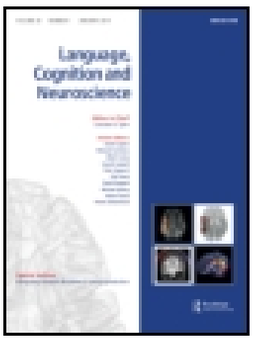

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REGULAR ARTICLE

Does hitting the window break it?: Investigating effects of discourse-level and verb-level information in guiding object state representations

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ABSTRACT

During language comprehension, comprehenders form mental representations of the described events. We investigate discourse-level and verb-level cues that guide this process. In particular, we investigate how comprehenders represent object states when events are described with manner verbs that do not entail change-of-state (e.g. *hit*, *wash*): a potential change-of-state of the object can be inferred but is not semantically required. We report two reaction-time-based experiments (Experiment 1: lexical decision, Experiment 2: self-paced reading) that investigated how rapidly comprehenders process linguistic material associated with potential change-of-state inferences, in contexts where the preceding discourse context and verb-level information are manipulated. In both experiments, we find an interaction between discourse-level information and verb-level information in guiding object state representations. We highlight the need to take into account discourse-level factors in theorising about the cognitive process of understanding the dynamics of event representation during language comprehension.

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Event comprehension; verb semantics; object state change; discourse context; questions under discussion

Introduction

During communication, comprehenders build mental representations of the events described by sentences (e.g. Johnson-Laird, 1983; van Dijk & Kintsch, 1983), using information from the lexical semantics of individual words, grammatical markers such as tense and aspect, prosody, and many other sources. At the same time, comprehenders are also faced with the task of understanding how individual utterances – and the inferences drawn from them – contribute to the conversational goals and the broader discourse. The present work investigates the construction of event representations during language processing, in particular how information from different levels of linguistic representation, namely (i) verbs' lexical semantics, (ii) grammatically-encoded temporal properties (tense) and (iii) discourse-level conversational context, guides the event representations constructed by comprehenders.

Mental representations of events have multiple dimensions, including temporal information, spatial information, and information about the relevant entities, including potential changes they may undergo. In this paper, we focus on this third component, namely the mental representations of entities that get acted upon during the event (in linguistic terms, entities with the thematic role of "theme" or "patient"). The representation of **object states** is a fundamental component of event representations as it is central to understanding the trajectory of changes that happen in an event (e.g. Altmann & Ekves, 2019; Altmann & Kamide, 2007; Hindy et al., 2012; Kang et al., 2020; Solomon et al., 2015). For example, successfully understanding events described by sentences like *The woman broke the window* or *The man cleaned the shirt* involves understanding that the window and the shirt undergo a change-of-state from their initial states (intact window, dirty shirt) to result states (broken window, clean shirt). (The term "*object* state" does not imply that the entity is an object in the syntactic argument-structure sense. There is an established tradition – which we follow – of using the term "objects" to refer, broadly speaking, to "things" in the real world.)

Tracking object states during language processing – i.e. figuring out the changes that an entity may or may not undergo – is not a trivial task, as the compositional meaning of the sentence-level linguistic input is often underspecified. In particular, **verbs** differ in whether their meaning clearly specifies whether an object undergoes a change-of-state or whether their meaning leaves this underspecified. On the one hand, the meaning of verbs like *break* and *clean* specifies that the object undergoes a change-of-state. Following linguistic

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tradition (e.g. Rappaport Hovav & Levin, 1998), we call these *result verbs*. On the other hand, verbs like *hit* and *wash* describe the manner of the action but are underspecified regarding the result state. These are called *manner verbs*.

More concretely, the meaning of result verbs like *to clean* specifies that the object ends up in a certain result state (e.g. the shirt ends up clean). In contrast, manner verbs like *to wash* only describe the manner in which the action is carried out and do not say anything about the result state, e.g. do not indicate whether the shirt ends up being clean or not. For example, note that one can easily say *The man washed the shirt but it still has stains on it*. In other words, the linguistic meaning of manner verbs like *wash* is underspecified for whether the thing being acted on undergoes a change-of-state. What does this mean with respect to the mental models that comprehenders construct upon encountering linguistic event descriptions with manner verbs? After encountering a sentence like *The man washed the shirt*, do comprehenders represent the state of the shirt at the end of this event as dirty or clean?

In the current work, we examine how the information provided by verbs' lexical semantics (e.g. manner verbs like *wash*) interacts with two other kinds of information, namely (i) discourse-level information and (ii) temporal information, to guide comprehenders' construction of object state representations. (1) is an example of how discourse-level information can guide object state representations:

(1) Lisa: Do you think I can wear my blue shirt to my interview tomorrow? It had a big stain on it but I can't remember if I did laundry.
John: Don't worry, I washed that shirt.

Here, although the verb *wash* is underspecified about whether the thing being washed becomes clean or not, in this context we can easily infer from John's utterance that the shirt is now clean. Otherwise, the sentence *I washed that shirt* would not be contributing to the overarching *discourse goal* of answering the question of whether the shirt can be worn for an interview. This intuition suggests that, at least on some level, discourse-level information plays a role in guiding the mental representations of object states that comprehenders construct.

In the present paper, we report two experiments that test how (i) *temporal information* (verb tense) and (ii) *discourse-level information* (both general information about which event participant – subject vs. object – is being talked about, and more specific information about whether the discourse goal is oriented toward the result state of the object) shape the representation of object states during online event comprehension, and how these information sources interact with (iii) *lexical semantic information* encoded on the verb. Specifically, we test whether comprehenders' representations of object states – i.e. *whether an object has undergone a change-of-state* (e.g. the shirt changing from dirty to clean) – are influenced by the interplay of discourse-level information and verb-level information, namely tense (Experiment 1) and verbs' lexical semantics (Experiment 2). Before outlining our research aims and hypotheses in more depth, we review relevant work on tense, verb semantics, and discourse-level representations in the next sections.

The role of verb tense in object state representations

When the state of an object changes in an event, it changes *over time*. It is at its initial state *before* the event and ends up at its result state *after* the event. Therefore, it is natural to consider the temporal ordering of the described event when investigating the factors that can influence comprehenders' mental representation of object states. One of the linguistic cues that provide information about the temporal ordering is tense. Tense (past, present, future) indicates the temporal ordering of events by temporally situating an event to precede, overlap with, or follow the time at which the sentence is uttered (e.g. Reichenbach, 1947). English marks tense on the verb using grammatical markers, e.g. *Mary kick**ed** the ball* (past), *Mary **will** kick the ball* (future).

Prior work in psycholinguistics shows that during language processing, representations of the initial state and the end state of an object can compete with one another (e.g. Hindy et al., 2012) and that the salience of these states in comprehenders' mental representations can be modulated by information about temporal ordering as indicated by tense (e.g. Altmann & Kamide, 2007; Kang et al., 2020; For related work on grammatical aspect, see e.g. Misersky et al., 2019). Altmann and Kamide (2007) showed that verb tense (past vs. future) rapidly modulates the extent to which participants expect the resulting object state. They conducted a visual-world eye-tracking experiment where participants heard sentences such as "The man will drink … " and "The man has drunk … ". Even before hearing the object noun, participants launched more anticipatory looks to the full glass (the initial state) when hearing "will drink", but looked more at the empty glass (the result state) upon hearing "has drunk." This shows that grammatical cues about the

temporal ordering of events (with respect to the utterance time) influence the salience of each object state.

Further evidence that verb tense guides object state representations comes from Kang et al. (2020), who showed that the effects of tense interact with general non-linguistic information about events and objects to modulate the availability of the initial state and the end state of the object. Using picture verification, Kang et al. tested how event representations are influenced by tense and by the degree of change described by a sentence (e.g. *The woman chose / will choose the ice cream* = minimal change to the ice cream, *vs The woman dropped / will drop the ice cream* = substantial change to the ice cream). They found that only past-tense sentences elicit responses showing sensitivity to the degree of change: When the sentences were in past tense, participants were faster to verify the original state of the object (e.g. an upright ice cream) with minimal-change sentences than with substantial-change sentences. No such asymmetry was observed when the sentences were in future tense.

These studies suggest that the mental representations of objects (and thus also of events) that comprehenders construct during language comprehension are guided by tense. Specifically, although both states are available in future tense contexts which signal that the event has not yet happened, the initial state can be more available to comprehenders than the result state. Conversely, when past tense signals that the event has already happened, the end state can be more salient to comprehenders. In what follows, we refer to this finding that representations involving a changed object state are more salient with past than with future tense as the "**past tense advantage"**.

These prior studies, however, used verbs and/or contexts where the nature of the past-tense sentences made it clear that the object *must* have undergone a change-of-state (e.g. after you hear "The man has drunk the beer," you know that the glass is empty). In such contexts, the difference between past and future tense is perfectly correlated with presence and absence of change-of-state (which was exactly what the experimenters intended): Either the object has *not* undergone a change-of-state (future tense) or it *has* undergone a change-of-state (past tense).

