Processing appositive relative clauses: Effects of information structure and sentence structure

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ABSTRACT

In a self-paced reading experiment, we investigate the processing of complex sentences containing a matrix clause and a subordinate clause, specifically, an appositive relative clause (ARC), which has been posited to have distinct information structural properties. We test the predictions made by three long-standing ordering principles: the *given-new* principle (given before new information ordering facilitates processing), the *clause structure* principle (matrix clause before subordinate clause ordering facilitates processing) and the *clause-type mapping of information* principle (given information in subordinate clause and new information in matrix clause facilitates processing). Our results show that predictions made by the *given-new* principle and the *clause structure* principle hold for sentences with an ARC. We do not find evidence for the *clause-type mapping of information* principle. Instead, our findings suggest that the matrix clause in sentences with an ARC has a function usually associated with subordinate clauses, namely *grounding*, whereby its content serves as the thematic ground that supports understanding of what follows in the next clause. We suggest this is due to the matrix clause-like nature of ARCs with respect to both their syntactic structure and their expected information status.

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1. Introduction

In producing utterances, speakers are faced with choices about how to package the information they want to convey. Some of those choices take place clause-internally – e.g., in decisions regarding the use of different syntactic constructions to arrange constituents into preferred orderings. These orderings in turn can ease or impede processing for comprehenders. Clause internally, given-before-new orderings for instance facilitate processing and comprehension (Brown, Savova, & Gibson, 2012; Haviland & Clark, 1974) such that given information that picks up on familiar content preferentially appears before information that the speaker is introducing for the first time. In more complex sentences, the clauses themselves are subject to ordering constraints, with speakers making further decisions about how to package content into matrix and subordinate clauses and how to order those clauses in relation to each other.

Existing work points to principles that guide these decisions and in turn facilitate or disrupt comprehension. These principles sometimes converge and together favor a particular packaging of information in a complex sentence, but more interestingly they can also compete. To illustrate, compare the passages in (1), (2) and (3). In each passage, content is introduced in one sentence and then re-mentioned in a subsequent complex sentence that also introduces new content (given content underlined, new content in bold):

(1) Linda submitted a paper, two job applications, and wrote a conference abstract. She did so while **she was juggling a household and a part-time job**.

(2) Linda submitted a paper, two job applications, and wrote a conference abstract. **She was juggling a household and a part-time job** while she did so.

(3) Linda submitted a paper, two job applications, and wrote a conference abstract. While she did so, **she was juggling a household and a part-time job**.

In the complex sentence in (1), the given information precedes the new information (*given-new* principle, Chafe, 1976; Clark & Haviland, 1977; Gundel, 1988; Halliday, 1967a, 1967b; Haviland & Clark, 1974; Prince, 1981) and the matrix clause precedes the subordinate clause (*clause structure* principle, Diessel, 2005, 2008; Fodor, Bever, & Garrett, 1974; Gibson, 1998; Holmes, 1973). In (2), the matrix clause also precedes the subordinate clause (*clause structure* principle), but it is the new information that comes first, this time with the given information packaged in a subordinate clause and the new information appearing in a matrix clause (*clause-type mapping of information* principle, de Ruiter, Lieven, Brandt, & Theakston, 2020; Diessel, 2005; Gorrell, Crain, & Fodor, 1989. In (3), given information is packaged in a subordinate clause and the new information in a matrix clause (*clause-type mapping of information* principle), given information precedes new information (*given-new* principle), but here the subordinate precedes the matrix clause.

There are obviously more combinations than shown in (1-3) and none are ruled in or out by the grammar alone. The intuition is that clause position, type, and content are all candidate factors for determining the ease with which comprehenders process complex sentences. The question is *which* variations are most likely to facilitate processing (when they align with predictions made by one or more principles), or to hinder processing (when they do not align with predictions made by one or more principles). In each of the above examples, two of the mentioned principles predict faster processing, while one principle predicts the opposite. If the complex sentence in both (2) and (3) is processed faster than the complex sentence in (1), for example, this would be evidence that predictions made by the *clause-type mapping of information* principle have greater repercussions for processing than predictions made by the other two principles. If, however, the complex sentence in (1) is processed faster than that in both (2) and (3), this would be evidence that the specific combination of given-new ordering and matrix-subordinate ordering facilitates processing more so than the other possible combinations.[1]

This paper presents a reading-time study testing the principles that have been

[1]It is not possible for predictions made by all three principles to overlap simultaneously. If for example, given-new ordering and matrix-subordinate are present in a sentence (as in 1), this necessarily means that given information is hosted by the matrix clause and new information by the subordinate clause. If this 'mapping' of information were to be reversed, this would lead to given-new ordering no longer being adhered to (as in 2)

proposed for governing the packaging and structuring of information. We test whether predictions made by the principles under investigation generalise to a distinctive type of subordinate clause: the appositive relative clause (ARC). ARCs are a type of subordinate clauses that provide additional information about a noun phrase and are typically introduced by a relative pronoun such as "who", "which", or "that". For example, more information about the entity *Linda* in (1) can be included in the form of an ARC (underlined in 4):

(4) Linda, who is my next-door neighbour, submitted a paper, two job applications, and wrote a conference abstract. She did so while she was juggling a household and a part-time job.

ARCs have been argued to share a number of properties with matrix clauses. These properties include clause-internal syntactic properties: ARCs can exhibit root phenomena, i.e., syntactic patterns that are usually constrained to main/matrix clause environments such as verb phrase preposing, negative constituent preposing and topicalization (de Vries, 2012; Emonds, 1970; Green, 1976; Heycock, 2017; Hooper & Thompson, 1973). In addition, ARCs are able to express a speech act that is illocutionarily independent from the speech act expressed by the matrix clause (Frazier, Dillon, & Clifton, 2018; Jasinskaja & Poschmann, 2018; Koev, 2013; Syrett & Koev, 2015), a feature of ARCs that has been posited to influence processing (Dillon, Clifton, & Frazier, 2014; Dillon, Clifton, Sloggett, & Frazier, 2017). Lastly, ARCs generally contribute new information to discourse (Loock, 2007, 2010), which could also influence the way comprehenders respond to complex sentences that contain ARCs. Given the special status of ARCs, previous findings with respect to ordering principles may not be generalisable to sentences containing an ARC.

In addition, our methodology presents participants with items that consist of short discourses in which information status (given/new) can be manipulated directly. We present participants with target sentences preceded by a discourse context that provides the antecedents for subsequent given content. This approach with a larger discourse context differs from previous work in which the given/new status of sentential elements was determined only by surface cues (e.g. definiteness; see Clifton and Frazier (2004)).

