Language and Cognition (2023), 15: 1, 1–28
doi:10.1017/langcog.2022.22

ARTICLE

When sequence matters: the processing of contextually biased German verb–object metaphors

Camilo R. Ronderos[1,2*], Ernesto Guerra[3] and Pia Knoeferle[2,4,5]

[1]Department of Philosophy, Classics, History of Art and Ideas, University of Oslo, Oslo, Norway; [2]Institut für deutsche Sprache und Linguistik, Humboldt-Universität zu Berlin, Berlin, Germany; [3]Center for Advanced Research in Education, Institute of Education, Universidad de Chile, Santiago, Chile; [4]Einstein Center for Neurosciences Berlin, Berlin, Germany; [5]Berlin School of Mind and Brain, Berlin, Germany
*Corresponding author. Email: camilorr@uio.no

(Received 15 December 2021; Revised 15 July 2022; Accepted 05 August 2022)

Abstract

Several studies have investigated the comprehension of decontextualized English nominal metaphors. However, not much is known about how contextualized, non-nominal, non-English metaphors are processed, and how this might inform existing theories of metaphor comprehension. In the current work, we investigate the effects of context and of sequential order for an understudied type of construction: German verb–object metaphors. In two visual-world, eye-tracking experiments, we manipulated whether a discourse context biased a spoken target utterance toward a metaphoric or a literal interpretation. We also manipulated the order of verb and object in the target utterances (e.g., *Stefan interviewt eine Hyäne*, 'Stefan interviews a hyena', verb→object; and *Stefan wird eine Hyäne interviewen*, 'Stefan will a hyena interview', object→verb). Experiment 1 shows that contextual cues interacted with sequential order, mediating the processing of verb–object metaphors: When the context biased toward a metaphoric interpretation, participants readily understood the object metaphorically for the verb→object sequence, whereas they likely first understood it literally for the object→verb sequence. Crucially, no such effect of sequential order was found when context biased toward a literal interpretation. Experiment 2 suggests that differences in processing found in Experiment 1 were brought on by the interaction of discourse context and sequential order and not by sequential order alone. We propose ways in which existing theoretical views could be extended to account for these findings. Overall, our study shows the importance of context during figurative language comprehension and highlights the need to test the predictions of metaphor theories on non-English and non-nominal metaphors.

Keywords: metaphor processing; visual-world eye-tracking; experimental pragmatics; figurative language

The studies presented in this article were part of the first author's Ph.D. dissertation. Experiment 1 was previously reported in the non-archival proceedings of the Annual Meeting of the Cognitive Science Society (Ronderos et al., 2020). All data, analysis scripts, supplementary materials and experiment materials are available on the project's OSF repository (https://osf.io/85zwy/).

1. Introduction

A lot of work has gone into trying to understand how we process so-called 'nominal metaphors' such as *That broker is a hyena*, where *that broker* is referred to as the metaphoric topic and *a hyena* as the metaphoric vehicle. There are currently two leading views on the matter (Holyoak & Stamenković, 2018; for reviews, see Pouscoulous & Dulcinati, 2019). The first one, which we refer to as the Implicit Comparison view, states that a metaphor is understood via analogical reasoning, a cognitive mechanism in which topic and vehicle are scanned for relational similarities (Boroditsky, 2000; Coulson & Oakley, 2005; Gentner & Bowdle, 2008; Gentner et al., 2001; Wolff & Gentner, 2011). According to this view, the meaning of the topic and vehicle is retrieved as it would be if the same words were used literally. Initially, systematic mappings between the structures of topic and vehicle are established via structural alignment. Once the structures are aligned, inferences are projected from vehicle to topic, resulting in a metaphoric interpretation.

A second view, the Category Inclusion view, sees metaphor comprehension as a process in which the lexical meaning of the vehicle is spontaneously changed to represent a newly created, goal-oriented category. This is based on the interpretative dimensions provided by the topic (Glucksberg, 2003; McGlone & Manfredi, 2001; Rubio Fernandez, 2007; Wilson & Sperber, 2012). According to this view, a comprehender does not look for ways in which the internal structure of topic and vehicle are similar to one another. Instead, the meaning of the vehicle either acquires dual-reference (Glucksberg, 2008) or undergoes lexical modulation (Sperber & Wilson, 2008). This leads to the topic being understood as a member of an ad-hoc category represented by the vehicle. The cognitive mechanism involved here is category inclusion, which can be seen as an instance of conceptual combination (Estes & Glucksberg, 2000). In other words, the metaphoric expression is understood much like a literal category inclusion statement (e.g., *The broker is a hyena* is understood similarly to *apples are fruits*, for example).