But what about verbs such as *wash* that are semantically underspecified for whether the object undergoes a change-of-state or not? Even when *wash* is in past tense, it is not guaranteed that the shirt becomes clean. It is fine to say *The man washed the shirt but it still had stains on it* – a washing event in the past does not guarantee that the shirt has become clean. But despite this lack of a guarantee, it could still be that comprehenders are more likely to construct an event representation where the object has undergone a change-of-state when the verb is in *past tense* compared to when it is in *future tense*. Thus, the question is whether the past tense advantage for the change-of-state representation observed with result verbs like *clean* also exists with manner verbs like *wash* whose lexical semantics do *not* entail a change-of-state. It is not yet known whether and how tense modulates object state representations in events that are inherently underspecified for change-of-state. This is one of the key issues that we investigate in the present work.

How do object state representations go beyond verb meaning?

The question of how verb tense interacts with the lexical semantics of verbs has implications for how we think about fundamental aspects of how mental representations of events are constructed during language processing. First, let's note that (i) a linguistic event representation where an object undergoes a change-of-state is arguably semantically more complex than one where the object does not necessarily undergo a change-of-state (e.g. Beavers, 2006; Davis & Koenig, 2000; Dowty, 1991; Goldberg, 1995; Jackendoff, 1996; Rappaport Hovav & Levin, 1998) and that (ii) increased complexity in verb semantics is known to elicit a higher processing load (e.g. Gennari & Poeppel, 2003; McKoon & Love, 2011; McKoon & Macfarland, 2000, 2002; McKoon & Ratcliff, 2003, 2005, 2008). McKoon and Love (2011), in particular, show that processing times for *hit* verbs and sentences are shorter than those for *break* verbs and sentences. Given these two considerations, we might expect that comprehenders will opt for the most economical, minimalist approach and only "make the effort" to build event representations involving change-of-state when faced with clear semantic evidence about a change-of-state, such as a verb that entails a change-of-state, like *break/clean*, but not a verb like *hit/wash*. Let's call this the Semantic Entailment Hypothesis:

(2) ***Semantic Entailment Hypothesis***: Comprehenders construct representations where the object has undergone a change-of-state only when the verb semantics clearly specifies this (e.g. with result verbs like *clean*). In all other circumstances (e.g. with manner verbs like *wash*), comprehenders opt for the simpler representations without a change-of-state, regardless of other sentence-internal or external cues.

However, in light of prior work, we should also keep in mind the possibility that verb tense modulates the extent to which comprehenders are likely to consider an event representation involving change-of-state. In particular, it could be that the past tense advantage occurs not only with verbs that guarantee a change-of-state (e.g. *clean*), but also with verbs that do not guarantee a change-of-state (e.g. *wash*). Let's call this the Tense-based Inference Hypothesis:

(3) ***Tense-based Inference Hypothesis:*** When a sentence is in future tense, comprehenders focus more on the initial (unchanged) object state, and when a sentence is the past tense, comprehenders are relatively more likely to construct a representation where the object *has* undergone a change-of-state, regardless of the verb's lexical semantics.

Another possibility is that, in addition to verb-level factors like tense, discourse-level information can further modulate the extent to which a comprehender considers an event representation that involves object state change or not (ex.(1)). It could be that the extent to which comprehenders consider representations where the object undergoes a change-of-state depends not only on verb-level factors such as verb type and tense, but also interacts with the discourse context. This would yield an interaction between verb type/tense and discourse context. We call this the Discourse-based Inference Hypothesis:

(4) ***Discourse-based Inference Hypothesis***: Discourse-level contextual information that is external to the sentence itself can interact with verb-level information (such as lexical semantics and tense) to further modulate the extent to which comprehenders consider representations where the object has undergone a change-of-state.

Verbs differ in the information they provide about object state change: result verbs vs. manner verbs

To test the three hypotheses outlined above, we first focus on comprehenders' processing of manner verbs in Experiment 1. In Experiment 1, we keep verb class membership constant, to assess the interplay of discourse-level information and tense information on verbs. We then compare manner and result verbs in Experiment 2 to assess the interplay of discourse-level information and lexical semantics of verbs.

Earlier work on how verb tense influences object representations has tended to focus on scenarios where, due to the verb or real-world knowledge, past tense signals that an object's change-of-state is virtually guaranteed – akin to result verbs. However, as we already saw with *hit* vs. *break* or *wash* vs. *clean*, individual verbs vary considerably in their lexical meaning – their *lexical semantics* – and not all verbs pattern alike with regard to encoding the object's change-of-state.

However, prior experimental work on object state representations has not systematically manipulated verbs' lexical semantics. This may seem surprising, given that (i) in other areas of psycholinguistics, verb-related information is regarded as a key aspect of sentence processing (e.g. Garnsey et al., 1997; Trueswell et al., 1993), and (ii) there is a long tradition of theoretical linguistics work that recognises the importance of verbs' lexical semantics on object states in event representations and has identified systematic verb classes (e.g. Dowty, 1979; Fillmore, 1970; Rappaport Hovav & Levin, 1998; Vendler, 1957).

Since Fillmore's (1970) seminal work on the grammatical differences between verbs of *hitting* and *breaking*, theoretical work on lexical semantics has identified a dichotomy between (a) verbs that entail change-of-state and (b) verbs that do not. The first class consists of verbs like *break*, *clean, crack*, *fill*, *empty*, *melt*, *open*, and *shatter* which describe situations with a clear result: the object has to undergo a change-of-state. In other words, the lexical semantic representation of these verbs includes a well-defined change-of-state that is *entailed* by the action. In this context, the notion of entailment is a logical dependency: if the action occurs, the object's state changes. These verbs are called ***result verbs*** (e.g. Rappaport Hovav & Levin, 1998, 2010).

Result verbs can be distinguished from another class of verbs called ***manner verbs***. These are verbs like *hit, wash, kick, pour, shake, shovel, slap*, and *wipe*, which lexicalise the manner in which an action is carried out, but do not entail a result. For example, *hit* encodes the particular manner in which the agent comes in physical contact with the object that is acted upon, but does not entail that the object becomes broken (unlike the verb *break*). Thus, whereas use of a result verb reliably indicates to the comprehender that the object has undergone the relevant change-of-state (e.g. *Lisa broke the window* => window is broken), use of a manner verb fails to do so (e.g. *Lisa hit the window* => window may or may not break).

However, although manner verbs do not linguistically encode a change-of-state, a change-of-state can often be **inferred** (e.g. Alexiadou et al., 2017; Rappaport

Hovav & Levin, 1998; Talmy, 1991, 2000; Wittek, 2002), as we saw in example (1) above. Examples (5a, 6a) also illustrate this: The change-of-state of the object (shirt becoming clean, window breaking) described in the second sentence follows naturally from the first sentence. In what follows, we often refer to this as the *result state* of the object. (Other researchers have also used the term *end state*. We consider the two terms to be interchangeable.) However, this change-of-state is not semantically hard-wired into the meaning of the first sentence, as shown by the fact that (5b, 6b) are also natural. In other words, with manner verbs, the inference about a change-of-state occurring is *defeasible* (e.g. Rappaport Hovav & Levin, 1998). This is not the case with result verbs, where the change-of-state is entailed by the meaning of the verb itself, and thus cannot be denied. This is shown by the oddness (infelicity) of (7a, b).

(5) a. Greg washed the shirt. He finally got the stains out! [manner verb]
b. Greg washed the shirt but it is still dirty.
(6) a. Mary hit the window. It shattered into a thousand pieces. [manner verb]
b. Mary hit the window, but it didn't break.
(7) a. # John cleaned the shirt, but it is not clean. [result verb]
b. # John shattered the window, but it didn't break. [result verb]

In sum, whereas result verbs semantically entail a change in object state, manner verbs are underspecified in this regard: a change in object state can often be inferred but is not encoded in the semantics of the verb. This brings us back to the fundamental question of how comprehenders build event representations, and specifically, what guides the representation of object states when the verb does not provide deterministic evidence.

Do comprehenders pattern in accordance with the Semantic Entailment Hypothesis and only construct mental event representations involving a change-of-state of the object when forced to do so by the verb semantics? Or can other information – either in the sentence itself or in the discourse – push comprehenders to construct an event representation where the object undergoes a change-of-state, as predicted by the Tense-based Inference Hypothesis and the Discourse-based Inference Hypothesis respectively? To investigate these issues, we need to move beyond contexts where the verb entails a change-of-state and look at semantically more ambiguous contexts.

Does discourse-level information interact with verb-level information to guide the representation of object state change?