The following sections will provide an overview of the three principles under investigation and discuss how the current state of the art for each principle still leaves open a set of questions we intend to address with the present study.

1.1. Given-new principle

The *given-new* principle posits that sentences are easier to process and comprehend when given information precedes new information (Clark & Haviland, 1977; Haviland & Clark, 1974; Prince, 1981). When given information appears in the beginning of a sentence, it provides the comprehender with an established foundation on which they can then build new content as it is added later in the sentence (Dahí, 1976). Ease of comprehension then depends on how easy it is to locate the antecedent for given information in memory, and how easy it is to integrate subsequent new information with the given information (Haviland & Clark, 1974). The *given-new* principle has been well attested through different methodological approaches. For example, sentence recall tasks (Bock, 1977), acceptability judgment tasks (Clifton & Frazier, 2004), production experiments (Arnold, Losongco, Wasow, & Ginstrom, 2000; V. S. Ferreira & Yoshita, 2003) and processing experiments (Brown et al., 2012; de Ruiter et al., 2020; Scholman, Blything, Cain, Hoek, & Evers-Vermeul, 2022) all show evidence of the given-new principle.

That said, the vast majority of experimental evidence has relied on the distinction between given and new information as features encoded morphosyntactically. All of the previously mentioned experimental evidence (with the exception of de Ruiter et al., 2020 and Scholman et al., 2022) treat givenness as a feature of definiteness, and newness a feature of indefiniteness. In the acceptability judgment task from Clifton and Frazier (2004), for example, a sentence like *The pitcher threw the umpire a ball* (definite signalling given, indefinite signalling new, given-before-new order) was judged by participants to be more acceptable than a sentence like *The pitcher threw an umpire the ball* (indefinite signalling new, definite signalling given, new-before-given order). Prince (1992) however, describes numerous ways in which givenness and newness can be achieved, some of which are directly related to the syntactic nature of constituents (like (in)definiteness), while others depend on the pragmatic context. Moreover, prior

research has typically investigated effects of information status using lists of single, unrelated sentences or sentence pairs without additional discourse context. F. Ferreira and Lowder (2016) argue that both of these issues – narrow manipulation of givenness and item sets consisting of unrelated sentences that lack rich discourse context – should be addressed in future research, which is precisely what we aim to do here.

Sentences with ARCs have been investigated in the past to test which information orders are preferred. In one study, ARCs were compared with another type of subordinate clause, the restrictive relative clause (Gibson, Desmet, Grodner, Watson, & Ko, 2005, Experiment 2). An assumption was made that ARCs generally contribute new rather than old information to a discourse, whereas restrictive relative clauses were assumed to contribute given information. The context preceding the target sentences was manipulated accordingly, so that the ARCs contained new information, but the restrictive relative clauses did not. In line with the *given-new* principle, Gibson et al. (2005) hypothesized that restrictive relative clauses, contributing given information, would be read faster in sentence-early position and ARCs, contributing new information, would be read faster in sentence-final position. They compared reading times between restrictive relative clauses and ARCs in both sentence-final position where they modify the matrix clause object and in sentence-early position where they modify the matrix clause subject. In line with their predictions, the restrictive relative clauses were read faster in sentence-early position than in sentence-final position. However, no effects were found for the ARCs. Gibson et al. (2005) suggest that a possible explanation for this null result can be found in the design of their items: while the content of the restrictive relative clauses was always fully given information, the ARCs contained a mixture of given and new information. This could have led to a tradeoff where the given content facilitated faster reading times for the sentence-early ARCs, and the new content facilitated faster reading times for the sentence-final ARCs. One goal of the current study is therefore to replicate Gibson et al. (2005)'s study with a more explicit manipulation of the information status of ARCs by contrasting ARCs that contain only given information with ARCs that also contain new information.

1.2. Clause structure principle

The *clause structure* principle (also known as the *frame structure* principle, Diessel, 2005, 2008; Fodor et al., 1974; Gibson, 1998; Holmes, 1973) posits that sentences with a subordinate clause are easier to process when the matrix clause comes before the subordinate clause (5a) than when clauses are in the opposite order (5b):

(5) a. My aunt was gossiping with my mom, who was drinking gin & tonic.

b. My aunt, who was drinking gin & tonic, was gossiping with my mom.

In the case of (5a), the arguments of the matrix clause are all adjacent, whereas in (5b), the subordinate clause interrupts the matrix clause, and the matrix clause subject head noun needs to be held in memory until the matrix clause can be completed, leading to greater processing difficulty. The *clause structure* principle is supported by evidence from sentence recall and sentence comprehension studies (Fodor et al., 1974; Holmes, 1973) as well as processing experiments (Gibson, 1998; Gibson et al., 2005). Additionally, evidence from corpus studies shows that this ordering of clauses in a sentence is also the more frequent one (Diessel, 2005, 2008).

While there are processing studies that have investigated the *clause structure* principle at the full sentence level (de Ruiter et al., 2020; Scholman et al., 2022), these have not considered sentences with an ARC. Moreover, those studies that specifically investigate sentences with a relative clause more commonly focus on the relative clause (ARC and/or restrictive relative clause) in isolation and on how its processing is influenced by its sentential position (Gibson, 1998; Gibson et al., 2005; Santi, Grillo, Molimpakis, & Wagner, 2019). Moreover, prior studies report different findings depending on the type of relative clause they investigate. For restrictive relative clauses, appearing in sentence-final position was found to be harder to process than appearing in a sentence-early position (Gibson et al., 2005; Santi et al., 2019), but for ARCs, results were inconclusive (Gibson et al., 2005). This leaves open the question of whether these results would be different if the relative clauses were considered together with the matrix clause, as processing ease or difficulty might not be attributable to just the ARC in isolation in these sentences. If processing differences here are only visible when considering the full sentence, it would explain why Gibson et al. (2005) did not find

any effects when only considering processing of the ARC.

