, similar to the findings in Roberts and Liszka (2013) for adverb-verb (in)congruence. Such an effect could also be interpreted as evidence for the simple past functioning as a default past tense in English, as suggested by Schaden (2009).

Self-paced reading times

Effects of lifetime-tense congruence were expected in cumulative self-paced reading times from as early as the verb region (following the finding in Experiment 1 of a congruence effect in first-pass reading time), with effects strongest in the sentence-final region, reflecting re-reading of earlier sentence regions. The present perfect (Experiments 2 and 3) was expected to elicit longer self-paced reading times in the incongruent versus congruent lifetime-tense condition. The simple future was expected to elicit effects in the opposite direction in post-verb regions, following the findings from post-hoc analyses in Experiment 1 (shorter regression path duration for incongruent versus congruent conditions in post-verb regions). As with total-sentence reading times, this pattern of effects would be taken to reflect (i) the detection of the lifetime-tense violation in the dead-simple future condition and a subsequent speed-up, and (ii) sustained processing difficulties associated with consolidating the present perfect in an incongruent dead lifetime context. In the simple past (Experiment 3), an absence of nested congruence effects was expected in self-paced reading, following the absence of incremental congruence effects in the past tense in Dragoy et al. (2012) and Roberts and Liszka (2013), and would be taken to reflect a lack of difficulty integrating the simple past in the absence of specific past temporal reference, perhaps due to pragmatic competition between the tenses (Schaden, 2009). Alternatively, if the incongruent (living) simple past condition elicits processing difficulties, then longer self-paced reading times were expected from as early as the verb region onward.

4.3 Results (Experiments 2 and 3)

Based on the exclusion criteria outlined in 4.1.3, 22 participants were removed from the Experiment 2 data (14%), and 14 participants were removed from Experiment 3 (9%). A similar proportion of participants have been excluded from previous internet-based experiments using similar filler-sentence based exclusion criteria (Laurinavichyute & von der Malsburg, 2023; Ronderos et al., 2023). Analyses were run on the remaining 138 and 146 participants, respectively. Model estimates are presented with 95% confidence intervals, test statistics (z- or t-value), and Bonferroni p-values. Naturalness rating estimates and confidence intervals are in log-odds. Reading and reaction time estimates and confidence intervals are back-transformed to milliseconds.

4.3.1 Binary naturalness responses

The distribution and mean responses are visualised in **Figure 5** (with 95% confidence intervals). Observed proportions of acceptances are provided in the supplementary materials on the OSF. Model summaries for Experiments 2 and 3 are provided in **Table 6** (one model per experiment with sum contrast coding and one with nested contrast coding). Observed proportion of acceptances and predicted probabilities of acceptances per condition are provided in **Table 6**.

An effect of trial order was found in both experiments, reflecting higher acceptance rates for later trials in Experiment 2 ($\hat{\beta}$ = 0.048 [0.012, 0.084], t = 2.65, p < .01), but lower acceptance rates for later trials in Experiment 3 ($\hat{\beta}$ = –0.03 [–0.054, –0.0051], t = –2.36, p .018).[6] A main effect of tense emerged in both experiments. In Experiment 2, the present perfect elicited more acceptances than the simple future condition ($\hat{\beta}$ = –4.3 [–4.9, –3.8], z = –15.12, p < .001). In Experiment 3, the simple past elicited more acceptances than the present perfect condition ($\hat{\beta}$ = 1.1 [0.42, 1.7], z = 3.26, p < .01). A main effect of lifetime-tense congruence was found in both Experiment 2 ($\hat{\beta}$ = –4.8 [–5.3, –4.2], z = –16.59, p < .001) and Experiment 3 ($\hat{\beta}$ = –2.2 [–3.1, –1.4], z = –5.06, p < .001). In both experiments, the congruent conditions elicited more acceptances than the incongruent conditions.

[6] In exploratory analyses suggested by a reviewer, interaction effects between trial order (experimental half) and tense and congruence, respectively, were found in Experiment 3. Effects of both tense and congruence were significant in each experimental half, but were larger in the second half of the experiment. Trial order did not have a significant interaction effect in any other case across experiments. These analyses can be found in the Supplementary materials folder on the OSF repository.