As mentioned above, prior experimental work, e.g. Altmann and Kamide (2007) and Kang et al. (2020), focused on verbs/events that are associated with an obvious result state, akin to result verbs. Altmann and Kamide (2007) used destruction verbs (e.g. *drink, eat*) where the object disappears at the end of the action. Kang et al.'s (2020) substantial-change event descriptions also necessarily involve a change of the object's state (e.g. *The woman dropped the ice cream*.) Thus, their findings provide information about how comprehenders use the result state information inherent in the event together with tense cues, but do not shed light on what happens in situations where the linguistic input is underspecified about whether or not the object undergoes a change-of-state. Their results are compatible with the *Semantic Entailment Hypothesis*, but do not directly speak to the *Tense-based* or *Discourse-based Inference Hypotheses*.

This brings us to one of the key questions that we explore in the present work: *In situations where the verb does not pre-specify whether the object undergoes a change-of-state, what kinds of information guide the object state representations constructed by comprehenders?* The intended meaning of an underspecified event description may be context-sensitive, as we saw in the exchange in (1). In order to investigate how comprehenders understand events based on underspecified event descriptions, we examine the discourse-level factors that affect this process, and how they interact with linguistic information encoded on the verb itself, namely tense marking (past vs. future) and the verb's lexical semantics. In doing so, we assess the three hypotheses outlined above, namely the Semantic Entailment Hypothesis, the Tense-based Inference Hypothesis, and the Discourse-based Inference Hypothesis.

We frame our discussion of discourse factors within the framework of **Questions-Under-Discussion (QUD)**. We use the QUD approach because it allows us to articulate our predictions in a precise way, as it is well-established in theoretical work (e.g. Roberts, 1996/2012) – and has proven to be very fruitful for linguistic theorising (see e.g. Beaver & Clark, 2008; Beaver et al., 2017; Büring, 2003; Onea, 2016; Schoubye, 2009; Simons et al., 2010; Umbach, 2005) – and because it is supported by a substantial number of experimental studies (e.g. Clifton & Frazier, 2012, 2018; Cummins & Rohde, 2015; Degen & Goodman, 2014; Delogu et al., 2020; Grant et al., 2012; Kehler & Rohde, 2017; Tian et al., 2010; Zondervan, 2009, 2010; Zondervan et al., 2008). However, it is

important to note at the outset that the validity of our claims does not rely on the specific notion of QUDs; a different discourse-based approach could, in principle, also be used. We chose to use the notion of QUDs because they are theoretically and empirically well-understood.

The core idea of the QUD approach is that discourse is structured around questions-under-discussion which represent the interlocutors' joint discourse goals – the aims/goals of the current communicative exchange. QUDs are often implicit, i.e. often they are *not* explicitly worded as questions, and can be introduced by means of various cues (see e.g. Roberts, 1996/2012; see also Carlson, 1983). Under the QUD approach, a felicitous utterance is one that is relevant to the current QUD(s) and thus the interpretation of a sentence may depend on the QUD(s) that it addresses. For example, in (1), one relevant QUD is "Can the shirt be worn for the interview?" which then leads to the sub-question "Is the shirt clean?" In order for John's utterance "I washed that shirt" to be relevant to the question of whether the shirt is clean or not, an inference may be drawn: "I washed that shirt, so it is now clean."

A growing body of psycholinguistic evidence suggests that QUDs play a significant role in guiding language processing (e.g. Clifton & Frazier, 2012, 2018; Cummins & Rohde, 2015; Degen & Goodman, 2014; Delogu et al., 2020; Grant et al., 2012; Kehler & Rohde, 2017; Tian et al., 2010; Zondervan, 2009, 2010; Zondervan et al., 2008). These findings point to the conclusion that when processing an utterance, comprehenders prefer to interpret it as being relevant to the QUD, i.e. contributing to the current communicative goals of the discourse. This idea is captured in Clifton and Frazier's (2018) *General QUD Processing Principle*, which states that comprehenders "preferentially analyze new material such that it comments on the QUD" (p.109). The current work builds on and expands this literature by investigating a novel domain in which QUDs can guide interpretation: the representation of object states during event comprehension.

Aims of this work

The two experiments reported in this paper investigate how a key aspect of event representations, namely object state representations, is influenced by information from verb-level grammatical factors (verb tense and verb semantics), and discourse-level information (which we conceptualise in terms of the QUD framework). We test three hypotheses about whether and how grammatical and discourse-level information guide comprehenders' construction of object states: the Semantic Entailment Hypothesis, the Tense-based Inference Hypothesis and the Discourse-based Inference Hypothesis (as defined in (2)–(4)).

We conducted two reaction-time-based experiments that examine how rapidly comprehenders process linguistic material associated with potential change-of-state inferences, in contexts where the preceding discourse context and verb-level information are manipulated. Experiment 1 (using lexical decision) investigates whether verb tense (past vs. future) and discourse-level information modulate the object state representations that participants construct based on manner verbs, which are verbs that do not semantically specify whether or not the object has undergone a change-of-state. Experiment 2 (using self-paced reading) takes a finer-grained look at the interplay of discourse-level information and verb semantics by testing both manner verbs and result verbs, and by assessing the effects of more specific discourse-level cues.

Both lexical decision and self-paced reading methods have been used in various studies to investigate comprehenders' mental representations in many linguistic domains, including issues related to event representation (e.g. Allbritton, 2004 on predictive inferences; Ferretti et al., 2001 and subsequent work on activation of event-related knowledge; Fincher-Kiefer, 1993; Magliano et al., 1993; Pickering et al., 2006). We build on prior literature showing that it is easier to process words that relate to expectations comprehenders have already constructed, relative to unexpected words (e.g. expectation-based models of language processing and the notion of surprisal, e.g. Hale, 2001; Levy, 2008).

Thus, we predict that, in contexts where comprehenders have already constructed (based on prior context) an event representation where the object has undergone a change-of-state, then words related to the change-of-state will be easier to process – recognised faster (Experiment 1) or read more quickly (Experiment 2) – than in contexts where the event representation that the participant has constructed so far does not include a change-of-state for the object. Put together, these two experiments can shed light on how verb-level and discourse-level information guide the interpretation of underspecified event descriptions in sentence processing.

Experiment 1

Experiment 1 investigates manner-verb event descriptions which are underspecified for change-of-state, to see how verb tense and discourse-level cues guide how people construct representations of object states. Consider the sentence "Arthur poked the balloon."

Poke is a manner verb and does not specify whether or not the balloon undergoes a change-of-state (such as getting popped). What kind of representation do comprehenders construct upon encountering this kind of sentence? The Semantic Entailment Hypothesis predicts that participants do not construct a representation where the object has undergone a change-of-state. Why bother to construct a more complex event representation that involves a change-of-state, unless the verb demands this? In contrast, the Tense-based Inference Hypothesis and the Discourse-based Inference Hypothesis predict that tense and discourse context can push comprehenders to construct event representations where the object does undergo a change-of-state, even with manner verbs.

We used a lexical decision task to test whether (i) verb tense (past vs. future) and (ii) discourse-level cues (subject-oriented vs. object-oriented QUDs) modulate the extent to which participants consider a change-of-state representation for the object. The critical transitive sentences (e.g. *Arthur poked / will poke the balloon*) were (i) preceded by context clauses that marked either the subject or the object as the focus of the current QUD (*Talking about Arthur / Talking about the balloon*) and were (ii) followed by a lexical decision task with target words associated with the potential change-of-state (e.g. *popped*). We assume that lexical decision RTs indicate how strongly a comprehender is considering an event representation where the object undergoes a change-of-state, based on prior context (faster RTs indicate more activation of a representation where the object has undergone a change-of-state).

Method

Participants

Adult native speakers of American English were recruited via Amazon's Mechanical Turk (MTurk). Participants were compensated for their participation. We only included self-reported US-born native English speakers. Furthermore, we excluded 34 participants[1] who performed poorly on either the lexical decision task (below 75% accuracy, mean accuracy of excluded participants = 54.48%, mean accuracy of included participants = 96.43%) or on comprehension questions that occurred after each item (below 75% accuracy, mean accuracy of excluded participants = 53.77%, mean accuracy of included participants = 89.65%). All exclusion criteria reported in this paper were determined before data analysis on the targets was conducted. After excluding these participants, 102 participants were included in the final analysis. All experiments reported in this paper were reviewed and approved by the USC Institutional Review Board.

Design and materials

Each item had two main components: A two-line text component (shown on one screen) and a single-word lexical decision component (shown on the next screen). An example is given in (8) and (9). In the text component, we manipulated (i) the QUD-introducing context clause that precedes the critical sentence and (ii) the tense of the critical sentence (2×2 within-subjects design). The study included 24 target items. See Appendix A for the target stimuli.

(8) Sample text component:
   a. *Subject-related QUD + Future tense*
      Talking about Arthur:
      "Arthur will poke the balloon."
   b. *Subject-related QUD + Past tense*
      Talking about Arthur:
      "Arthur poked the balloon."
   c. *Object-related QUD + Future tense*
      Talking about the balloon:
      "Arthur will poke the balloon."
   d. *Object-related QUD + Past tense*
      Talking about the balloon:
      "Arthur poked the balloon."