1.3. Clause-type mapping of information principle

The *clause-type mapping of information* principle posits that ease of processing is optimal when given information is hosted by a subordinate clause and new information by a matrix clause. This principle was first proposed by Gorrell et al. (1989), who found that children performed better at a comprehension task when given information appeared in a subordinate clause than when this same information appeared in a matrix clause. They found that children were more sensitive to this mapping of information (given-in-subordinate) than to the ordering of information (given-before-new). The ordering preference encapsulated in the *clause-type mapping of information* principle receives additional support from corpus data in that adverbial clauses more often host given information, especially in preposed position (Diessel, 2005). In line with this, a processing advantage is reported for sentences in which the given information is hosted in a preposed adverbial clause (de Ruiter et al., 2020; Scholman et al., 2022). However, neither de Ruiter et al. (2020) nor Scholman et al. (2022) found evidence for the *clause-type mapping of information* principle for subordinate adverbial clauses in a sentence-final position. Rather, it is hypothesised that when a subordinate clause is in sentence-final position, it serves to add new information to the assertion made in the matrix clause, whereas when it is in preposed position and contains given information, it has a grounding function: It provides the context which supports understanding of what follows in the subsequent clause, and this function is assumed to facilitate processing (Chafe, 1984; Scholman et al., 2022; Thompson, 1985).

If it is the case that the preferential mapping of given information to a subordinate clause only holds when the subordinate clause is in a preposed position, ARCs pose a problem, as they can never be preposed in English (*# Who was drinking rum and coke, my aunt was gossiping with my mom*). In sentences with an ARC, either the subject of the matrix clause or the full matrix clause precedes the ARC and provides the antecedent necessary to be able to interpret the relative pronoun in the ARC. In fact, the ARC could be omitted entirely and the matrix clause would still be conceptually complete. This dependence of the ARC on the matrix clause for an antecedent that

enables the interpretation of the ARC is independent of sentential position, as an ARC can never fully precede their subordinating matrix clause. As such, the matrix clause could be argued to have a grounding function in both sentence-early and sentence-final position in sentences with an ARC, whereby the matrix clause provides the context which is necessary to support understanding of the ARC. Restrictive relative clauses, in contrast, are necessary to identify a referent in the matrix clause and their omission would impact how the matrix clause referent is interpreted (Verhagen, 2001, p. 340).

We propose the *reverse mapping* hypothesis to capture this prediction, whereby matrix clauses in sentences with an ARC are expected to be more likely hosts for given information in both sentence-early and sentence-final position, and ARCs for new information. This hypothesis is additionally supported by corpus studies that have shown that ARCs nearly always host new information (Loock, 2007, 2010). If it is not the subordinate clause that has the grounding function in sentences with an ARC, but the matrix clause, it could mean that ARCs are actually easier to process when they contain new information, in contrast to a preference for given information in other types of subordinate clauses. This role for the matrix clause potentially suggests that we should predict matrix(given)-ARC(new) to be the easiest configuration in our study, but that would run contrary to the *clause structure* principle. Gibson et al. (2005) also assumed that ARCs are more likely hosts for new information and that they should therefore be expected to be processed more easily later in a sentence, in line with the *given-new* principle. They did not find evidence for such an effect, but this might have been due to their design, which compared ARCs that contained a mix of given and new information in both conditions.

2. Reading time experiment

In this experiment we investigate these three principles – the *given-new*, *clause structure* and *reverse mapping* – in two-clause constructions that consist of an ARC and a matrix clause. Our experiment uses self-paced reading (SPR, Just, Carpenter, & Woolley, 1982) to measure comprehenders' processing of sentences consisting of an ARC and a matrix clause in passages in which the preceding context establishes the information

status of particular content. The goal is to see whether processing times are influenced by the order of information, the order of the clauses, and the mapping between clause type and information status. We manipulate two factors in our items: information order (given-new vs new-given) and clause order (matrix-ARC vs ARC-matrix). The mapping between clause type and information status follows automatically from these manipulations.

We manipulate givenness by means of two main strategies: 'single occurrence of habitual' and 'probable consequence'. In the case of 'single occurrence of habitual', a habitual event is described in the context (*she often drops by to make sure everything is OK*, underlined in (6)), which is the antecedent for the single occurrence of this habitual event mentioned in the target sentence (*...went to check on my grandma*, in italics in (6)) where it is then assumed given information:

(6) **SINGLE OCCURRENCE OF HABITUAL**

My grandma is having some trouble lately getting up and down the stairs. My mom is very worried that one day she might fall and break something, so she often drops by to make sure everything is OK. Today,
my mom *went to check on my grandma*, who had been to water aerobics earlier.

In the case of 'probable consequence', a state or characteristic of a person is described in the context (*My niece loves to get everything in pink* and *pretty much all her clothes are pink*, underlined in (7)), which is the antecedent of a subsequent event in the target sentence (*...was wearing pink leggings*, in italics in (7)) that is a likely consequence of the described state/characteristic. This 'probably consequence' is then assumed given information:

(7) **PROBABLE CONSEQUENCE**

My niece loves to get everything in pink. Most of the furniture she has in her bedroom is pink, pretty much all her clothes are pink, and sometimes, her mom even lets her dye her hair pink. Yesterday,
my niece, who *was wearing pink leggings*, drew a picture of her mom.

In addition, we use synonyms (e.g.: *(went) to check on* for *(drops by) to make sure everything is OK* in (6)) and hyponyms (e.g.: *pink leggings* for *pink clothes*) to avoid

possible processing costs incurred as a result of literal repetitions of NPs (Repeated Name Penalty, Gordon, Grosz, & Gilliom, 1993). Synonyms and hyponyms were verified through Open English Wordnet (`https://en-word.net/`).

Four native speakers of English judged all items in all conditions on whether they perceived the information in the ARCs and matrix clauses as given information – based on whether it could be classified as 'single occurrence of habitual' or 'probable consequence' – or new information. Their judgments overlapped with our intuitions on average 92.6% of the time (between 87.5–95.3% across judges). For one item, and more specifically, one condition in this item, all judges agreed that the information status deviated from our intuitions. Excluding this item from the analyses, however, did not lead to different results, so we decided to not exclude it in the analyses reported below. A detailed item-by-item overview of our manipulation of givenness as well as the native speaker judgments are available here: `https://osf.io/3tjwv/`.

The study design uses four conditions which allow us to probe the three principles under investigation. Consider below an example with the target region in italics. In this example, the order of information is GIVEN-NEW, the order of clauses is MATRIX-ARC, and the given information (underlined) appears in the matrix clause:

(8) **GIVEN(MATRIX)-NEW(ARC)**

My aunt loves to be part of the rumor mill, and just like my mom, takes any opportunity to engage in the latest stories. Because of this, I always pay close attention to what I'm saying around her. At my birthday party,
my aunt <u>was gossiping with my mom</u>, who was drinking gin & tonic.
As I walked by, I heard they were talking about me. My mom got startled and spilled her drink all over my aunt.