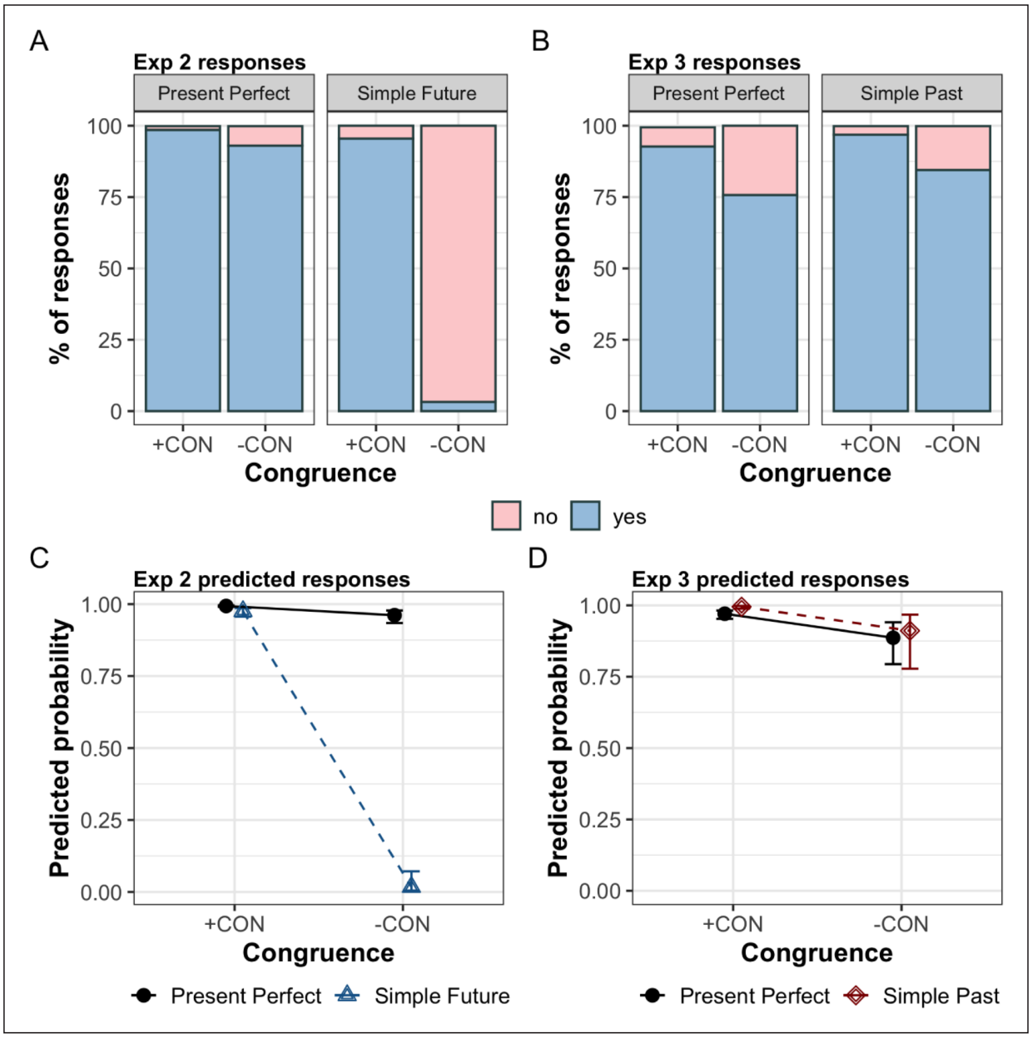

Figure 5: Distribution of binary naturalness responses for Experiments 2 (A) and 3 (B). +CON: congruent; –CON: incongruent.

An interaction of tense and congruence was also found in both Experiment 2 ($\hat{\beta}$ = –5.9 [–7, –4.8], z = –10.81, p < .001) and Experiment 3 ($\hat{\beta}$ = –1.6 [–2.5, –0.61], z = –3.22, p < .01). Models with nested contrast coding revealed lifetime-tense congruence effects nested within each level of tense per experiment. In the present perfect, the incongruent (dead) condition received significantly fewer acceptances than the congruent (living) condition in both Experiment 2 ($\hat{\beta}$ = –1.8 [–2.6, –1.1], z = –4.81, p < .001) and Experiment 3 ($\hat{\beta}$ = –1.2 [–1.9, –0.48], z = –3.32, p < .001). This finding was similar to the findings from Experiment 1 and in line with predictions. In Experiment 2, the incongruent dead-simple future received significantly fewer acceptances than the congruent living-simple future condition, similar to the findings from Experiment 1 and in line with predictions ($\hat{\beta}$ = –7.7 [–8.5, –6.9], z = –18.64, p < .001).

Table 6: Model summaries for naturalness ratings in Experiment 1 (estimates are in log odds).

Term	$\hat{\beta}$	SE	z	p
Experiment 2				
Intercept	1.47	0.27	5.39	$< .001$
Trial order	0.05	0.02	2.65	$< .01$
Tense	–4.31	0.29	–15.12	$< .001$
Congruence	–4.77	0.29	–16.59	$< .001$
Congruence × Tense	–5.90	0.55	–10.81	$< .001$
Experiment 3				
Intercept	3.62	0.29	12.48	$< .001$
Trial order	–0.03	0.01	–2.36	$< .05$
Tense	1.06	0.32	3.26	$< .01$
Congruence	–2.23	0.44	–5.06	$< .001$
Congruence × Tense	–1.57	0.49	–3.22	$< .01$
Experiment 2: nested effects				
PP: Congruence	–1.82	0.38	–4.81	$< .001$
SF: Congruence	–7.72	0.41	–18.64	$< .001$
Experiment 3: nested effects				
PP: Congruence	–1.16	0.35	–3.32	$< .001$
SP: Congruence	–2.44	0.44	–5.52	$< .001$

In Experiment 3, the simple past likewise elicited fewer acceptances in the incongruent (living) versus congruent (dead) condition ($\hat{\beta} = -2.4$ [–3.3, –1.6], $z = -5.52$, $p < .001$). In all three tenses, the incongruent condition elicited more rejections than congruent condition. This effect was significantly larger in the simple future than the present perfect, as reflected in the interaction effect and same direction of nested effects within each tense.

4.3.2 Total sentence times

Predicted total-sentence reading times (from presentation of the verb-1 region until final button press after verb + 4) are shown in **Figure 6** and the observed means in the supplementary materials. Model summaries in **Table 7** report main and interaction effects and nested effects.

An effect of trial order was found in both experiments, reflecting shorter reaction times for later trials (Experiment 2: $\hat{\beta} = -90$ ms [–98, –81], $t = -20.59$, $p < .001$; Experiment 3: $\hat{\beta} = -97$ ms [–107, –88], $t = -19.69$, $p < .001$). A main effect of tense was found in total-sentence reading times in both experiments. The present perfect elicited longer reading times, compared to the simple future in Experiment 2 ($\hat{\beta}$ = –374 ms [–498, –249], t = –5.94, p < .001), and compared to the simple past in Experiment 3 ($\hat{\beta}$ = –335 ms [–446, –224], t = –5.92, p < .001).

A main effect of lifetime-tense congruence was found in Experiment 3 ($\hat{\beta}$ = 603 ms [469, 737], t = 8.97, p < .001), with longer reading times elicited by the incongruent versus congruent conditions . An effect of congruence was not significant in Experiment 2 ($\hat{\beta}$ = –161 ms [–327, 4], t = –2.03, p .055).