(9) Sample lexical decision word: *popped*

Text component. The first line of the text component consisted of a context clause that signalled that the QUD (which reflects the immediate topic of discussion) is either about the subject or object of the following sentence (e.g. *Talking about {Arthur/the balloon}:*). We chose to use the "Talking about X" frame because "about"-phrases provide a means to manipulate attention to either the subject or the object without providing additional (and potentially asymmetric or biasing) information about other aspects of the event or the context. Other studies have used "about"-phrases to effectively manipulate the discourse context: mentioning a referent in an "about"-phrase influences the information structural status of the referent (e.g. Burmester et al., 2014; Burmester et al., 2018; Cowles, 2007; Cowles & Ferreira, 2012). Based on Clifton and Frazier's (2018) General QUD Processing Principle and attention allocation in discourse (e.g. Birch & Rayner, 1997; Cutler & Fodor, 1979; Sturt et al., 2004), we assume that the QUD manipulation modulates whether participants will focus more on the subject (Subject-QUD conditions) vs. the object (Object-QUD conditions) as the answer to the QUD.

The second line was the critical sentence. All targets used manner verbs – in past or future tense – that

refer to events of contact-by-impact which may or may not cause the object's state to change (e.g. *whack*, *pound*, *kick*, *hit*, *knock*, *tap*, *poke*), identified based on Levin (1993) as well as established semantic tests. The object nouns had no strong bias about whether the event would or would not lead to a change-of-state of the object. The study had 24 targets, and each target used a different manner verb and a different noun.

Lexical decision word (target word). The text component of each trial was followed by a single word on the next screen (e.g. *popped*). Within an item, the target word was held constant. Participants indicated whether this word was a real word of English (lexical decision). Reaction times were recorded and analysed.

On target trials, the lexical decision word (e.g. *popped*, *cracked*, *squashed*) was a past participial form of a result verb associated with a potential change-of-state of the object. These forms are associated with object change-of-state interpretations relative to both the subject *and* the object of the critical sentence. If a participant reads (8) and constructs an event representation where the object undergoes a change-of-state (e.g. the balloon pops), then "popped" should be easier to process regardless of whether it is construed as (i) an active form related to the subject (*Arthur has popped the balloon*) or (ii) a passive form related to the object (verbal passive: *The balloon was/got popped,* adjectival passive: *the popped balloon*),[2] compared to a situation where the participant constructs an event representation with *no* object state change. Thus, the lexical decision target words provide a maximally sensitive way of tapping into whether participants' event representations in the different conditions differ in terms of how strongly an object change-of-state is activated.

We did not test target words *unrelated* to change-of-state; our hypotheses and results are cast in relative terms and focus on comparing the conditions to each other. In other words, our design allows us to test whether the four conditions differ in terms of the extent to which participants consider a representation where the object undergoes a change-of-state.

In addition to 24 targets, the study included 36 fillers. Fillers also consisted of a context clause (*Talking about …*) and a sentence that describes a transitive event in future or past tense. On 26 of the 36 filler trials, the lexical decision word was a nonce word with adjectival morphology (e.g. *vulperous*, *lindful*) and on the remaining 10 filler trials, the lexical decision word was a real word (e.g. *edible, magenta, excited*) that was not related to the text component associated with it.

As this study had a 2×2 design, four lists were created and presented to participants using a standard Latin Square design: each participant was presented with only one condition of each target item and each of the four conditions appeared the same number of times on any given list. Each of the four lists contained the same set of filler items, pseudo-randomly distributed throughout the list.

Procedure

The experiment was hosted online on PennController IBEX (Zehr & Schwarz, 2018; https://www.pcibex.net/), and participants did it remotely via the internet. Participants completed three practice trials before the start of the main experiment. Each trial began with a presentation of the two-line text component (see (8)). Participants were instructed to read both lines and then press the spacebar to advance. The next screen displayed a fixation cross for 1000 ms, which was then replaced by the lexical decision word. Participants indicated whether this target word was a real word of English by pressing F (word) or J (non-word). The target word remained on the screen until a button press was registered. Afterwards, participants answered a yes-no comprehension question about the text component. When participants made errors either on the lexical decision task or on the comprehension questions, they saw an error feedback message. The experiment session lasted approximately 20 minutes.

Predictions

If participants only construct event representations where the object has undergone a change-of-state when the verb semantically entails this, as predicted by *the Semantic Entailment Hypothesis*, we expect no effects of tense or QUD on lexical decision times (given that Experiment 1 tests manner verbs which do not entail a change-of-state). Absence of any tense or QUD effects would be compatible with the claim that regardless of tense or discourse context, participants do not construct a change-of-state representation if the verb semantics do not entail it. (We test result verbs in Experiment 2).[3]

In contrast, *the Tense-based Inference Hypothesis* predicts that tense guides the construction of object state representations, even with manner verbs. According to this hypothesis, with a future tense verb, comprehenders focus more on the initial (unchanged) object state representation, but with a past tense verb, comprehenders are more likely to construct a representation where the object *has* undergone a change-of-state, regardless of the verb's lexical semantics. So, if participants make the tense-based inference that a past action leads to a result state, we expect to see a past tense advantage in the lexical decision response times

(faster RTs in past tense conditions than future tense conditions).

Furthermore, if effects of verb-level information (in this case tense) on object state representations are modulated by discourse-level information, as predicted by the *Discourse-based Inference Hypothesis*, we expect an *interaction* between verb tense and discourse-level (QUD) effects: We predict that tense effects will be stronger when the focus of attention is on the object (Object-QUD conditions), compared to the subject (Subject-QUD conditions). This predicted interaction is rooted in the observation that in transitive sentences of the type we are testing, tense affects the representation of objects more than subjects: It is the objects that undergo the change-of-state. The representation of *Arthur* is largely the same before and after the poking-the-balloon event, but the state of *the balloon* is potentially very different after the poking event (past tense conditions). Thus, if discourse-level information interacts with verb tense in guiding the construction of object state representations, we predict an interaction between tense and QUD.

If we find effects of verb tense but no effects of the QUD manipulation, this would be compatible with the Tense-based Inference Hypothesis but not the Discourse-based Inference Hypothesis. It would support a view where only core aspects of grammar (e.g. verb tense), but not discourse-level information, shape comprehenders' construction of object state representations.

In addition to an interaction between tense and QUD type, we may also find a main effect of QUD type, which would be orthogonal to the hypotheses we are testing. A main effect of QUD type would be related to the fact that our target (lexical decision) words are past participial forms (e.g. *popped*), which are ambiguous between (i) active (e.g. *John (has) popped* …) and (ii) passive forms (e.g. *The balloon is/was popped*). We chose to use these ambiguous forms because they can be associated with change-of-state event interpretations relative to both the subject and the object of the critical sentence – an active interpretation being subject-oriented and a passive interpretation being object-oriented. Thus, these forms provide a maximally sensitive way of tapping into whether participants' event representations in the different conditions differ in terms of how strongly a change-of-state representation is activated (tense x QUD interaction). We may also find – for reasons orthogonal to our research aims – that subject-oriented QUDs make it more likely that participants will interpret the target word as an active form, while object-oriented QUDs make it more likely that participants interpret it as a passive form. Given that actives are much more frequent in English than passives (e.g. Hopper & Thompson, 1980; Svartvik, 1966), and that lexical decision RTs are sensitive to word frequency (e.g. Whaley, 1978), this may elicit a main effect of QUD type such that Subject-QUDs elicit faster lexical decision RTs to *popped* than Object-QUDs. However, a main effect of QUD type is not relevant for the hypotheses we are testing in this paper.

Likelihood-of-change norming study

The targets in Experiment 1 used a range of verbs and nouns in the critical sentences and as the target words in the lexical decision task. To control for differences between items, we ran a norming study to obtain an independent measure of how likely it is that the verb + noun pairs used in target items (e.g. *poke* + *the balloon*) make people expect that the noun undergoes the change-of-state described by the target word in the lexical decision task (e.g. *popped*).

\We computed the likelihood-of-change measure for each item based on norming data from 35 adult native speakers of American English. (One participant who answered incorrectly on four out of the five attention-check trials was excluded. None of the other participants made more than one error.) Participants saw 24 target items like (10) and rated the likelihood of the object undergoing the change-of-state. The study also included five attention-check trials involving recall of a word from the preceding screen. The mean likelihood-of-change rating for all twenty-four items was 4.78 (sd = 1.79). The ratings were z-scored, and we used the z-scored ratings as a fixed effect in the reaction time analyses in order to control for item-level variation (see Results section below).