We make the assumption that the information in the matrix clause receives given status by having been made part of the common ground in the context preceding the target region, where the reader of the narrative is made aware of the speaker's aunt's inclination to gossip. Upon encountering the target region and reading that the speaker's aunt is indeed gossiping, the gossiping is new with respect to the situation in which it is happening but given with respect to the reader's general knowledge

concerning what they know about the speaker's aunt. In other words, *My aunt loves to be part of the rumor mill* is an antecedent for the event in the matrix clause such that *my aunt was gossiping with my mom* is a 'probable consequence', and likewise ... *takes any opportunity to engage in the latest stories* is an antecedent for the event in the matrix clause, which is a 'single occurrence of (the) habitual event' mentioned in the context. The given status of the matrix clause content is especially clear when we contrast this information with the information provided in ARC: *who (my mom) was drinking gin & tonic*. With no antecedents for either drinking or gin & tonic in the narrative prior to reaching the target region, the content of the ARC is unpredictable and new.

When we change the order of clauses in the target region, this leads to the following condition:

(9) **NEW(ARC)-GIVEN(MATRIX)**

My aunt loves to be part of the rumor mill, and just like my mom, takes any opportunity to engage in the latest stories. Because of this, I always pay close attention to what I'm saying around her. At my birthday party,
my aunt, who was drinking gin & tonic, was gossiping with my mom.
As I walked by, I heard they were talking about me. My mom got startled and spilled her drink all over my aunt.

Here, the order of information is NEW-GIVEN, the order of clauses is ARC-MATRIX and the given information appears in the matrix clause.

When we keep the order of clauses in the target region the same as in (9), but adapt the context preceding the target region to make the ARC contain given information and the matrix clause new information, this leads to the following condition:

(10) **GIVEN(ARC)-NEW(MATRIX)**

My aunt, like my mom, is a big fan of drinking gin. She thinks she is really good at hiding it by adding some tonic to it. Everybody knows what is actually in her glass of course. A few weeks ago, at my birthday party,
my aunt, who was drinking gin & tonic, was gossiping with my mom.
As I walked by, I heard they were talking about me. My mom got startled and

spilled her drink all over my aunt.

In this condition, the reader of the narrative is made aware of the speaker's aunt's penchant for drinking gin & tonic – which reappears in the ARC content where it is a 'probable consequence'. The matrix clause predicate – *was gossiping* – in contrast, is now completely new information. The order of information is GIVEN-NEW, the order of clauses is ARC-MATRIX and the given information appears in the matrix clause.

Lastly, when we change the order of clauses in the target region and make *my mom* the participant of the narrative with the penchant for drinking gin & tonic (as it now reappears in the ARC, of which *my mom* is the subject rather than *my aunt*), this leads to the final condition:

(11) **NEW(MATRIX)-GIVEN(ARC)**

My mom, like my aunt, is a big fan of drinking gin. She thinks she is really good at hiding it by adding some tonic to it. Everybody knows what is actually in her glass of course. A few weeks ago, at my birthday party,
my aunt was gossiping with my mom, who was drinking gin & tonic.
As I walked by, I heard they were talking about me. My mom got startled and spilled her drink all over my aunt.

The order of information is NEW-GIVEN, the order of clauses is MATRIX-ARC and the given information appears in the ARC.

Our main interest is the processing time of both clauses in the target sentence combined because this full-sentence analysis will allow us to observe effects of information order, clause order and information mapping. Following the full-sentence analysis, we will also report reading time analyses for the clauses in isolation. In doing so we are able to more directly replicate the analysis from Gibson et al. (2005) – who analyzed reading times for just the ARCs – but with a more explicit manipulation of information status and conditions that have contrasting information status.

2.1. Predictions

Table 1 below shows the predictions made by each of the principles we investigate about which conditions will yield faster processing. As noted earlier, there is reason

to reconsider how the *clause-type mapping of information* principle applies to sentences with an ARC and consider instead an effect in the opposite direction (faster reading times when the ARC is the clause to host new information). We thus include one additional hypothesis here – the *reverse mapping* hypothesis – to account for an expectation that in sentences with an ARC, ease of processing will result from new information being hosted by the ARC and given information by the matrix clause. As shown in Table 1, each of the principles makes different predictions about which conditions will yield faster processing. The *given-new* principle favors the two conditions with given-before-new ordering. The *clause structure* principle favors the two conditions with matrix-before-ARC ordering. The *clause-type mapping of information* favors the two conditions in which the matrix clause contains new information (and the ARC given information), whereas the *reverse mapping* hypothesis favors the two conditions in which the matrix clause contains given information (and the ARC contains new information).

Table 1. Overview of all patterns related to our predictions exhibited by each condition. Patterns that are expected to facilitate faster processing receive a check mark for those conditions that exhibit these patterns.

pattern	*condition*			
	ARC$_{given}$ –matrix$_{new}$	matrix$_{given}$ –ARC$_{new}$	-ARC$_{new}$ –matrix$_{given}$	matrix$_{new}$ –ARC$_{given}$
given-before-new	✓	✓		
matrix-before-ARC		✓		✓
matrix new information	✓			✓
ARC new information		✓	✓	

Predictions we make at the sentence level can also be observed at the level of the individual clauses. The *given-new* principle predicts an interaction between the information status and position of either or both clauses such that an effect of faster reading times for given information would be stronger in sentence-early position than in sentence-final position, or that an effect of faster reading times for new information would be stronger in sentence-final position than in sentence-early position. The *clause structure* principle predicts faster reading times for the matrix clause when it is in sentence-early position, where all of its arguments are adjacent, than when it is in sentence-final position, where the subject has to be held in memory from sentence-

initial position until the matrix clause can be completed. We do not have expectations for ARCs individually following from this principle. For the *clause-type mapping of information* principle, we expect faster reading for ARCs when they contain given information and slower reading times when they contain new information, and we expect faster reading times for matrix clauses when they contains new information and slower reading times when they contain given information. Lastly, for the *reverse mapping* hypothesis we expect the effect of information mapping to go in the opposite direction: we expect faster reading times for ARCs when they contain new information, and faster reading times for matrix clauses when they contain given information.

2.2. Method

2.2.1. Participants

We recruited 234 participants through Amazon Mechanical Turk. We removed those whose accuracy on comprehension questions (see section 2.2.2) was not above chance (below 75% of questions answered correctly: n=34), and those who did not report having English as a first language (n=5), leaving 195 participants for analysis. All of these were self-reported native English speakers between the ages of 20–72 (mean=40) living in the United States. All participants had to have at least 500 previously approved tasks (called Human Intelligence Tasks, HITs, on MTurk) and a 95% or greater HIT approval rate. They provided informed consent and were compensated USD 10 for their participation, which corresponds to a rate of roughly USD 10/hr.