An interaction effect was found in both Experiment 2 ($\hat{\beta}$ = –1249 ms [–1454, –1048], t = –12.44, p < .001) and Experiment 3 ($\hat{\beta}$ = –452 ms [–677, –230], t = –3.99, p < .001). Sentences containing the present perfect elicited longer total-sentence reading times in incongruent (dead) versus congruent (living) conditions in Experiment 2 ($\hat{\beta}$ = 453 ms [315, 593], t = 6.42, p < .001) and Experiment 3 ($\hat{\beta}$ = 833 ms [657, 1011], t = 9.43, p < .001). The simple future (Experiment 2) elicited shorter reaction times in the incongruent (dead) versus congruent (living) conditions ($\hat{\beta}$ = –778 ms [–919, –638], t = –10.98, p < .001). The simple past (Experiment 3) elicited longer reaction times in the incongruent (dead) versus congruent (living) conditions ($\hat{\beta}$ = 375 ms [202, 549], t = 4.28, p < .001). Congruence effects were larger in the simple future than the present perfect (Experiment 2), and larger in the present perfect than simple past (Experiment 3).

4.3.3 Reading times

Reading times across sentence regions are visualised in **Figure 7** in back-transformed model predictions for Experiment 2 (A) Experiment 3 (B). Predictions per condition are also provided with observed means in the supplementary materials available on the OSF repository. Model summaries with sum contrast coding across sentence regions are given in the supplementary materials on the OSF. Model summaries with nested contrast coding for both experiments are given in **Table 8**. Reported p-values are corrected for multiple comparisons (p-values multiplied by 5, for each region analysed), unless otherwise stated.

An effect of trial order was found across regions in both Experiment 2 (verb: $\hat{\beta}$ = –7 ms [–7, –6], t = –15.69, p < .001; verb + 1: $\hat{\beta}$ = –10 ms [–11, –9], t = –16.03, p < .001; verb + 2: $\hat{\beta}$ = –9 ms [–10, –8], t = –13.47, p < .001; verb + 3: $\hat{\beta}$ = –11 ms [–12, –9], t = –12.33, p < .001; verb + 4: $\hat{\beta}$ = –45 ms [–50, –41], t = –18.90, p < .001) and Experiment 3 (verb: $\hat{\beta}$ = –8 ms [–8, –7], t = –21.31, p < .001; verb + 1: $\hat{\beta}$ = –10 ms [–11, –9], t = –18.69, p < .001; verb + 2: $\hat{\beta}$ = –13 ms [–14, –11], t = –16.64, p < .001; verb + 3: $\hat{\beta}$ = –8 ms [–10, –7], t = –11.72, p < .001; verb + 4: $\hat{\beta}$ = –55 ms [–61, –49], t = –16.84, p < .001). In all cases, later trials elicited shorter self-paced reading times.

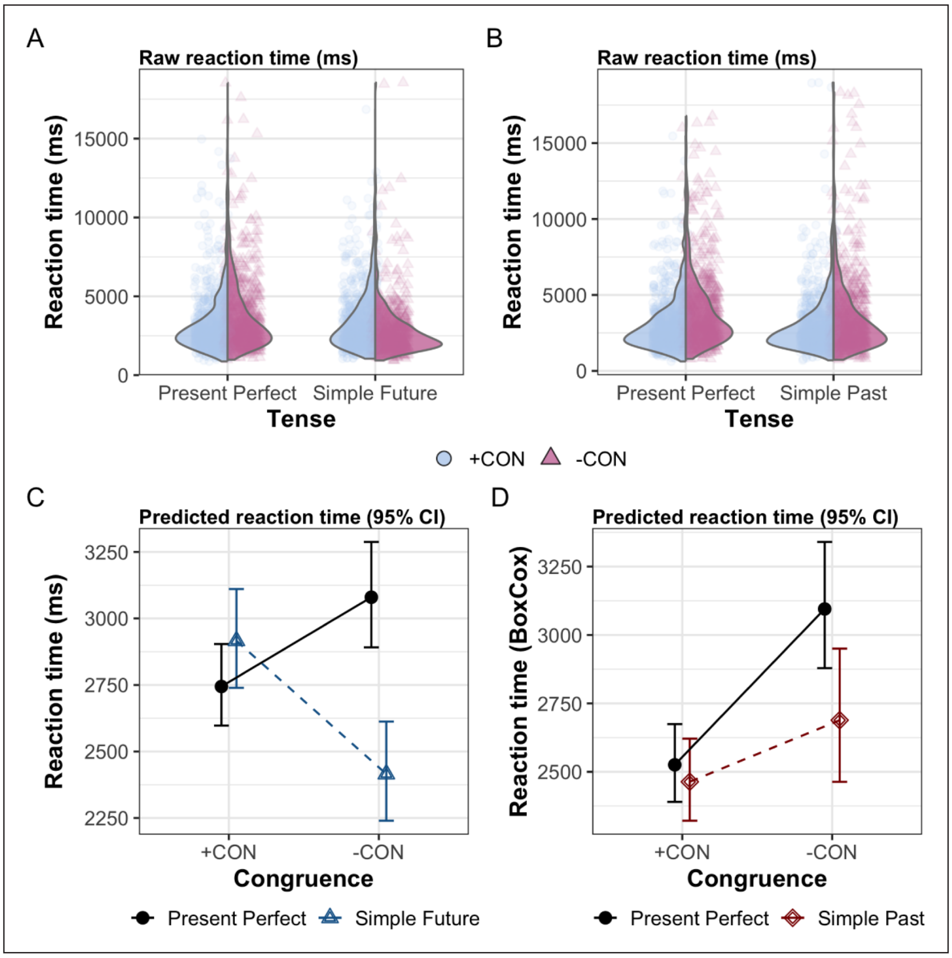

Figure 6: Total sentence reaction times for Experiments 2 **(A, C)** and 3 **(B, D)**. Top row: violin-scatter plot of raw reaction time distributions. Bottom row: back-transformed model predictions for reaction times per condition (with 95% CIs).