(10) [POKE – the balloon] / *popped*

If you imagine a situation that is related to [POKE – the balloon], how likely are you to imagine that the balloon gets popped?

not likely at all						extremely likely
1	2	3	4	5	6	7

Data processing and analysis

When analysing the reaction times in the lexical decision task, we first removed incorrect lexical decision responses (2.67% of the data) and RTs over 5000 ms (2.1% of the data), following Baayen and Milin (2010). Then, RTs more than 2.5 SDs from a participant's mean RT were excluded. This affected 2.71% of the data. For statistical analyses, we used linear mixed effects models with RT as the dependent variable, and tense (contrast-coded, future tense = 0.5, past tense = −0.5), QUD type (contrast-coded, Object-QUD = 0.5, Subject-QUD = −0.5), and the tense x QUD

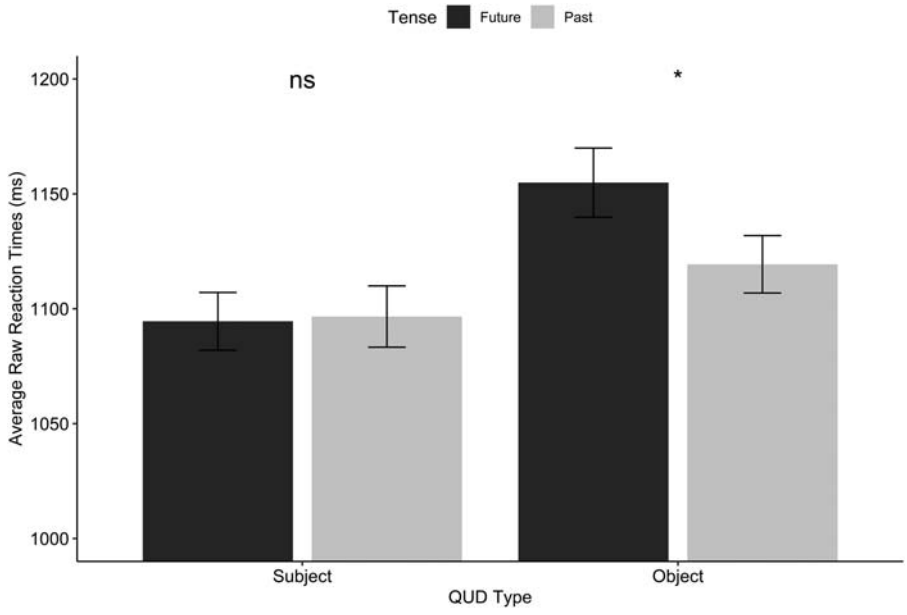

Figure 1. Mean reaction times by condition in Experiment 1 (The y-axis shows the raw reaction times to the lexical decision task in milliseconds (ms). Error bars show +/− 1 SE).

type interaction as fixed effects. Models were estimated using the lme4 package (version 1.1.21) (Bates et al., 2015) and lmertest (version 3.1.1) (Kuznetsova et al., 2017) in the R software environment (R Development Core Team, 2019). We used the same R packages for planned comparisons. Our models also included word frequency (word frequency per million words from the SubtlexUS database, Brysbaert & New, 2009), word length, likelihood-of-result scores (in z-scores) and presentation order as fixed effects. As random effects, we entered intercepts for subjects and items, as well as by-subject and by-item random slopes for the effects of tense type, QUD type, and their interaction when justified by model comparison: Random effects started out fully crossed and fully specified with by-subject and by-item effects of tense type, QUD type, and their interaction. They were then reduced (starting with by-item effects) via model comparison, wherein only random effects that contributed significantly to the model ($p < 0.05$) were included (Baayen et al., 2008).

Results

Figure 1 shows the average lexical decision RTs by condition, i.e. how quickly participants correctly identified the target word as a real word of English. Two numerical patterns are clearly visible: First, overall RTs in the Subject-QUD conditions are faster than in the Object-QUD conditions. Second, tense has no effect in the Subject-QUD conditions whereas there is a past tense advantage (or future-tense penalty) in the Object-QUD conditions: RTs are slower in the future tense conditions than in the past tense conditions.

The main effect of QUD type (RTs in Subject-QUD conditions being faster than in Object-QUD conditions) is not relevant to the claims we are making in this paper. We attribute it to the (intended) active/passive ambiguity of the target word and the fact that active verb forms are much more frequent than passive verb forms (see the Predictions section above).

Statistical analyses are reported in Tables 1–3. As can be seen in Table 1, we found a main effect of QUD type, a marginal main effect of tense, but no interaction.

Table 1. Experiment 1: results of the lmer model.

	β	SE	df	*t* value	Pr (>|t|)	
(Intercept)	1303.2204	95.2597	118.4234	13.681	<2e−16	***
QUD type	35.5868	11.6873	2156.1279	3.045	0.00236	**
Tense type	22.2045	11.6838	2153.3115	1.900	0.05751	.
likelihood-of-result score	12.5101	14.3771	20.0479	0.870	0.39452	
word length	−5.6787	6.1711	19.6034	−0.920	0.36865	
word frequency	−0.4245	0.1797	19.6837	−2.363	0.02857	*
presentation order	−6.1973	0.8507	2156.1558	−7.285	4.48e−13	***
QUD type:Tense type	26.9589	23.3806	2157.4864	1.153	0.24902	

Table 2. Experiment 1: planned comparisons, object-QUD conditions only.

	β	SE	df	t value	Pr (>|t|)	
(Intercept)	1282.6470	111.1086	87.2899	11.544	<2e−16	***
Tense type	36.5302	16.8896	1017.1898	2.163	0.0308	*
likelihood-of-result score	3.2456	21.4307	18.5734	0.151	0.8813	
word length	1.0092	9.3177	18.8055	0.108	0.9149	
word frequency	−0.3547	0.2808	21.1967	−1.263	0.2203	*
presentation order	−6.8462	1.2285	1017.8299	−5.573	3.21e−08	***

However, given that we predicted differential effects of tense in Subject-QUD and Object-QUD conditions, we conducted planned comparisons to test this. Thus, we looked separately at Object-QUD conditions (Table 2) and Subject-QUD conditions (Table 3), to test our hypothesis that tense effects will be modulated by QUD type (the Discourse-based Inference Hypothesis). As expected based on Figure 1, there is a significant effect of tense in the Object-QUD conditions but not in the Subject-QUD conditions: When the QUD inquired about the object, RTs in the past tense condition were faster than in the future tense condition (Table 2). In contrast, when the QUD inquired about the subject, this tense effect was not observed (Table 3). These results support the Tense-based and the Discourse-based Inference hypotheses.

Discussion

In order to gain insights into what kinds of information guide the representation of events, in particular object state changes, Experiment 1 tested the processing of transitive sentences with manner verbs which are underspecified with respect to whether or not the object changes state (e.g. *Arthur poked the balloon* may or may not result in the balloon popping). This study used a lexical decision task to investigate the effects of (i) discourse-level information (specifically, which event participant the contextual Question Under Discussion (QUD) is related to) and (ii) verb tense (future vs. past) on how quickly comprehenders process words related to the potential change-of-state.

We tested three hypotheses about how different kinds of information guide the representation of object states. According to the Semantic Entailment Hypothesis, participants only construct event representations with a change-of-state of the object if the verb semantically entails a change-of-state. Since Experiment 1 tested manner verbs, this hypothesis predicts that no change-of-state representation is constructed in any condition, regardless of tense or QUD. According to the Tense-based Inference Hypothesis, tense guides the construction of object state representations, even with manner verbs. Furthermore, if verb-level effects (in this case verb tense) can interact with discourse-level information, as predicted by the Discourse-based Inference Hypothesis, a stronger past tense advantage is predicted with Object-QUDs than with Subject-QUDs.

Our results go against the Semantic Entailment Hypothesis, because we find that tense *does* have an effect on the lexical decision times for the target words associated with the potential change-of-state. Indeed, we find a past tense advantage in the Object-QUD conditions but not in the Subject-QUD conditions.

We interpret our results as suggesting that, when the QUD drives people to attend to the object (by introducing an expectation that the sentence is interpreted as providing an answer to a question about the object), tense modulates the object state representations and makes a change-of-state inference more likely with past tense verbs than with future tense verbs. This is in line with the predictions of the Tense-based and Discourse-based Inference hypotheses. These findings suggest that the mental representations of events built from linguistic input can go beyond the lexical semantics of verbs. In doing so, other verb-level factors such as tense and discourse-level factors such as the QUD can play a modulating role.

Thus, our results highlight the interplay between grammar-level and discourse-level information and support the idea that the mental representations of events are modulated by the QUD (i.e. what is being discussed in the current discourse). This finding is in line with Clifton and Frazier's (2018) General QUD Processing

Table 3. Experiment 1: planned comparisons, subject-QUD conditions only.

	β	SE	df	t value	Pr (>|t|)	
(Intercept)	1341.6957	96.3847	115.6697	13.920	<2e−16	***
Tense type	8.2611	15.8885	1018.6536	0.520	0.6032	
likelihood-of-result score	23.4310	15.7977	20.4959	1.483	0.1532	
word length	−14.6623	6.9554	21.4070	−2.108	0.0470	*
word frequency	−0.5348	0.2025	20.6478	−2.641	0.0154	*
presentation order	−5.7106	1.1636	1021.6290	−4.908	1.07e−06	***

Principle which states that utterance interpretations are QUD-dependent.