2.2.2. Materials

The study had 32 target items in four conditions and 32 fillers. The target items were short narratives that consisted of 4–6 sentences. The critical region, consisting of an ARC and a matrix clause, always appeared in the second half of the short narrative. The first half of the short narrative served to provide the predicate in either the ARC or the matrix clause in the target region with given information: this information will be predictable by having an antecedent in the preceding context. The predicate in the other clause always contained information that is both discourse-new and hearer-new.

We will refer to the two conditions resulting from the order of information as GIVEN-NEW (8 & 10) and NEW-GIVEN (9 & 11). The order of the ARC and the matrix clause also varied across conditions, resulting in the ARC-MATRIX (9 & 10) and MATRIX-ARC (8 & 11) conditions.

To provide a region for observing potential spillover (delayed) effects for reading times of the full sentence, the critical region was followed by an additional clause, of which the first 3–4 words functioned as the spillover region (*As I walked by* in (8-11)). If that clause contained only 3-4 words in total, the entire additional clause was the spillover region. While our main focus is on the combined reading times of the ARC and the matrix clause, in a secondary analysis we also consider the clauses as individual regions. In this setting it is not possible to measure any delayed effects as the region following the individual clauses cannot be held constant across conditions.

The items were distributed across 4 lists in a Latin Square design such that all participants saw half of the target items in the GIVEN-NEW condition and the other half in the NEW-GIVEN condition. These lists were then further subdivided such that all participants saw half of the items in both of these lists in the ARC-MATRIX condition and the other half in the MATRIX-ARC condition. The distribution of the target items and fillers and the order in which participants saw these was fully randomized.

The 32 fillers consisted of two different sets. The first set were 20 items from an unrelated experiment that used items of similar length and style. The second set contained 12 short stories that did not contain any sentences with an ARC. Both sets followed the same first-person perspective and topics as described below. A quarter of all items were accompanied by a comprehension question: eight of the target items and eight of the fillers. These comprehension questions were simple statements about content in the items that participants had to judge as either true or false. Half of these were true, and half of these were false statements. In the case of the target items, the statements were always about content that preceded or followed the critical region (ARC + matrix clause) and never the critical region itself. Thirty-four participants, whose performance was not significantly above chance (below 75% of questions answered correctly), were excluded from the analysis. After exclusion, average performance on these questions was 86% answered correctly.

All target and filler items were presented in a first person perspective. Altogether they constituted a series of anecdotes told by a single narrator about their personal life, friends and family. This was done to create a narrative that sounded as natural as possible with cohesion throughout (though none of the items specifically related to each other), rather than presenting participants with seemingly unrelated or isolated sentences, as it has been shown that this can add to processing difficulty (Roland, Mauner, O'Meara, & Yun, 2012). In addition, verbs that are known to contribute an implicit causality bias (Ferstl, Garnham, & Manouilidou, 2011) were not used in our target regions. This exclusion aimed to avoid any causal inference being made between the matrix clause and the ARC, as it has been shown that when a relative clause stands in a causal relation to a matrix clause this can impact reading times (Hoek, Rohde, Evers-Vermeul, & Sanders, 2021).

2.2.3. Procedure

The experiment was deployed on the IbexFarm web-based experimental presentation platform (Drummond, 2013). Participants carried out the experiment remotely on their own computers via a link distributed through an Amazon Mechanical Turk HIT. The experiment uses a non-cumulative SPR paradigm. At six points during the experiment, the task was interrupted by a landscape image which required a mouse click in order to proceed, rather than a space bar press. This was done to reduce routinized space bar-pressing behavior, as well as to give participants natural breaks throughout the experiment.

Our target items consist of 14-18 chunks. The first 4-9 chunks make up the context in which either the ARC predicate or the matrix clause predicate is made given information. The first chunk following this is the subject NP of the matrix clause of the critical region, after the critical region follows which is made up of a chunk containing the ARC and one containing the matrix clause (in varying orders). The critical region is thus divided into two chunks, for which we add up the reading times in our primary analysis. The next chunk is the spillover region, which is followed by up to 6 more chunks which complete the short narrative. We measure the exposure duration for each chunk. For the primary analysis we focus on the critical regions and the

spillover regions for any delayed effects. For the secondary analyses we focus on the reading times of the individual ARCs and matrix clauses, with no region to observe delayed effects. See fig. 1 below for the chunked version of (10), with the critical region in italics.

[My aunt,] [like my mom, is a] [big fan of drinking gin. She thinks] [she is really good] [at hiding it by]
[adding some tonic to it.] [Everybody knows what is actually in her glass of course.] [A few weeks ago,]
[at my birthday party,] [*my aunt,*] [*who was drinking gin & tonic,*] [*was gossiping with my mom.*] [As I walked by,]
[I heard they were talking about me.] [My mom got startled and spilled her drink] [all over my aunt.]

Figure 1. Example of chunked condition: chunks are in square brackets. For convenience, the critical region has been put in italics (unlike in the actual experiment).

The items were presented over 3–5 lines. The critical region was always presented on either the second or third line, on a single line together with one chunk preceding it and the spillover region.

Before starting the experiment, participants were provided with several example items to familiarize themselves with the procedure. After completing the SPR part of the experiment, participants were asked to fill out a demographic questionnaire. Crucial questions here pertained to the languages they spoke growing up and in their current daily life. Participants were only included in the analysis if English was their majority language growing up and in their current daily life. All experimental materials and reported data are available here: `https://osf.io/3tjwv/`.

2.2.4. Analysis

Data was analyzed using R (R Core Team, 2013). Our outcome variable was residual reading time.[2] We constructed linear mixed-effects models (Baayen, Davidson, & Bates, 2008) using the `lme4` package (Bates, Mächler, Bolker, & Walker, 2015).

Primary analysis

For our primary analysis plan we model the combined reading times of the ARC and the matrix clause, with factors for *information order* (given first vs new first)

[2]Residual reading times were obtained as follows: the average raw reading time per character was calculated for each participant. Punctuation was disregarded for this calculation. The difference from what would be the mean reading time for a segment following this average reading time per character is the residual reading time. If a participant reads faster than their own average, this difference will be a negative number (in milliseconds), and if slower, a positive number.

and *clause order* (matrix first vs ARC first) and their interaction. We applied contrasts to both of these factors such that each factor was sum-coded: *information order*, given-new=−0.5/new-given=0.5 and *clause order*, ARC-matrix=−0.5/matrix-ARC=0.5). Because we carry out three analyses on the data that makes up the critical region variable (ARC & matrix clause, which is analysed once as a single region in the primary analysis, and then twice as two separate regions (ARC *or* matrix clause) in the secondary analysis), the Bonferroni adjusted alpha level for all three analyses of data in that region is .016 (.05/3). The data in the spillover region is only analysed once and is therefore not subject to this adjusted alpha level.