A main effect of tense emerged in Experiment 2 in the verb + 1 ($\hat{\beta}$ = –26 ms [–40, –12], t = –3.64, p < .01), verb + 2 ($\hat{\beta}$ = –44 ms [–64, –24], t = –4.67, p < .001), verb + 3 ($\hat{\beta}$ = –33 ms [–54, –12], t = –3.10, p < .05), and verb + 4 ($\hat{\beta}$ = –155 ms [–227, –84], t = –4.29, p < .001) regions. In all cases, the present perfect condition elicited longer reading times than the simple future condition. In Experiment 3, a main effect of tense was found in the verb region ($\hat{\beta}$ = –25 ms [–35, –16], t = –5.55, p < .001), verb + 1 region ($\hat{\beta}$ = –58 ms [–73, –43], t = –8.16, p < .001), verb + 2 region ($\hat{\beta}$ = –37 ms [–58, –15], t = –3.55, p < .05), and the verb + 4 region ($\hat{\beta}$ = –129 ms [–203, –56], t = –3.45, p < .01). In all cases, the present perfect elicited longer reading times than the simple past.

A main effect of lifetime-tense congruence emerged in Experiment 2 in the verb + 4 region ($\hat{\beta}$ = –147 ms [–240, –55], t = –3.29, p < .05). An effect of congruence in the verb + 3 region

Table 7: Model summaries for total-sentence reaction times in Experiments 2 and 3 (BoxCox-transformed; Experiment 2: λ = –0.51; Experiment 3: λ = –0.67).

Term	$\hat{\beta}$	**SE**	*t*	*p*
Experiment 2				
Intercept	1.9481	6e-04	3476.38	< .001
Trial order	–0.0004	0e + 00	–20.59	< .001
Tense	–0.0017	3e-04	–5.94	< .001
Congruence	–0.0007	4e-04	–2.03	0.055
Congruence × Tense	–0.0056	4e-04	–12.44	< .001
Experiment 3				
Intercept	1.4935	2e-04	8924.03	< .001
Trial order	–0.0001	0e + 00	–19.69	< .001
Tense	–0.0004	1e-04	–5.92	< .001
Congruence	0.0007	1e-04	8.97	< .001
Congruence × Tense	–0.0006	1e-04	–3.99	< .001
Experiment 2: nested effects				
PP: Congruence	0.0021	3e-04	6.42	< .001
SF: Congruence	–0.0035	3e-04	–10.98	< .001
Experiment 3: nested effects				
PP: Congruence	0.0010	1e-04	9.43	< .001
SP: Congruence	0.0005	1e-04	4.28	< .001

was significant before Bonferroni corrections, but not after ($\hat{\beta}$ = –31 ms [–59, –3], t = –2.29, uncorrected p = .034). In both regions, incongruent conditions elicited shorter reading times than congruent conditions. In Experiment 3, a main effect of lifetime-tense congruence was found in the verb + 1 region onward (verb + 1: $\hat{\beta}$ = 23 ms [10, 36], t = 3.56, p < .01; verb + 2: $\hat{\beta}$ = 34 ms [17, 51], t = 3.91, p < .001; verb + 3: $\hat{\beta}$ = 42 ms [26, 58], t = 5.20, p < .001; verb + 4 $\hat{\beta}$ = 327 ms [246, 409], t = 8.05, p < .001). In all cases, incongruent sentences elicited longer reading times than congruent sentences.

A significant interaction of tense and lifetime-tense congruence emerged from the verb + 2 region in Experiment 2 (verb + 2: $\hat{\beta}$ = –72 ms [–102, –41], t = –4.65, p < .001; verb + 3: $\hat{\beta}$ = –161 ms [–201, –122], t = –8.19, p < .001; verb + 4: $\hat{\beta}$ = –668 ms [–790, –551], t = –11.86, p < .001). An interaction also emerged in the verb + 1 region, but was not significant after Bonferroni corrections ($\hat{\beta}$ = –37 ms [–65, –9], t = –2.57, uncorrected p = < .05). In

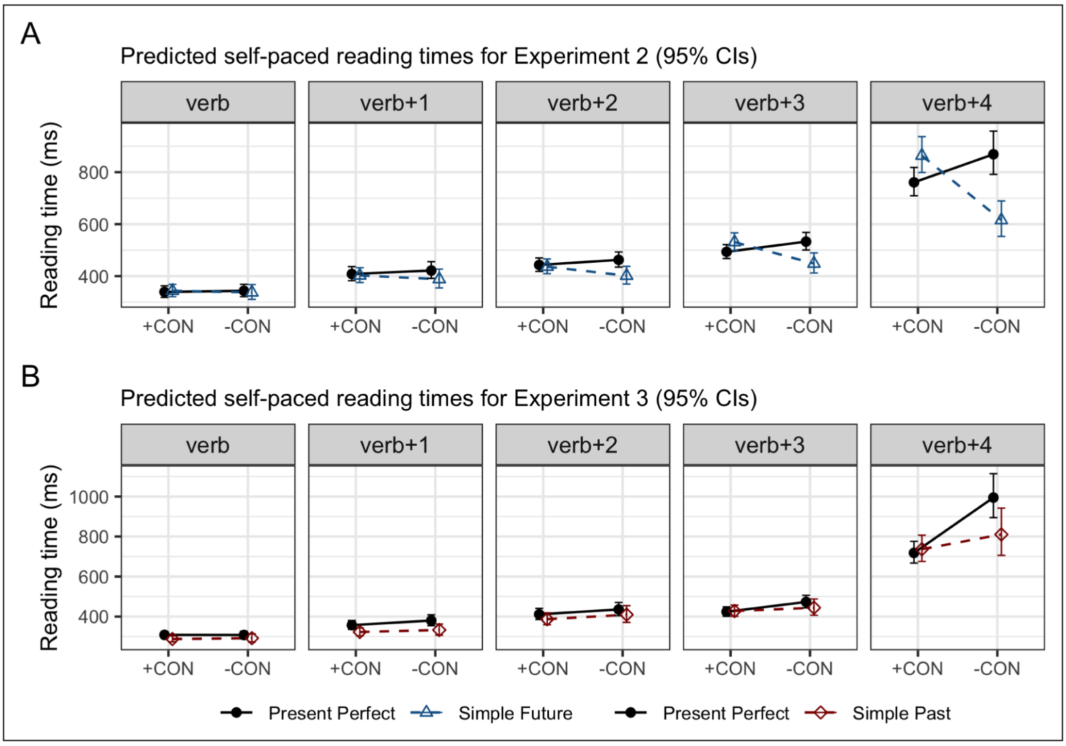

Figure 7: Back-transformed predicted self-paced reading times across sentence regions (with 95% confidence intervals) for Experiments 2 **(A)** and 3 **(B)**.