A possible concern is whether the past tense advantage that we observed in the Object-QUD conditions could be due to a morphological priming process driven by the presence of the *-ed* marker in both the critical sentence and in the target word. However, this is not a plausible explanation for our data: It fails to explain the lack of a past tense advantage in the Subject-QUD conditions. If the past tense advantage were only reflective of a morphological priming effect, the same effect should be observed across the board, regardless of the QUD manipulation. But this is clearly not the case.

In sum, the results of Experiment 1 extend the previous findings on tense effects (e.g. Altmann & Kamide, 2007; Kang et al., 2020) by providing evidence that the past tense advantage also holds for verbs that do not specify a result state and for which the result state can only be inferred. Thus, our results support the Tense-based Inference Hypothesis and go against the Semantic Entailment Hypothesis. Crucially, our results also show that in addition to sentence-level information, discourse-level information interacts with verb tense to contribute to the cognitive process of understanding the dynamics of event representation in language comprehension: We find evidence for both the Discourse-based and the Tense-based Inference hypotheses.

Experiment 2

Experiment 1 found that the ease of processing words associated with a potential change-of-state of the object is influenced by discourse-level information in conjunction with verb-level temporal information (past vs. future tense). These results suggest that in discourse contexts with object-oriented QUDs, the inference about the object having changed state – with manner verbs which are underspecified for change-of-state – is more available when the event description is in past tense than in future tense. The finding that both verb-based and discourse-based information play a role provides initial evidence against the Semantic Entailment Hypothesis, according to which only the lexical semantics of verbs matters for the purposes of representing the object state.

Experiment 2 uses the self-paced reading methodology and has two main aims. First, it tests the Semantic Entailment Hypothesis more directly, by comparing result verbs and manner verbs. Even though the results of Experiment 1 challenge the Semantic Entailment Hypothesis, they do so in a "one-sided" way because only manner verbs were tested. To fully test the hypothesis that comprehenders construct representations involving an object change-of-state only when the verb semantics entails such a change, we need to directly compare verbs that entail a change-of-state (result verbs) to verbs that do not (manner verbs).

Second, Experiment 2 also takes a closer look at the Discourse-based Inference Hypothesis, to see if a finer-grained discourse-level manipulation has effects on object state representations – especially with manner verbs. Whereas Experiment 1 tested a coarse-grained split of *object*-related vs. *subject*-related QUDs, in Experiment 2 we tested two kinds of object-related QUDs: We compared contexts with *aboutness QUDs* that simply ask about the object (e.g. *Trevor asked about the X,* similar to Experiment 1) to contexts with *change-of-state oriented QUDs* that specifically ask what happened to the object (e.g. *Trevor asked what happened to the X*).

A difference between aboutness QUDs and change-of-state oriented QUDs would provide evidence that the construction of event representations is sensitive not only to QUD-based distinctions between event participants (e.g. subject vs. object, Experiment 1) but also to the presence of fine-grained information in QUDs about event structure (Experiment 2).

In fact, given that result verbs semantically entail an object state change, we expect to see stronger QUD effects with manner verbs (verb type x QUD type interaction). We are especially interested to see whether change-of-state oriented QUDs can facilitate the processing of change-of-state descriptions after manner verbs so as to render it comparable to the processing of change-of-state descriptions after result verbs. Such a finding would both provide further evidence for the Discourse-based Inference Hypothesis – by showing that effects of verbs' lexical semantics can be modulated by discourse-level information – and against the Semantic Entailment Hypothesis.

Experiment 2 used past tense sentences in all targets; thus, it does not test the Tense-based Inference Hypothesis. Experiment 2 used self-paced reading, instead of lexical decision. This is because self-paced reading allowed us construct contexts that incorporate aboutness QUDs and change-of-state oriented QUDs in a more coherent way. Furthermore, self-paced reading allows us to measure RTs not only on the target word but also on subsequent words.

Methods

Participants

Students from the University of Southern California participated in return for course credit. We report data for

40 adult native English speakers with normal or corrected-to-normal vision and no reported reading or learning disabilities. One person was excluded due to dyslexia and one due to low performance on comprehension questions (only 70% correct; mean comprehension question accuracy of other participants = 82.05%, SD = 0.38).

Materials and design

In a 2 × 2 design, we manipulated (i) QUD type (*what happened to X* vs. *about X*) and (ii) verb type (manner verb vs. result verb) to create four conditions. All targets used nonce object nouns (e.g. *merick*) because we wanted to avoid object properties affecting result state representations (*stomp on an egg* vs. *stomp on a penny*, e.g. Hindy et al., 2012; see also Horchak & Garrido, 2020 on the effect of the object being affected by light vs. heavy items). Each target used a different nonce word. An example is in (11). See Appendix B for the target stimuli.

(11) Sample target stimuli

a. *what happened QUD + Manner verb*

Trevor called and asked Mary what happened to the merick.

She replied that she hit it in the morning on Monday.

She said that it is damaged and that she feels very sorry about this.

b. *about QUD + Manner verb*

Trevor called and asked Mary about the merick.

She replied that she hit it in the morning on Monday.

She said that it is damaged and that she feels very sorry about this.

c. *what happened QUD + Result verb*

Trevor called and asked Mary what happened to the merick.

She replied that she broke it in the morning on Monday.

She said that it is damaged and that she feels very sorry about this.

d. *about QUD + Result verb*

Trevor called and asked Mary about the merick.

She replied that she broke it in the morning on Monday.

She said that it is damaged and that she feels very sorry about this.

All targets were three sentences long, and each sentence was presented on a separate line. All sentences were presented word-by-word. The first sentence mentions two different-gender people using proper names and establishes the QUD. The *about* QUD is similar in effect to the Object-related QUDs in Experiment 1: it generally asks about the object but does not signal that the speaker is specifically interested in knowing about the *result state* of the object. In contrast, the *what happened* QUD indicates that the speaker wants to know about the result state of the object.

Based on Clifton and Frazier's General QUD Processing Principle, which states that comprehenders prefer to interpret utterances so that they relate to the QUD, we assume that when the QUD asks *what happened* to the object, a change-of-state inference about the object is more available than in the context of *about* QUDs. In other words, in the *what happened QUD + manner verb condition*, in order for the second sentence to be interpreted as an answer to the QUD, a change-of-state inference is to be drawn. If the manner verb is interpreted purely as its lexical semantic meaning of providing information about the manner in which the action was carried out, the sentence does not serve to meet the discourse goals.

The second sentence provides an answer to the QUD, using a manner verb (e.g. *hit*) or a result verb (e.g. *break*). All verbs were in past tense. We used 33 different result verbs (one was used twice) and 32 different manner verbs (two were used twice), selected based on Levin (1993).

The third sentence starts with the structure "he/she replied that … " and uses the target word in predicative position as shown in (11). The target word describes the (changed) result state of the object noun (e.g. *damaged*). Most of the target words are past participial adjectives (e.g. *damaged*, *shattered, cracked*), like Experiment 1, while some are (non-past participial) adjectives and related expressions (e.g. *shiny, rough*). All target words describe the changed state of the object. We used 25 different target words (7 were used twice and 1 was used three times.) The target word is followed by a coordinated "that" clause with a pronominal subject with the structure *and that he/she feels quite/very/rather … .*

In the result verb conditions, the changed state is entailed by the verb. In the manner verb conditions, it is not entailed, but can be inferred. Therefore, successful integration of the result state into the existing event representation depends on the generation of a change-of-state inference.

The critical region for the RT analysis consists of the target word and the five subsequent words. For completeness, we report RTs for the entire critical sentence, i.e. also for the two words before the adjective (*it is*), although these are not relevant for our predictions because the critical adjective has not yet been encountered at that point.

In addition to 34 targets, the experiment included 4 practice trials and 48 fillers. The study had 32 "core" target items as part of the 2 × 2 design, as well as two "extra" target items, for a total of 34. As in Experiment 1, four lists were created using the core targets and were presented to participants using a standard Latin Square design: Each participant was presented with only one condition of each target item and each of the four conditions appeared the same number of times on any given list. Each of the four lists contained the same set of filler items, pseudo-randomly distributed throughout the list. The two extra targets were not integrated fully into the Latin Square because of potential semantic concerns (they differ from the others in using a potentially non-gradable target word: *spotless, shiny*). However, it turns out that the basic RT patterns with and without these items are the same, so we include them in our analyses. Thus, each participant saw either eight or nine target items per condition.

Procedure

Participants were tested individually in the Language Processing Lab on the University of Southern California campus. We used a moving-window self-paced reading paradigm implemented with *Linger* (D. Rohde, http://tedlab.mit.edu/dr/Linger/) on an HP Spectre X360 laptop computer, running Windows 10. Participants read the sentences one word at a time. With each press of the spacebar, the currently displayed word turned back into dashes and the next word was displayed. Each trial was followed by a yes-no comprehension question which participants answered with the F (yes) or J (no) keys. Incorrect responses triggered an error feedback message. Comprehension questions were related to the content of a balanced range of sentence regions. Each experimental session lasted approximately 20–25 minutes.