Secondary analysis

Our secondary analysis models the reading times of the individual clauses that make up the target region. For both the ARC and the matrix clause, we model the reading time with factors for *information status* (given vs new) and *clause position* (sentence-early vs sentence-final) and their interaction. Factors in this analysis were also sum-coded: *information status*, given=−0.5/new=0.5 and *clause position*, early=−0.5/final=0.5. The Bonferroni adjusted alpha level for these analyses is .016 (.05/3).

In both analyses, the factors representing the conditions, *trial number* and their interactions were fixed effects in our models. We were not interested in any direct effects of *trial number*, but we included it as a fixed effect and random slope to account for any possible learning effects of either condition in all models. The numerical value for *trial number* was centered.

As random effects, we had intercepts for participants and items in all models. We added by-item random slopes for the two conditions and their interaction, and by-subject random slopes for the two conditions, *trial number*, and their interactions. If the model with maximal random effect structure did not converge, we used the methods described in Barr, Levy, Scheepers, and Tily (2013) to reach a model that did converge. To assess significance, we conducted likelihood ratio tests (`anova`, Girden (1992)) between the full model and a model without the condition (or interaction) of

interest.

2.3. Results

Table 2 presents the average residual reading times for the critical region and the spillover region by condition (GIVEN-NEW/NEW-GIVEN and ARC-MATRIX/MATRIX-ARC). This data is visualised in Figure 2 for the critical region and in Figure 3 for the spillover region. The results from the primary analysis (see Table 3) show that at the critical region, the GIVEN-NEW order was read faster than the NEW-GIVEN order ($\chi^2(1) = 7.3$, $p < .001$), which is in line with predictions made by the *given-new* principle. We do not find this effect of information order repeated at the spillover region, but we do find an effect here of *clause order* ($\chi^2(1) = 5.33$, $p = .02$), see Table 4. The spillover region was read faster when it followed the critical region in MATRIX-ARC order than when it followed ARC-MATRIX order. This confirms predictions made by the *clause structure* principle. We also find a significant effect of *trial number* for both the critical region and the spillover region such that items were read faster as the experiment progressed, but in the absence of an interaction with either condition this does not imply a learning effect.

Table 2. Mean residual reading times for the critical region and spillover region in each condition. By-participant standard error is shown in parentheses.

	given-new		new-given		
	ARC-matrix	matrix-ARC	ARC-matrix	matrix-ARC	*Overall means*
critical	283.02 (15.29)	293.37 (15.78)	324.4 (15.54)	322.36 (15.54)	305.81 (7.75)
spillover	15.63 (5.98)	4.36 (5.98)	11.16 (6.03)	−1.96 (5.72)	7.3 (2.96)

For the secondary analysis, Table 5 presents the average residual reading times for the individual clause regions (ARC and matrix) by condition (GIVEN/NEW and EARLY/FINAL). This data is visualised in Figure 2.3. The likelihood ratio test showed a significant difference between the full model and the model without the *information status* condition for ARCs ($\chi^2(1) = 12.55$, $p < .001$) and matrix clauses ($\chi^2(1) = 15.02$, $p < .001$), see Table 6. This significant effect of *information status* captures the fact that the clauses were read faster when the information in them was GIVEN than when it was NEW. We find a similar effect of position for both ARCs ($\chi^2(1) = 57$, $p < .001$)

Table 3. Model results for the critical – *ARC & matrix* – region: Coefficient estimates, standard errors of those estimates, chi-squared value from the likelihood ratio test comparing each model to a model not including 'condition', and the *p*-value for that test statistic. All *p*-values in boldface are significant at the Bonferroni corrected alpha level.

	ARC & matrix			
	β	SE	$\chi^2(1)$	p
information order	38.4	14.22	7.3	**<.001**
clause order	1.83	14.23	0.02	.9
trial#	−12.94	1.34	75.6	**<.001**
information order × *clause order*	−0.15	46.15	0	1
information order × *trial#*	1.14	1.6	0.53	.47
clause order × *trial#*	0.63	1.58	0.16	.69
information order × *clause order* × *trial#*	−2.49	3.15	0.62	.43

Table 4. Model results for the spillover region: Coefficient estimates, standard errors of those estimates, chi-squared value from the likelihood ratio test comparing each model to a model not including 'condition', and the *p*-value for that test statistic.

	spillover			
	β	SE	$\chi^2(1)$	p
information order	−4.82	5.09	0.89	.34
clause order	−11.74	5.09	5.33	**.02**
trial#	−4.57	0.44	85.76	**<.001**
information order × *clause order*	−0.21	12.52	0	.99
information order × *trial#*	−0.39	0.55	0.5	.48
clause order × *trial#*	−0.19	0.55	0.11	.74
information order × *clause order* × *trial#*	−0.09	1.1	0.01	.94

and matrix clauses ($\chi^2(1) = 51.17$, $p < .001$): both clauses were read faster in EARLY position than in FINAL position. In addition, we find an interaction between *information status* and *position* for the matrix clauses ($\chi^2(1) = 6.13$, $p < .01$), such that the effect of givenness (faster reading times for GIVEN than NEW) was larger in the EARLY position (fastest reading times were GIVEN/EARLY). We find a significant effect of *trial number* for both ARCs and matrix clauses. For matrix clauses *trial number* additionally comes up in an interaction with *information status*, such that GIVEN matrix clauses were read faster as the experiment progressed.

3. General discussion

The goal of this study was to investigate how three ordering principles – the *given-new*, *clause structure* and *clause-type mapping of information* principles – affect the

Figure 2. Errorbar plot showing the residual reading times and means for the critical region – matrix clause & ARC taken together – in all conditions. Errorbars represent 95% confidence intervals.

