



Retrieval interference and semantic interpretation

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ABSTRACT

Similarity-based interference has played an important role in motivating cue-based models of memory retrieval during language comprehension. One example of interference comes from *illusions of grammaticality*, where ungrammatical sentences are perceived as grammatical (e.g. ‘the key to the cabinets were rusty’). While such effects indicate interference influences perception of sentence grammaticality, less is known about how interference influences the semantic interpretation assigned to a sentence. We report two reading experiments that manipulated sentence plausibility, rather than grammaticality, as a diagnostic of interference. In both experiments, although reading times were longer for implausible sentences, this plausibility effect was reliably attenuated when a distractor item partially matched the cues at retrieval. We interpret these results as being compatible with the predictions of cue-based parsing. The *illusions of plausibility* that we report indicate that similarity-based retrieval interference has a potent influence on the semantic interpretation that is assigned to a sentence during processing.

Introduction

Similarity-based retrieval interference has played an important role in models of short term memory (Jonides et al., 2008). Research on the comprehension of linguistic dependencies also indicates that similarity-based interference is a determinant of memory retrieval during language comprehension (Lewis, Vasishth, & Van Dyke, 2006; Van Dyke & Johns, 2012). According to cue-based models of parsing (e.g. Lewis & Vasishth, 2005; Lewis et al., 2006; McElree, 2000; Van Dyke, 2007), interference arises as a result of the match between the set of cues utilised at retrieval and the number of items in memory that match these cues. One piece of evidence for retrieval interference during language comprehension comes from so-called *illusions of grammaticality*, where ungrammatical sentences are perceived as grammatical (Phillips, Wagers, & Lau, 2011). Although such illusions suggest interference can influence perception of sentence grammaticality, it is less clear how this type of interference may influence the semantic interpretation that is assigned to a sentence as it unfolds.

The aim of this study was to investigate how retrieval interference influences semantic interpretation during sentence processing. To this aim, we manipulated sentence plausibility, rather than grammaticality, to investigate memory retrieval during language comprehension. Thus, while previous studies have examined illusions of grammaticality as evidence of retrieval interference, we probed for *illusions of plausibility* in fully grammatical, but implausible, sentences. We begin below by

discussing cue-based parsing and illusions of grammaticality in more detail, before outlining previous research that has utilised plausibility effects to investigate the time-course of sentence processing.

Interference effects in language comprehension

Successful language comprehension relies on the ability to form dependencies between non-adjacent constituents. For example, in (1a), there is a dependency between the verb ‘read’ and the non-adjacent constituent ‘the book’, which is interpreted as the verb’s direct object even though it appears some words distant from the verb in the sentence. This type of dependency is typically called a *filler-gap* or *unbounded* dependency (Traxler & Pickering, 1996), as a displaced *filler* (‘the book’) needs to be associated with a corresponding *gap* (adjacent to ‘read’) at a later point in the sentence.

- (1a) John saw the book that the boy very happily read while on holiday.
(1b) John saw the book that the boy with the magazine very happily read while on holiday.

According to cue-based parsing (Lewis & Vasishth, 2005; Lewis et al., 2006; McElree, 2000; McElree, Foraker, & Dyer, 2003), dependency resolution in sentences like (1) involves retrieving a representation of the filler from memory at the verb. This retrieval operation is hypothesised to be guided by a set of cues that are matched against all

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items in memory in parallel. Cues can be derived from the local syntactic context, and other inherent properties of sentence constituents. For example, the verb ‘read’ may cue retrieval of an item marked as [+DIRECT OBJECT], a feature that can be derived from the local syntactic context. Cues can also potentially be derived from other sources, such as the lexical properties of nouns and verbs (Van Dyke, 2007; Van Dyke & McElree, 2006). For example, the verb ‘read’ may cue retrieval of items marked as being [+READABLE]. In (1a), this combination of syntactic and lexical cues will uniquely identify the intended *retrieval target* ‘the book’. In (1b) however, a *distractor* constituent partially matches the cues to retrieval, as ‘the magazine’ is a plausible but ungrammatical direct object of ‘read’. As retrieval involves matching cues against all items in memory in parallel, the possibility of similarity-based interference arises when multiple items in memory partially match a set of retrieval cues. In this case, distractor constituents, such as ‘the magazine’ in (2b), may sometimes be retrieved.

One example of interference during language processing comes from subject-verb agreement, as in (2), from Wagers, Lau, and Phillips (2009).

- (2a) The key to the cell unsurprisingly was rusty from many years of disuse.
- (2b) The key to the cells unsurprisingly was rusty from many years of disuse.
- (2c) The key to the cells unsurprisingly were rusty from many years of disuse.
- (2d) The key to the cell unsurprisingly were rusty from many years of disuse.