Experiment 3, an interaction of tense and congruence was found in the verb + 4 region only ($\hat{\beta}$ = –345 ms [–500, –195], t = –4.55, p < .001).

Follow-up nested comparisons were run on the regions which yielded a significant interaction effect. In Experiment 2, the present perfect elicited significantly longer reading times in incongruent (dead) versus congruent (living) conditions in the verb + 3 and verb + 4 regions (verb + 3: $\hat{\beta}$ = 49 ms [15, 83], t = 2.95, p .026; verb + 4: $\hat{\beta}$ = 175 ms [69, 282], t = 3.34, p < .01). The same effect was found in verb + 2, but was not significant after Bonferroni corrections ($\hat{\beta}$ = 23.9 ms [0.3, 47.5], t = 2.03, p .235). The simple future elicited shorter reading times in the incongruent (dead) versus congruent (living) condition from the verb + 2 region onward (verb + 2: $\hat{\beta}$ = –47.6 ms [–71.3, –24.1], t = –4.05, p < .001; verb + 3: $\hat{\beta}$ = –111.4 ms [–145.6, –77.5], t = –6.66, p < .001; verb + 4: $\hat{\beta}$ = –478.1 ms [–591.2, –367.9], t = –8.97, p < .001).

In Experiment 3, nested effects of lifetime-tense congruence were found in the verb + 4 region for both the present perfect ($\hat{\beta}$ = 506 ms [392, 624], t = 8.99, p < .001) and simple past ($\hat{\beta}$ = 153 ms [45, 263], t = 2.78, p .034). For both tenses, longer self-paced reading times were elicited by the incongruent (versus congruent) condition, following predictions.

Table 8: Self-paced reading times model summaries (nested contrast coding) per region for Experiments 2 and 3 (BoxCox-transformed; Experiment 2: λ = –0.46; Experiment 3: λ = –0.59).

Term	$\hat{\beta}$	SE	*t*	df	p^1	Bonf.sig.[2]
Experiment 2: verb + 2						
PP: Congruence	0.0025	0.0012	2.03	54.11	< .05	n.s.
SF: Congruence	–0.0050	0.0012	–4.05	54.05	< .001	< .001
Experiment 2: verb + 3						
PP: Congruence	0.0042	0.0014	2.95	42.45	< .01	< .05
SF: Congruence	–0.0095	0.0014	–6.66	42.47	< .001	< .001
Experiment 2: verb + 4						
PP: Congruence	0.0059	0.0018	3.34	48.47	< .01	< .01
SF: Congruence	–0.0158	0.0018	–8.97	48.31	< .001	< .001
Experiment 3: verb + 4						
PP: Congruence	0.0063	0.0007	8.99	486.86	< .001	< .001
SP: Congruence	0.0019	0.0007	2.78	486.24	< .01	< .05

[1] Pre-Bonferroni corrected p-values.
[2] Post-Bonferonni corrections.

4.4 Discussion

Experiments 2 and 3 aimed to replicate and extend the findings from Experiment 1 via internet-based cumulative self-paced reading experiments. Experiment 2 replicated the directionality of the eye-tracking results from Experiment 1: When preceded by an incongruent lifetime context, the present perfect elicited longer reading times than when it was preceded by a congruent lifetime context, and lower naturalness judgement responses. Conversely, in the simple future condition, shorter reading times were elicited in post-verb regions in incongruent versus congruent lifetime contexts. Total sentence reaction times and binary naturalness responses likewise patterned similarly to Experiment 1, with the incongruent (versus congruent) condition eliciting longer reaction times and fewer acceptances in the present perfect condition, but shorter reaction times and fewer acceptances in the simple future condition. The internet-based experiment thereby replicated the unexpected directionality of the violation in the simple future conditions. The earlier emergence and larger size of lifetime-congruence effects in the simple future compared to present perfect conditions indicate that the incongruence in the simple future was more readily detected. This is supported by the significantly larger congruence effect in naturalness responses in the simple future compared to the present perfect, as well as the shorter self-paced reading and total-sentence reaction times in the dead-simple future condition.

Experiment 3, which replaced the simple future condition with the simple past, elicited lifetime-tense congruence effects in the same direction in the present perfect and simple past tenses, with both tenses eliciting congruence effects in the expected direction but with differences in the size of the respective effects. The present perfect again elicited longer reading times and lower ratings in the incongruent (dead) compared to congruent (living) condition, similar to Experiments 1 and 2. The simple past elicited congruence effects in the same direction: the incongruent (living) condition elicited fewer acceptances and longer reading and reaction times than the congruent (dead) condition, although effects in self-paced reading at the sentence-final region were significantly smaller, as indicated by the interaction of tense and congruence in this measure.

Interestingly, visual inspection of **Figures 5A** and **B** shows that naturalness responses differed substantially between Experiments 2 (**Figure 5A**) and 3 (**Figure 5B**), in that the present perfect elicited more rejections overall in Experiment 3 compared to Experiment 2, most notably in the incongruent condition. We take this to reflect the influence of the contrasting tense in both experiments. In Experiment 2 the present perfect is contrasted with the simple future, which, in the incongruent (dead) condition, elicited near-total rejections and speed-up effects in reading and reaction times (compared to the congruent living-simple future condition). Conversely, Experiment 3 contrasted the present perfect with the simple past, which elicited smaller congruence effects compared to the simple future in naturalness responses. An alternative, or additional, reason for this change in the present perfect naturalness responses could be the removal of the temporal phrase *in the past*, which was present in present perfect sentences in Experiments 1 and 2. As discussed above, this region was removed in Experiment 3 because it could potentially license the simple past in living contexts. However, it could be that the inclusion of this region in Experiments 1 and 2 also licensed the present perfect in the incongruent (dead) condition (e.g., *Whitney Houston… has performed in many packed stadiums in the past*), leading to higher overall acceptances for this condition. While this goes against our intuition, it cannot be excluded as a possible contributing factor to the differences in results. It seems, then, that the contrasting condition (the simple future or the simple past), and/or the inclusion of the temporal phrase *in the past*, may have affected the magnitude of observed effects in the present perfect naturalness responses.