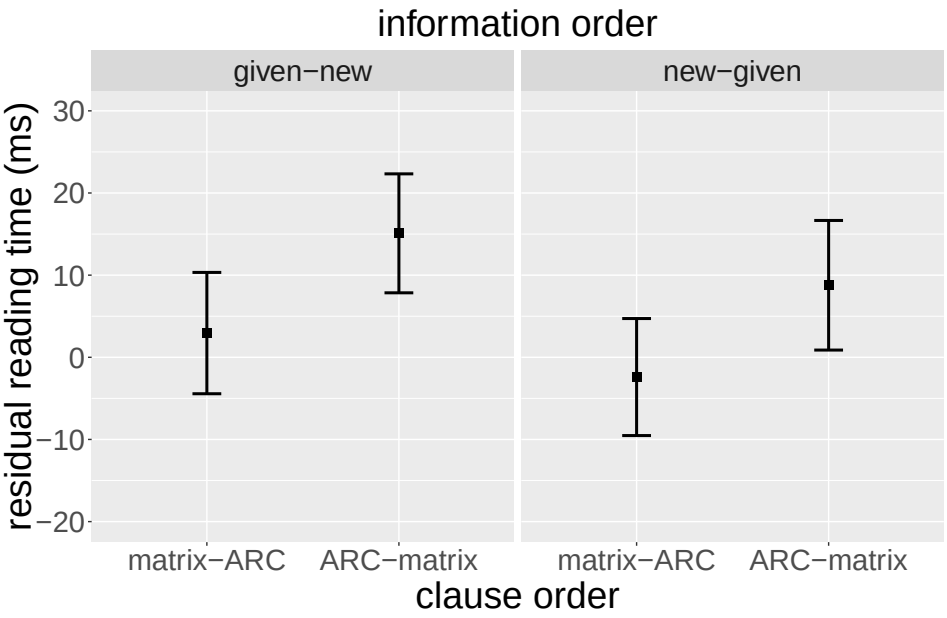

Figure 3. Errorbar plot showing the residual reading times and means for the spillover region in all conditions. Errorbars represent 95% confidence intervals.

processing of complex sentences containing an ARC, and to see whether effects we find can be more so attributed to one of the two clauses (ARC or matrix clause) in these sentences. We carried out a self-paced reading experiment to test this.

In line with previous studies, the results of the reading-time study show that

Table 5. Mean residual reading times for the individual clause regions in each condition. By-participant standard error is shown in parentheses.

	given		new		
	early	final	early	final	*Overall means*
ARC	−164.14 (9.99)	−87.32 (10.34)	−94.98 (9.77)	−14.87 (11.32)	−90.4 (5.23)
matrix	−177.2 (8.62)	−75.33 (9.69)	−91.58 (9.36)	−37.49 (9.66)	−95.38 (4.72)

Table 6. Model results for the individual clause regions: Coefficient estimates, standard errors of those estimates, chi-squared value from the likelihood ratio test comparing each model to a model not including 'condition', and the p-value for that test statistic. All p-values in boldface are significant at the Bonferroni corrected alpha level.

	ARC				*matrix clause*			
	β	SE	$\chi^2(1)$	p	β	SE	$\chi^2(1)$	p
info.status	68.69	17.8	12.55	**<.001**	80.59	18.71	15.02	**<.001**
position	74.97	9.91	57	**<.001**	62.83	8.77	51.17	**<.001**
trial#	−6.09	0.54	126.63	**<.001**	−5.92	0.48	152.62	**<.001**
info.status × *pos.*	−2.98	19.84	0.2	.88	−43.41	17.54	6.13	**.01**
info.status × *trial#*	0.39	1.07	0.13	.71	−3.26	0.95	11.08	**<.001**
pos. × *trial#*	−0.35	1.07	0.1	.75	−1.54	0.95	2.63	.11
i.s. × *pos.* × *trial#*	−2.33	2.15	1.19	.28	−2.14	1.9	1.28	.26

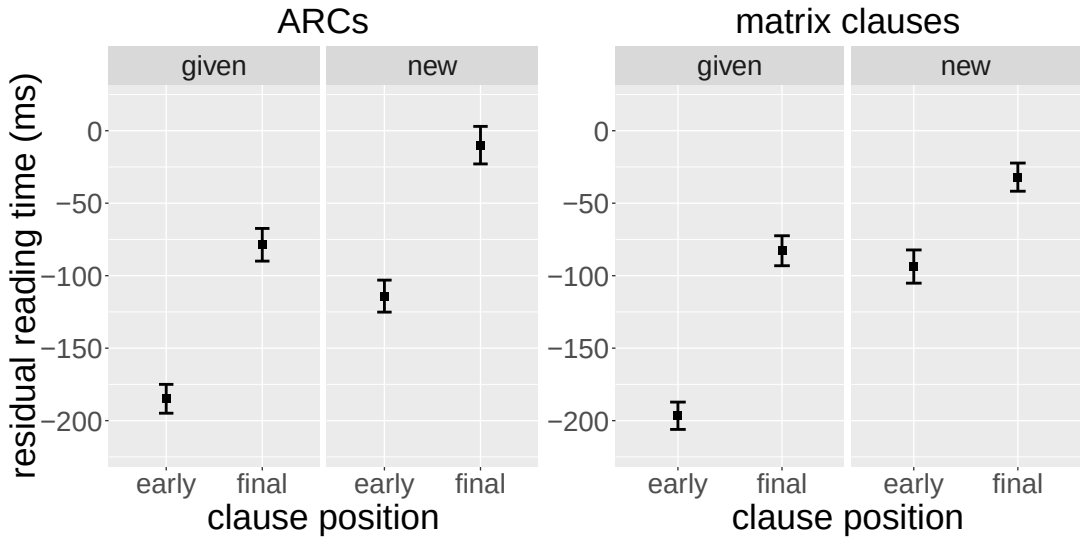

Figure 4. Errorbar plot showing the residual reading times and means for the ARCs and the matrix clauses in all conditions.

predictions made by the *given-new* principle and the *clause structure* principle indeed extend to constructions containing an ARC. These findings suggest that even if ARCs' similarity to matrix clauses influences their processing, this similarity is obscured by effects of information order and clause order. Moreover, the findings hold even for

discourses in which information status follows from cues in the discourse context rather than from definiteness or other sentence-internal morphosyntactic cues.

Our suggestion that in sentences with an ARC, reading times would be faster when information mapping proceeds in the opposite direction as predicted by the *clause-type mapping of information* principle, such that new information is hosted by the ARC and given information hosted by the matrix clause (*reverse mapping* hypothesis), was not borne out in our data when considering the full sentences. However, considering that ARCs have been observed to most often provide new information to the discourse, and that the given information in our items was a new instance of a discourse-old event, this might have contributed to matrix-ARC order facilitating processing over ARC-matrix order.