Data processing and analysis

Prior to data analysis, RTs faster than 100 ms or slower than 2000ms were excluded, which affected 1.77% of the data. We also excluded any RTs more than 2.5 standard deviations from the mean in any given word position. This affected an additional 2.26% of the entire data.

We analysed the target word (e.g. *damaged*) and the five words following it. Statistical analyses were carried out on the raw RT data using linear mixed-effects models. Models were estimated using the lme4 package (version 1.1.21) (Bates et al., 2015) and lmerTest (version 3.1.1) (Kuznetsova et al., 2017) in the R software environment (R Development Core Team, 2019). We used the same R package for planned comparisons. The models included fixed effects of verb type (contrast-coded: manner verb = 0.5, result verb = −0.5), QUD type (contrast-coded: *about* QUD = 0.5, *what happened* QUD = −0.5), and their interaction. The random effect structures were identified in the same way as in Experiment 1.

Predictions

We expect to find a main effect of verb type: The target word – which describes a changed object state – is predicted to be read faster in the result verb conditions (where the verbs semantically entail that the object undergoes a change-of-state) than in the manner verb conditions (where the result state is not encoded in the lexical semantics of the verb itself).

Crucially, according to the *Semantic Entailment Hypothesis*, this verb effect should be unaffected by the discourse-level QUD manipulation (*about* QUD vs. *what happened* QUD).

In contrast, the *Discourse-based Inference Hypothesis* predicts that discourse-level information can interact with verb-level information (here: the lexical-semantic distinction between manner vs. result verbs) to modulate the extent to which comprehenders consider representations where the object has undergone a change-of-state. This leads us to expect that the QUD manipulation can boost the availability of an event representation in which the object changes state, even when the lexical semantics of the verb does not include a notion of change-of-state (manner verbs). More specifically, the prediction is that when the QUD specifically asks about the change-of-state (*what happened* QUD), the change-of-state representation will become more available – compared to the *about QUD* – and this will affect reading times at the target word region. This leads us to expect an interaction between QUD type and verb type: With *what happened* QUDs, effects of verb type on reading times at the target word are expected to be smaller than with *about* QUDs, because the inference triggered by *what happened* QUDs after manner verbs will help comprehenders to process the target word that describes an object change-of-state.

In fact, we may find that reading times at the target word in the *about* QUD conditions are comparable for manner verbs and result verbs, if the effect of QUD on event representations is strong enough to "overcome" effects of verbs' lexical semantics. This would provide further support for the *Discourse-based Inference Hypothesis*.

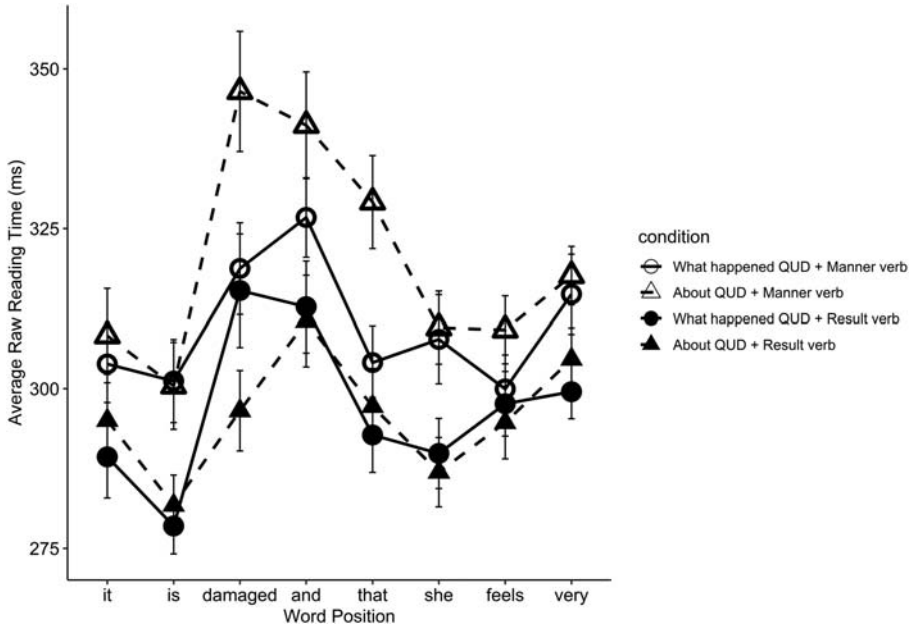

Figure 2. Experiment 2: Average reading times by word position (error bars represent +/− 1 SE).

Results

Figure 2 shows the RTs in the critical region. Visual inspection of the data shows that at and after the target word (e.g. *damaged*), the RTs were longer in the *about QUD + manner verb* condition compared to the result verb conditions. On the other hand, RTs in the *what happened QUD + manner verb* condition do not exhibit such a severe slowdown relative to the result verb conditions. Statistical analyses confirmed these observations:

Pre-target region. At two words (e.g. *it is*) before the target word, reading times are faster in the result verb conditions than in the manner verb conditions. This is likely a spillover effect from the preceding sentence (sentence 2), where manner verbs were read more slowly than result verbs (sentence 2 mean RT at the manner verb: 346.63 ms vs. result verb: 314.28 ms).

Target word. At the target word position (e.g. *damaged*), there was again a main effect of verb type, no main effect of QUD type, and, crucially, an interaction of verb type and QUD type. Planned comparisons at the target word position show that in the *about QUD* conditions (triangles in Figure 2), the target word is read slower in the manner verb conditions than in the result verb conditions (effect of verb type: $\beta = 49.07$, SE = 17.31, $t = 2.83$, $p = 0.008$), but in the *what happened QUD* conditions (circles in Figure 2), the target word is read equally fast after both verb types (no effect of verb type: $\beta = 1.77$, SE = 10.88, $t = 0.16$, $p = 0.87$). In other words, in the *what happened* QUD conditions, the slowdown associated with a preceding manner verb is absent.

In other words, in *about* QUD contexts, when comprehenders are faced with a word that describes a potential changed object state, RTs are slower after manner verbs than after result verbs. But when the QUD specifically highlights the possibility of object state change (*what happened* QUDs), target words describing potential result states are read equally quickly in both the manner and result verb conditions. This goes against the Semantic Entailment Hypothesis and supports the Discourse-based Inference Hypothesis.

(One might wonder why the target word in the *about QUD* conditions with result verbs seems to be read numerically more slowly than in the *what happened QUD* conditions with result verbs; crucially, this is not a statistically significant difference ($t = -1.22$, $p > 0.2$), nor does it relate to our hypotheses, so we will not discuss it further.)

Spillover region. The main effect of verb type is found throughout the spillover region (first, second, third, and fifth spillover word). There is a main effect of QUD type at the second spillover word. There is no interaction between verb type and QUD type in the spillover region (five words after the critical word, see Table 4 for details.)

Discussion

Experiment 2 was designed to investigate how lexical semantics of verbs and discourse-level information from QUDs guide the event representations that comprehenders construct for events where the object may

Table 4. Results of lmer models for each word in the target region.

Word position		β	SE	df	t-value	Pr(>t)	
it	(Intercept)	298.923	10.759	41.035	27.784	<2e−16	***
	verb type	12.675	6.759	1249.027	1.875	0.061	.
	QUD type	4.857	6.759	1249.128	0.719	0.472	
	verb type:QUD type	−3.361	13.521	1248.689	−0.249	0.804	
is	(Intercept)	290.3278	9.5820	42.5583	30.299	<2e−16	***
	verb type	20.2636	5.6627	1247.0603	3.578	0.000359	***
	QUD type	0.6366	5.6580	1246.6245	0.113	0.910440	
	verb type:QUD type	−4.9833	11.3245	1246.6375	−0.440	0.659979	
Damaged	(Intercept)	319.152	13.446	47.765	23.736	<2e−16	***
(critical word)	verb type	25.170	7.795	1242.191	3.229	0.00127	**
	QUD type	4.907	7.792	1241.988	0.630	0.52896	
	verb type:QUD type	46.105	15.586	1242.047	2.958	0.00315	**
and	(Intercept)	322.900	12.070	45.042	26.753	<2e−16	***
(spillover1)	verb type	22.724	7.167	1248.340	3.171	0.00156	**
	QUD type	5.154	7.157	1247.063	0.720	0.47156	
	verb type:QUD type	15.122	14.325	1247.517	1.056	0.29135	
that	(Intercept)	305.423	10.311	43.846	29.622	<2e−16	***
(spillover2)	verb type	21.097	6.162	1246.410	3.424	0.000638	***
	QUD type	13.845	6.158	1246.630	2.249	0.024717	*
	verb type:QUD type	19.976	12.328	1246.886	1.620	0.105385	
she	(Intercept)	298.334	11.178	43.512	26.689	<2e−16	***
(spillover3)	verb type	19.367	6.531	36.949	2.965	0.00527	**
	QUD type	−1.071	5.827	1220.703	−0.184	0.85421	
	verb type:QUD type	4.692	11.661	1217.466	0.402	0.68746	
feels	(Intercept)	301.003	10.486	46.711	28.704	<2e−16	***
(spillover4)	verb type	8.645	5.235	1245.035	1.651	0.0989	.
	QUD type	2.214	5.229	1244.486	0.423	0.6721	
	verb type:QUD type	11.814	10.467	1244.615	1.129	0.2592	
very	(Intercept)	309.158	9.592	46.771	32.230	<2e−16	***
(spillover5)	verb type	13.956	4.868	1250.567	2.867	0.00422	**
	QUD type	3.965	4.865	1250.055	0.815	0.41528	
	verb type:QUD type	−3.117	9.736	1250.123	−0.320	0.74891	

or may not undergo a change-of-state. Experiment 2 goes beyond Experiment 1 in two main ways. First, it tests the Semantic Entailment Hypothesis more directly, by comparing result verbs and manner verbs. Second, it takes a closer look at the Discourse-based Inference Hypothesis by investigating finer grained differences between aboutness QUDs and change-of-state oriented QUDs.