Why might lifetime-tense congruence effects be smaller in the simple past than the present perfect? The incongruent living-simple past does not constitute a lifetime-tense violation per se, but is rather odd when uttered out-of-the-blue. This is due to the lack of an overtly specified or contextually implied completed past time reference, as the English past tense requires a past temporal antecedent (Kratzer, 1989, 1998; Partee, 1984). The findings of main effects of congruence in incremental processing and naturalness responses would seem to support the hypothesis that the use of the simple past in an implicit infelicitous time frame (i.e., an incomplete lifetime) elicits stronger processing costs than when used in an explicitly stated infelicitous time frame (e.g., *Since last week*, from Roberts & Liszka, 2013). However, the current experiment utilised cumulative self-paced reading, whereas Roberts and Liszka (2013) used the moving-window self-paced reading presentation style, which may lead to some differences in the emergence and/or detection of effects, especially in later sentence regions. The results are discussed in further detail in Section 5.

In sum, effects of lifetime-tense congruence were found in both Experiments 2 and 3, with differences in the latency, size, and directionality of nested effects across tenses. Taken together, Experiments 1 through 3 suggested the observed nested effects of lifetime-tense congruence are robust and incremental in nature. Importantly, the incongruent dead-present perfect condition reliably elicited processing costs across experiments, providing evidence of processing difficulties associated with violations of the Perfect Lifetime Effect, whereby the English present perfect is appropriate for living, but not dead, referents.

5. General discussion

Across three reading experiments, we investigated the influence of referent-lifetime knowledge on the processing of past, present, and future tenses in English, with particular interest in lifetime-tense congruence effects in the present perfect. We utilised eye-tracking during reading (Experiment 1) and cumulative self-paced reading (Experiments 1 and 2) to measure incremental processing, and naturalness ratings (Experiment 1) or binary naturalness judgements (Experiments 2 and 3) to tap into metalinguistic knowledge. Total-sentence reaction times were analysed in order to capture cumulative processing costs that may not have emerged in incremental measures.

Lifetime-tense congruence effects were found in all three tenses across measures and experiments, with discrepencies in terms of their temporal emergence, magnitude, and direction. Following predictions, all three tenses elicited lower naturalness judgements in the incongruent versus congruent lifetime conditions, with the largest effect in the simple future condition. Also in line with predictions, the present perfect (Experiments 1–3) and simple past (Experiment 3) elicited longer reading times and total-sentence reaction times when preceded by an incongruent versus congruent referent. Conversely, the simple future (Experiments 1 and 2) elicited shorter reading and reaction times in the incongruent versus congruent condition, against initial predictions for Experiment 1. A main effect of lifetime-tense congruence was found in first-pass reading times at the critical verb region in Experiment 1, indicating the rapid availability of referent-lifetime information in the expected direction for both the present perfect and simple future. We explore these findings in relation to the three overarching research questions in more detail below.

5.1 Referent-lifetime knowledge during incremental processing

Effects of lifetime-tense congruence emerged in reading time measures across Experiments 1 through 3. In Experiment 1, a main effect of lifetime-tense congruence was found in first-pass reading time at the verb region. Effects were observed as early as in the verb + 1 region in self-paced reading times in Experiment 2 (interaction effect) and Experiment 3 (main effect of congruence). Specifically, the finding of a main effect of lifetime-tense congruence in first-pass reading times at the verb region suggests referent-lifetime knowledge is rapidly available during processing of temporal verb morphology, eliciting processing costs when verb tense is incongruent with the referent's lifetime as early as the first-pass of the verb. These findings are in line with the results reported in Chen (2017), as well as the broader literature on the effects of high-level world knowledge (e.g., Hagoort et al., 2004; Nieuwland & Martin, 2012; Troyer & Kutas, 2020) and narrative/discourse contexts on language processing (e.g., Federmeier & Kutas, 1999; Nieuwland & van Berkum, 2006). However, Experiment 1 was the only case in which effects of lifetime-tense congruence emerged at the earliest examined measure. The later post-verb emergence of effects in Experiments 2 and 3 could be attributed to the lower temporal resolution of self-paced reading times compared to eye-tracking during reading, as well as the cumulative nature of the former. The effects in the cumulative self-paced reading experiments mirrored congruence effects found in post-hoc analyses of the post-critical regions in Experiment 1, where lifetime-tense congruence effects emerged in the simple future condition in the verb + 3 and verb + 4 regions, with the congruent (living) condition eliciting longer reading times than the incongruent (living) condition. Regardless of the discrepancies between the temporal resolution of eye-tracking during reading and self-paced reading, the findings from Experiment 1 suggest referent-lifetime information is rapidly available during processing, incurring processing costs when followed by incongruent temporal morphology.