When we consider the ARCs and matrix clauses individually, we find that any clause containing given information is read faster than when it contains new information. This might seem to suggest that both ARCs and matrix clauses are more likely hosts for given information, but a more likely explanation is that given information is just generally processed faster than new information independent of clause type or position. While corpus data has revealed that ARCs contribute new information to discourse over 95% of the time (Loock, 2007, 2010), this 'preference' for new information cannot be found reflected in processing if given information, then, is consistently processed faster than new information independent of clause type. A possible solution could be to compare the processing of ARC content that contributes new information to discourse to that same content in a different type of clause for which the expectation is that it contributes given information to discourse. Whether any differences then should be attributed to processing costs incurred by expected information status mismatches or to processing costs incurred by the different structures of the clauses, or both, could then prove to be a complicating factor.

A similar issue to the 'given information is always processed faster'-issue arises when we consider the effect of position for the individual clauses: both ARCs and matrix clauses were read faster in early position. For matrix clauses, this effect of position aligns with predictions made by the *clause structure* principle, for which we also find evidence when we consider the full sentence. For ARCs, however, this finding does not

align with predictions made by any of the principles that were under investigation.

The above finding that ARCs were read faster in sentence-early position than in sentence-final position is in contrast to findings in Gibson et al. (2005). They suggest that because the ARCs in their experiment contained a mixture of given and new information, this could have led to a trade-off effect leading to a null result. However, such a trade-off effect cannot explain why we *did* find a difference between positions. Consequently, it follows that the information status of ARC content is not responsible for any processing differences – or lack thereof – between ARCs in different positions. Additionally, if it were the case that information status was responsible for such differences, this would have manifested as an interaction effect between information status and ARC position in our study. We did find such an interaction effect for matrix clauses. The effect of faster reading times for these was greater in sentence-early position than in sentence-final position. This interaction suggests that matrix clauses, instead of ARCs, may have a grounding function when they appear in initial position in sentences with an ARC, similarly to what de Ruiter et al. (2020) and Scholman et al. (2022) find for adverbial clauses in this position. For sentence-initial matrix clauses to have such a grounding function in sentences with an ARC was in line with our expectations. Our prediction that this grounding function would be found reflected in processing independent of the position of the matrix clause was not borne out in our data.

With the exception of the interaction we find for matrix clauses, evidence from the individual clauses – both in our study and in Gibson et al. (2005) – highlights the importance of looking at the full sentence. Evidence from individual clauses is confounded by a general effect of faster reading times for clauses containing given information and those in sentence-early position. Because new information is always processed more slowly than given information, any comparisons at the level of individual sentence-final clauses will inevitably yield results that suggest that given information facilitates processing in that position. Similarly, because clauses in sentence-early position will always be read faster than clauses in sentence-final position, any comparisons between ARCs in these two positions are bound to yield results that suggest that ARCs in sentence-early position are read faster. It is only possible to observe ease of processing

for clauses containing new information in sentence-final position, or for appositives in sentence-final position, when reading times for the full sentence are considered.

4. Conclusion

In this paper we investigated the influence of three ordering principles – the *given-new* principle, the *clause structure* principle and the *clause-type mapping of information* principle – on the processing of sentences containing an ARC. We found that predictions made by the *given-new* principle and the *clause structure* principle were borne out in our data: sentences were read faster when the order of information was given-new, and a delayed effect of matrix-ARC order at the spillover region suggests that matrix-ARC order facilitates processing as well. Both of these findings are somewhat surprising considering the special status ARCs have among subordinate clauses. In addition, we expected to find effects of clause-type mapping such that sentences would be easier to process when the ARC contained new information, as corpus studies have shown that ARCs almost always contribute new information to discourse. For this we posited the *reverse mapping* hypothesis. We do not find such an effect, however, we did find an interaction effect for matrix clauses when these were analyzed individually in the secondary analysis. The effect of faster reading times for these was greater in sentence-early position than in sentence-final position. This interaction suggests that sentence-early matrix clauses may have a grounding function in sentences with an ARC, an effect that previously has been suggested for sentence-initial subordinate clauses and empirically demonstrated for sentence-initial adverbial clauses. ARCs being more likely hosts for new information might indirectly contribute to matrix clauses in sentence-early position appearing to have a grounding function in sentences with an ARC.

Taken together, our findings replicate previously observed patterns predicted by well-established principles and provide particularly strong evidence for the *given-new* principle: Where prior research primarily provides evidence for situations in which given and new information are distinguished at the morphosyntactic level, the current investigation extends the *given-new* principle to situations in which contextual cues are responsible for distinguishing given from new information. Additionally, our focus

was on sentences containing an ARC, which is a clause that has a special status among subordinate clauses. This special status did not lead to sentences containing ARCs violating the *given-new* principle or the *clause structure* principle, but it might have contributed to a shift of the grounding function in these sentences from the subordinate clause to the matrix clause. Considering that ARCs have been observed to most often contribute new information and that they syntactically depend on the matrix clause for an antecedent, this result was in line with our expectations. However, as far as we know, ours is the first study that has found evidence to suggest that sentence-early matrix clauses have a grounding function in sentences with an ARC, so further research is needed to determine whether this interaction effect we find for matrix clause in sentence-early position indeed can be ascribed to such a grounding function.

Lastly, our study highlights a potential shortcoming in methodologies that focus on the processing of individual clauses. Effects of information status and clause position were present in our analysis across the board, such that any matrix clause or ARC containing given information was read faster than when it contained new information, and any matrix clause or ARC in sentence-early position was read faster than when it was in sentence-final position. Consequently, it seems that an expectation for new information in certain clause types, or an expectation that certain types of clauses will be encountered sentence-finally, may be missed if one analyses only the processing of these individual clauses. However, as the results of our primary analysis show, it is possible to observe such effects when the full sentence is considered: the location of new information in the sentence and the clause type of the clause in sentence-final position then can potentially be observed to either facilitate or not, processing of the full sentence. This is why it should be noted that when an investigation aims to find evidence for new information to facilitate processing, or having a certain clause in sentence-final position to facilitate processing, such effects of information status and clause position should be investigated by considering the full sentence.

Ethics

All experiments in this study were carried out in accordance with the research ethics procedures of the Department of Linguistics and English Language at The University of Edinburgh (Ref # 438-1819/5). Informed consent was obtained from all participants prior to participation.

Data accessibility

The data that support the findings of this study are openly available in the Open Science Framework repository: `https://osf.io/3tjwv/`.

Disclosure statement

We declare we have no competing interests.

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