According to the Semantic Entailment Hypothesis, verbs' lexical semantics constrain comprehenders' construction of event representations: This hypothesis predicts that because manner verbs do not entail a change-of-state, comprehenders do not include a change-of-state notion in their event representations in the manner verb conditions (regardless of QUD type), and because result verbs *do* entail a change-of-state, comprehenders construct event representations involving change-of-state in the result verb conditions (again, regardless of QUD type).

In contrast, the Discourse-based Inference Hypothesis predicts that even with manner verb sentences, comprehenders can be driven by the QUD to consider a change-of-state of the object. An interaction between verb type and QUD type on the RTs at the critical result state adjective would support the Discourse-based Inference Hypothesis.

Indeed, our results support the Discourse-based Inference Hypothesis: In conditions with change-of-state oriented QUDs, participants read the target word equally quickly in the manner verb and the result verb conditions. This suggests that, even if the verb does not semantically entail a change-of-state, the presence of a change-of-state oriented QUD makes participants more likely to construct a representation where the object undergoes a change-of-state.

In other words, when the QUD indicates that the inquiry is about the (changed) result state of the object, the event representation can be enriched to include a notion of a changed state, even though this not included in the lexical semantics of manner verbs (e.g. *hit*). This inferred information can in turn facilitate processing of linguistic material that is dependent on the inferential process, to an extent comparable to how information from verb entailments facilitates processing of linguistic material associated with the entailed meaning.

General discussion

What kinds of information guide how comprehenders construct mental representation of linguistically-described events? It is unquestionable that the lexical

semantics of verbs plays a crucial role, as lexical semantics provides the basic skeletons of an event representation, including information about the changes entailed by the action described by the verb. Does verb meaning, then, strictly constrain the event representations available to comprehenders, or can other sources of information also contribute? In this work, we investigated three hypotheses: (i) the Semantic Entailment Hypothesis, which states that comprehenders only consider event representations supported by a verb's semantic entailments, (ii) the Tense-based Inference Hypothesis and (iii) the Discourse-based Inference Hypothesis, which state that verb-based information and discourse-level information, respectively, can modulate the event representations constructed by comprehenders.

As a test case, we examined how comprehenders represent object states when events are described with manner verbs, which do not entail change-of-state of the object, compared to result verbs, which do entail a change-of-state. We report two experiments investigating how comprehenders process linguistic material related to change-of-state when provided with event descriptions with manner and result verbs. Experiment 1 focused specifically on manner verbs, and used a lexical decision task to test the Semantic Entailment Hypothesis, the Tense-based Inference Hypothesis, and the Discourse-based Inference Hypothesis. The results support the Tense-based and the Discourse-based Inference hypotheses over the Semantic Entailment Hypothesis, because we found that tense and discourse context interacted to mediate the availability of the change-of-state inference, even when the event description used manner verbs. In Experiment 2, we directly compared manner verbs and result verbs and manipulated discourse context in more specific ways to further test the Semantic Entailment Hypothesis and the Discourse-based Inference Hypothesis. Results provide evidence for the Discourse-based Inference Hypothesis and against the Semantic Entailment Hypothesis: We found that a change-of-state oriented context can make the change-of-state representation equally available with manner verbs and result verbs.

Taken together, results from both experiments suggest that comprehenders use information beyond verb semantics to draw inferences concerning the representation of the object. This provides important insights into the mechanisms underlying the online representation of events during language processing. Language is limited to being able to describe only so much of an event, and we can plausibly think that there are numerous details about events that are not captured in linguistic descriptions. Our results suggest that in deciding at what level of detail and granularity the event component should be represented, and in deciding *how* to represent the unsaid part(s), comprehenders draw from multiple available sources. They are also strategic in choosing how to mentally represent the event being described, especially when the description is underspecified: Our results are compatible with a view where comprehenders prioritise their limited attentional resources toward representing only the event components that are relevant to answering the current communicative goals of the discourse, which we operationalised in terms of the Question-Under-Discussion (QUD) approach (e.g. Roberts, 1996/2012). Under this view, discourse is structured around questions under discussion which represent the interlocutors' joint discourse goals, i.e. the aims/goals of the current communicative exchange.

This study adds support to the growing body of evidence showing that the notion of Questions-under-discussion – or something resembling it – plays an important role in the interpretive processes related to interpreting ambiguous, underspecified, or context-sensitive aspects of language. Our findings are broadly in line with the General QUD Processing Principle (Clifton & Frazier, 2018), which states that utterance interpretation is guided by QUDs. We conclude that event representations, such as how the comprehender keeps track of the dynamic changes that occur during events, are QUD-sensitive as well.

Although the methods of the two studies may seem different at first glance – Experiment 1 used a lexical decision task and Experiment 2 used a self-paced reading task – it is worth noting that these are both reaction-time tasks and in both experiments, the critical word was a past participle or adjective that provided information about the object state (e.g. *popped, damaged*). Indeed, our results suggest that information about object state representations can be probed both at the offset of the critical sentence (with a 1000 ms delay, as in Experiment 1) and in a word embedded in the subsequent sentence (Experiment 2). In light of earlier work in other domains (e.g. Swinney, 1979) on lexical ambiguity, future studies could use cross-modal lexical decision to test different timepoints, in order to gain insights into the time-course of activation of object state representations.

In conclusion, the experiments reported in this paper provide initial evidence that discourse-level information exerts an influence on the mental representation of object states during event comprehension. Prior work on object state representations in language comprehension had largely focused on morphosyntactically-

encoded semantic information such as grammatical tense (e.g. Altmann & Kamide, 2007; Kang et al., 2020) and grammatical aspect (e.g. Misersky et al., 2019). Object-specific semantic properties are also known to play a role on the object state representations that comprehenders construct (e.g. Hindy et al., 2012, Horchak & Garrido, 2020), in line with what one might expect based on situation models (e.g. Zwaan & Radvansky, 1998). We believe that our findings open up a fruitful area of research on the role of *discourse-level information* in event representations and indicate that discourse-level factors need to be incorporated into models of event processing.

Notes

1. While this exclusion rate may seem high, it is not unusual for MTurk studies (see e.g. Chmielewski & Kucker, 2020, who observed 38–62% of MTurk participants failing at least one data quality validity indicator in summer/fall 2018 and spring 2019). In light of concerns about MTurk data quality, we used a variety of data validity indicators/quality checks to exclude participants, in line with the advice of Chmielewski and Kucker (2020).
2. Whether these words are called past participles or adjectives is irrelevant for present purposes. What is relevant is that they can describe a possible result state of the object. 22 of the 24 target words are homographic and homophonic on their simple past tense use (*X popped Y*) and past participial use (e.g. *Y is/has been popped*). Two have a one-letter difference (*tore/torn, broke/broken*); we used the past participial form (*torn/broken*) as this allows subject-related (e.g. *Arthur has torn …*) and object-related readings (e.g. *X is torn*). We report the results for all 24 words; excluding these two items yields the same numerical data pattern.
3. As a reviewer points out, Experiment 1 does not compare manner verbs to result verbs. This was a deliberate choice on our part, given that Experiment 1 focuses on how event representations constructed on the basis of *manner verb* event descriptions – which are *linguistically underspecified* for change-of-state – are influenced by verb tense and discourse-level cues. If one were to run another version of this experiment with *result verbs*, one might expect that the salience of change-of-state representations might still be at least somewhat modulated by tense and by attention to the subject vs. object for result-verb event descriptions. However, this interaction may be difficult to detect, because a high degree of semantic overlap/association between result verbs and the lexical decision target words may result in a floor effect across the board. Crucially, we chose to test manner verbs, because our aim in Experiment 1 was to test effects of tense and discourse cues on change-of-state representations in a context where verb semantics does not entail a change-of-state.

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No potential conflict of interest was reported by the author(s).

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