While the experiments presented have provided evidence of the influence of referent-lifetime contexts on the processing of ensuing tense, they do not disentangle prior held referent-lifetime knowledge (e.g., the knowledge that Whitney Houston is dead) from contextually-mentioned referent-lifetime information (e.g., stating that Whitney Houston died in California). There is prior evidence that either source of referent-lifetime knowledge may be rapidly integrated with temporal information during processing. Regarding the role of contextually defined lifetime information, Chen (2017) reported that the contextually defined lifetime status of two fictional referents affected the self-paced reading times and acceptability ratings of ensuing sentences containing the simple present (but not simple past) with individual-level predicates. These findings are in line with previous studies reporting context effects during processing (e.g., Nieuwland & van Berkum, 2006; van Berkum et al., 1998; van Berkum et al., 2003). Regarding the role of prior held lifetime information, factual trivia-type knowledge of the world (e.g., that the Beatles were popstars in the 1960s) and familiar fictional worlds (the Wizarding World of Harry Potter) have been shown to elicit rapid processing costs, eliciting the N400 effect in EEG experiments (Filik & Leuthold, 2013; Hagoort et al., 2004; Hald et al., 2007; Martin et al., 2014; Metzner et al., 2015; Nieuwland & Martin, 2012; Troyer et al., 2020; Troyer & Kutas, 2018, 2020), longer self-paced reading times (Filik, 2008; Filik & Leuthold, 2013; Rapp, 2008), and longer first-fixation and first-pass reading times in eye-tracking during reading (Metzner et al., 2015). Based on these previous findings, both prior knowledge of our famous referents' lifetimes and their explicitly stated lifetime status were presumably sufficient to constrain ensuing verb tense, but the extent to which one or both modulated reading times is beyond the scope of the current study.

5.2 Differences in lifetime effects between tenses

We found evidence of the Lifetime Effect at play during incremental processing in all three experiments. The present perfect elicited longer reading times and lower naturalness acceptances in the incongruent (dead) condition compared to the congruent (living) condition. Likewise, the simple past condition (Experiment 3) elicited longer reading times and fewer acceptances in the incongruent (living) condition than the congruent (dead) condition. Against predictions, the opposite effect was found in reading times for the simple future condition (Experiments 1 and 2), where the incongruent (dead) condition elicited shorter reading times than the congruent (living) condition, despite a high rejection rate in the naturalness judgement tasks.

Perhaps the most surprising finding from the experiments presented was the speed-up effect for lifetime-tense violations in the simple future condition. This finding goes against typical linking hypotheses which stipulate that violations elicit processing delays, i.e., longer reading times at or after the critical region (e.g., Clifton et al., 2007). We have proposed that this effect was due to task adaptation, following previous evidence that the expected task can influence the processing of syntactic ambiguities (Logačev & Vasishth, 2016; Swets et al., 2008) and agreement attraction (Laurinavichyute & von der Malsburg, 2023). Importantly, Laurinavichyute and von der Malsburg (2023) observed agreement attraction effects only when participants expected to rate sentence acceptability and not when they expected to answer a comprehension question. Though this does not account for the opposite direction of the effect observed in the simple future condition, it does suggest that the awareness of a trial-final task can alter observed effects in incremental processing. The dead-simple future violations were highly prominent, and presumably led participants to detect the violation quickly (shorter reading/reaction times) and reliably (near-basement judgements) upon encountering the verb region compared to the more subtle dead-present perfect condition. This seems feasible given the obviousness of the violation in a statement like *Einstein will visit Princeton* compared to *Einstein has visited Princeton*, despite Einstein not being alive at reference time for either utterance. A further study involving an alternative task (or no task at all) could explore to what extent the awareness of a judgement task sped up reading times upon encountering an infelicitous sentence in the simple future, and whether lifetime-tense congruence effects would emerge at all (as in Laurinavichyute & von der Malsburg, 2023). Such a follow-up study could address whether the direction of the effect in reading/reaction times would be reversed if the naturalness judgement task were removed, and how this would affect the observed effects in the present perfect condition.

An additional explanation for the stronger effect in the simple future condition could be the inclusion of the temporal phrase in the verb + 3 region (*in the past/future*) in Experiments 1 and 2, as pointed out by a reviewer. The phrase *in the past* is temporally congruent with a dead referent's lifetime and the present perfect, even though a dead referent is incongruent with the present perfect. Thus, *in the past* did not contribute any additional source of lifetime incongruence. In contrast, the phrase *in the future* is incongruent with a dead referent's lifetime, and so provided an additional source of lifetime incongruence. The phrases *in the past* and *in the future* therefore interacted differently with referent lifetime. However, effects of lifetime-tense congruence emerged prior to the first reading (Experiment 1)/presentation (Experiment 2) of the verb + 3 region in both experiments: In Experiment 1, a main effect of congruence was found in first-pass reading times of the critical verb region, as well as congruence effects within the simple future in first-pass reading and regression path duration in post-hoc analyses at the verb + 1 and verb + 2 regions that were significant before, but not after, Bonferroni corrections. In Experiment 2, a nested effect of congruence was found in the simple future in self-paced reading from the verb + 2 region onward. In all of these pre-verb + 3 measures, the incongruent dead-simple future condition elicited shorter reading times than the congruent living-simple future condition. These effects could not have been affected by the upcoming verb + 3 region. We cannot, however, exclude the possibility that the verb + 3 region may have affected total reading times in the verb region (which includes regressions from downstream regions; Experiment 1), or self-paced reading times from the verb + 3 region onward (Experiment 2), nor total-sentence reaction times, or naturalness responses in both experiments. However, this does not seem like a plausible explanation for the finding in Experiment 1 of congruence effects nested in total reading times at the verb region for the present perfect condition (where *in the past* was congruent with both dead and living lifetimes), but not the simple future condition (where *in the future* was incongruent with dead lifetimes only). In addition, given the findings in pre-verb + 3 regions, we do not discount the effect of lifetime-tense congruence in the findings in the simple future condition, nor the potential for a task effect in the speed-up for the incongruent condition in this tense.