In (2), the verb (‘was/were’) cues retrieval of the sentence subject (‘the key’), which is the head of the phrase ‘the key to the cell/s’. In (2a,b) this retrieval target matches the number properties of the verb, while (2c,d) is ungrammatical as the plural form of the verb mismatches the number properties of the singular subject. The ungrammaticality in (2c,d) leads to longer reading times compared to (2a,b). The size of this grammaticality effect is attenuated in (2c), when the distractor (‘the cells’) matches the number of the verb. Cue-based parsing explains this *illusion of grammaticality* as resulting from a partial-match between the cues at retrieval and the items held in memory. In (2c), no item *fully* matches the verb’s retrieval cues (e.g. [+HEAD], [+PLURAL]), as the intended target is [+HEAD] but [-PLURAL], while the distractor is [+PLURAL] but [-HEAD]. On some proportion of trials, the partially-matching distractor may become activated to the extent that it is retrieved, which in turn will lead to an attenuation of the grammaticality effect and an illusion of grammaticality. Following Jäger, Engelmann, and Vasishth (2017) we will refer to this pattern of results as *facilitatory interference*, as reading times for ungrammatical sentences are attenuated in the presence of a partially-matching distractor. Interference in such cases is typically restricted to ungrammatical sentences, where no item in memory fully matches the retrieval cues (Dillon, Mishler, Sloggett, & Phillips, 2013; Lago, Shalom, Sigman, Lau & Phillips, 2015; Wagers et al., 2009). In addition to subject-verb agreement, facilitatory interference has also been reported for other linguistic dependencies (e.g. Parker & Phillips, 2016, 2017; Vasishth, Brüssow, Lewis, & Drenhaus, 2008; Xiang, Dillon, & Phillips, 2009; for review, see Jäger et al., 2017). To our knowledge however, facilitatory interference has not yet been observed in filler-gap dependencies.

Another type of interference has been reported in grammatical sentences. Van Dyke (2007) examined sentences such as (3), where successful comprehension requires retrieval of the sentence subject (‘the worker’) at ‘was complaining’. However, a linearly closer distractor (‘the warehouse’/‘the neighbour’), which is an ungrammatical subject for this verb, intervenes. Van Dyke observed longer reading times after the critical verb when the distractor was a plausible (‘the neighbour’) compared to implausible (‘the warehouse’) subject for this verb, which was interpreted as indexing reanalysis following an initial

misretrieval of plausible distractors on some proportion of trials. Following Jäger et al. (2017), we refer to this as *inhibitory interference*, as reading times are longer in grammatical sentences when a distractor partially matches the cues to retrieval.

- (3) The worker was surprised that the resident who said that the warehouse/neighbour was dangerous was complaining about the investigation.

Similar results were reported by Van Dyke and McElree (2011) and by Glaser, Martin, Van Dyke, Hamilton, and Tan (2013) using fMRI. Although inhibitory interference for some linguistic dependencies is thus well attested, for some other dependencies inhibitory interference has not been consistently reported. For example, in subject-verb agreement, inhibitory interference might be expected in grammatical sentences, such that (2a), where both the retrieval target and distractor match the number properties of the verb, should have longer reading times compared to (2b), when only the retrieval target matches the verb’s number. However, a number of studies have not reported such effects (Dillon et al., 2013; Lago et al., 2015; Wagers et al., 2009). Similarly in anaphora resolution, although one earlier study reported inhibitory interference in the resolution of reflexives and object pronouns (Badecker & Straub, 2002), subsequent studies have not consistently replicated this finding (Chow, Lewis, & Phillips, 2014; Cummings & Sturt, 2014; Dillon et al., 2013; Patterson, Trompelt, & Felsler, 2014; Sturt, 2003). This may indicate that inhibitory interference effects are small and may be difficult to observe under certain conditions (for review, see Jäger et al., 2017). Indeed, in a recent study, Nicenboim, Vasishth, Engelmann, and Suckow (2018) estimated inhibitory interference in subject-verb agreement to have a magnitude of 9 ms, based on an analysis of 184 participants. As Nicenboim et al. argue, inhibitory effects may thus sometimes be numerically small and difficult to detect without adequate statistical power.

Although facilitatory and inhibitory interference effects have been taken as evidence for cue-based parsing, different implementations of cue-based retrieval account for such effects in different ways (for discussion, see Nicenboim & Vasishth, 2018). In the Lewis and Vasishth (2005) activation-based implementation, retrieval is a race process in which the item that receives the most activation is subsequently retrieved. As such, the more active an item is, the faster it is retrieved. In this model, inhibitory interference in grammatical sentences indexes longer retrieval times as a result of activation spreading to distractor constituents, while facilitatory interference is explained in terms of the distractor being retrieved quicker than the retrieval target some proportion of the time, when the target doesn’t fully match the cues to retrieval. In McElree’s (2000) direct access account of cue-based parsing however, retrieval speed is constant but the probability of retrieving the target representation is dependent on how well the cues match it and other distractors. In this way, differences in reading times relate to the probability of retrieving either the target or distractor constituent, rather than the speed of retrieval. Our study was not designed to tease apart these different accounts of similarity-based interference effects, and as such we do not discuss these two different implementations of cue-based parsing in detail. Instead, our focus is on how interference influences the semantic interpretation that is assigned to a sentence.

While illusions of grammaticality indicate that similarity-based interference can influence perception of sentence grammaticality, less is known about how such effects influence semantic interpretation. For example, in (2c), it is not known if readers misinterpret ‘the cells’ to be the subject of the predicate ‘were rusty’ rather than the grammatical sentence subject (‘the key’). Some studies have utilised offline comprehension question measures as an index of how interference may influence the interpretation assigned to a sentence. Using forced-choice comprehension questions following word-by-word sentence reading, Patson and Husband (2016) found that readers sometimes misinterpret the number properties of nouns used in sentences like (2c), incorrectly answering ‘yes’ to questions such as ‘Was there more than one key?’.

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