In Experiment 3, we found longer reading times and lower acceptances for the simple past following an infelicitous living context compared to a felicitous dead context, similar to the congruence effects found between the dead- and living-present perfect conditions. However, the effect in the present perfect was larger than in the simple past, comparable to Roberts and Liszka (2013),[7] in which processing differences were found for adverb-tense violations in the present perfect (*Last week, John *has gone swimming twice.*) and simple past (*Since last week, John *went swimming twice.*). The authors reported that the present perfect elicited longer reading

[7] Roberts and Liszka (2013) present results from three English-speaker groups: L1-English, L1-German, and L1-French speakers. We refer only to the results from the L1-English speaker control group.

times in post-verb regions (compared to its congruent counterpart *Since last week…has gone*), while the simple past did not elicit processing costs, although both tense violation conditions elicited lower grammaticality ratings than their congruent counterparts. This was explained by the asymmetrical relationship between the present and past, in which the time frame *Since last week* entails the congruent past time frame *Last week*. This is not the case for the present perfect, as the incongruent time frame *Last week* does not include the present. In our study, the presence of a larger effect for violations of the present perfect compared to the simple past suggests that (i) similar to Roberts and Liszka (2013), the present perfect constitutes a stronger violation than the simple past in the context of mismatching lifetime reference, and (ii) compared to Roberts and Liszka (2013), the absence of a specified past time reference (living-simple past) elicits processing costs, whereas the presence of an incomplete time reference does not (as in Roberts & Liszka, 2013), although such a claim would need to be directly investigated in a future experiment. The smaller magnitiude of the congruence effects in the simple past compared to the present perfect could alternatively be seen as due to the simple past's status as the default tense for describing past events in English (Schaden, 2009; Yoon, 2012), or as due to the comparatively weaker violation present in the incongruent living-simple past condition, in which the utterance is left "hanging in the air" compared to the violation of the lifetime inference elicited by the present perfect in the dead-present perfect conditions.

5.3 The (Perfect) Lifetime Effect

Experiments 1 through 3 provide empirical evidence of the requirement of the present perfect to have a living referent at speech time (e.g., Chomsky, 1969; Mittwoch, 2008b; Pickbourn, 1789). The larger effects of lifetime-tense congruence for the present perfect than for the simple past condition suggest larger processing costs associated with violations of the present perfect than the simple past. This could be taken as support for the present perfect as a marked competitor of the simple past in English (Schaden, 2009; Yoon, 2012), but could also be taken to reflect the different mechanisms at play for the relationship between the two tenses and the lifetime of a referent. While the present perfect is incongruent with dead referents, the simple past is not incongruent with living referents, but rather requires an anchor to a specified past time frame. A statement such as *Laura treated many patients* does not necessarily imply Laura is deceased, but is left "hanging in the air" unless some past time frame has already been established as time reference, such as when following the statement *Laura used to be a nurse* (Klein, 1992, p. 543). However, our findings of effects in the simple past condition are at odds with those reported by Roberts and Liszka (2013), where no effects of adverb-tense congruence were reported for the simple past (but were for the present perfect). This difference between the current findings and those from Roberts and Liszka (2013) could be taken as evidence that temporal incongruence elicits effects in the present perfect, but not the simple past, when time reference is explicitly established through temporal phrases, but that both tenses elicit congruence effects when time reference is less explicit, as in our referent-lifetime contexts. Furthermore, the presence of congruence effects at all in Experiment 3 in the simple past conditions seems to contradict the suggestion in Meyer-Viol and Jones (2011) that the simple past does not make any claim about a referent's lifetime. However, it could be argued that our critical sentences might not trigger lifetime inferences in isolation (e.g., *He has won/won many prestigious awards, according to Wikipedia*), but that with living referents the present perfect is preferred (e.g., *Will Smith has won/won many prestigious awards, according to Wikipedia*). At the very least, the simple past can be said to interact with a referent's lifetime, as congruent dead (versus incongruent living) referents facilitated processing and elicited higher naturalness judgements in the simple past condition. However, the claim that the simple past is "anomalous" (Michaelis, 1994, p. 122) or "not interpretable without some understood past time reference" (Partee, 1984, p. 254) is contradicted by the relatively high naturalness responses for the incongruent simple past condition. Across experiments, the present perfect likewise elicited relatively high naturalness responses. Effects of lifetime-tense congruence may be more subtle in terms of awareness or acceptance of violations of this congruence, despite consistent elicitation of processing costs in incremental processing.

6. Conclusions

In three experiments we found effects of lifetime-tense congruence on the processing of temporal verb morphology in eye-tracking during reading, self-paced reading, and naturalness responses. Importantly, congruence effects emerged at the earliest possible region when temporal information became available (the verb region) in first-pass reading time in eye-tracking during reading. This can be taken to reflect the rapid availability of referent-lifetime information during the processing of verb morphology, although effects emerged in later sentence regions in the less fine-grained self-paced reading measures. Congruence effects differed between tenses in post-critical regions and measures reflecting later and/or cumulative processing costs, with quick and reliable rejection of incongruent conditions in the simple future, sustained processing costs for the present perfect, and comparatively weaker downstream effects for the simple past. Naturalness judgement responses revealed high metalinguistic awareness of the incongruence of a dead referent with the simple future, with significant but smaller effects of lifetime-tense congruence for the present perfect and simple past. The emergence of effects in the expected direction in the present perfect (i.e., processing costs and lower acceptances in the dead condition) across experiments provides evidence of the Perfect Lifetime Effect during processing, while the presence of congruence effects in the simple past condition (i.e., processing costs and lower acceptances in the living condition) provides evidence of the complementary (temporal) distribution of the two tenses, and the results in the simple future condition reflect the quick and reliable detection of lifetime-tense violations in this tense.

Data accessibility statement

The data, analysis code from all three experiments, and experimental items (critical, fillers, and practice) are available on the OSF repository: https://osf.io/6sra7/.

Ethics and consent

The studies presented were conducted under a laboratory-wide ethics approval granted by the German Linguistics Society ethics review board (DGfS, ethics vote number 2020-10-200807).

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Competing interests

The authors have no competing interests to declare.

Authors' contributions

The authors made the following contributions. Daniela Palleschi: Conceptualization, Experimental set-up, Analyses – Implementation, Writing – Original Draft Preparation, Writing – Review & Editing; Camilo R. Ronderos: Analyses – Code review, Writing – Review & Editing; Pia Knoeferle: Funding acquisition, Supervision, Writing – Review & Editing.

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