Throughout the last 40 years, there has been empirical evidence supporting one view or the other (see the reviews in Gentner & Bowdle, 2008; Glucksberg, 2008), and the debate is far from being resolved. Holyoak and Stamenković (2018) suggest that a way forward is to study contextualized metaphor processing. They point out that the majority of studies has examined decontextualized metaphors only, even though metaphors are typically embedded in rich communicative and extralinguistic contexts. Previous psycholinguistic research has shown that literal utterances are integrated incrementally with context, influencing even the earliest stages of sentence interpretation (see Huettig et al., 2011; Knoeferle, 2019; Knoeferle & Guerra, 2016; Tanenhaus & Trueswell, 2006, for reviews). The integration of an utterance in context determines the unfolding interpretation and helps generate expectations about upcoming input (Altmann & Kamide, 1999; Sedivy et al., 1999; Tanenhaus et al., 1995, among many others). This amounts to language comprehension being an intricate interplay of integration and anticipation (see Ferreira & Chantavarin, 2018), and there is no reason to believe that metaphor comprehension should be an exception.

Holyoak and Stamenković (2018) also suggest to study different types of metaphors and examine languages other than English. Most studies on metaphor comprehension have focused on English nominal metaphors ('X is a Y'), potentially limiting the scope of the theoretical accounts and the predictions they generate. One

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

example of this limitation involves the sequential order of the elements of a metaphor. The Implicit Comparison view claims that the sequence of topic and vehicle (i.e., whether the topic is encountered before the vehicle or not) is not relevant during early stages of processing. This is spelled out in Structure-Mapping Theory, developed by Dedre Gentner and collaborators (Gentner & Boronat, 1992; Gentner & Bowdle, 2008; Gentner et al., 2001; i.a.). According to this model, a comprehender first understands how the structures of topic and vehicle are mutually coherent. This is done by grouping together structurally consistent predicates across elements (topic and vehicle), forming large clusters of shared structure. The sequential order of the elements is irrelevant during the alignment stage (Wolff & Gentner, 2011, p. 1459).

The Category Inclusion view, on the other hand, assigns role-specific tasks to topic and vehicle from the earliest stages onward (Glucksberg, 2001, pp. 55–56; Glucksberg et al., 1997). The topic provides relevant interpretative dimensions that select features of the vehicle for lexical modulation. Upon encountering the vehicle, an ad-hoc category is constructed on the basis of the vehicle's meaning and the dimensions provided by the topic. This makes sequential order critical: The topic must be processed prior to the vehicle for metaphor comprehension to succeed.

It is not clear, however, how sequential order effects (if any) unfold for metaphors in which the topic is not explicitly mentioned, or for metaphors in languages that have flexible syntax and allow for a reversal of the sequence of metaphoric elements. How are metaphors processed when sequence relationships differ from English nominal metaphors? And is it possible for the theories, in their current form, to account for such cases? It would be beneficial for metaphor research to study how contextualized, non-nominal, non-English metaphors are processed. Doing so would allow us to assess the degree to which the existing theories may or may not be able to account for their processing. It would also allow us to generate hypotheses linking the theories to these data, under the assumption that current theoretical approaches wish to account for more than just English nominal metaphors.

That is the goal of the current study. We investigated a previously overlooked construction, namely German verb–object metaphors, such as *Stefan interviewt eine Hyäne* ('Stefan interviews a Hyena'), where *Hyäne* metaphorically refers to a broker. These metaphors have properties that make them interesting for the development of metaphor theory. First, they can only be understood as metaphors when embedded in a context that makes it clear that we are talking about a broker and not an African animal. Second, they do not have an explicit metaphor topic. Instead, they are made up of a verb (*interviewt*) with narrow selectional restrictions (Katz & Fodor, 1963; Wilks, 1975) that indirectly select the potential topic (the broker), and a vehicle (*Hyäne*) that serves as the object of the verb. Third, given the flexibility of German syntax, the sequence of these two elements can be felicitously altered by switching between present and future tense (*Stefan wird eine Hyäne interviewen*). This allows us to examine both how processing changes when the sequence is altered, as well as whether any changes are exclusive to metaphor comprehension.

In two eye-tracking experiments, we investigated how such metaphors are processed. With this, we hope to (1) understand how processing unfolds in the absence of an explicit metaphoric topic, (2) investigate how sequence alternations affect processing metaphoric and literal verb–object constructions, and (3) generate linking hypotheses for existing metaphor theories to these empirical data.

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

The paper is structured as follows: In the next section, we describe previous findings on the role of context during metaphor processing. We then turn to an examination of the impact of the sequence of metaphoric elements on nominal metaphor comprehension, followed by a closer look at German verb–object metaphors. We then present our two experiments and discuss how they could contribute to extending metaphor processing theories to non-nominal metaphors.

1.1. The role of context in metaphor processing

Previous research on metaphor comprehension has identified a pivotal role for context. Metaphors that follow a long discourse context, for example, are processed just as fast as literal equivalents (Gerrig, 1989; Inhoff et al., 1984; Ortony et al., 1978). Poorly apt metaphors (e.g., *a marriage is an icebox*) are processed differently from apt metaphors when no context is given (Gildea & Glucksberg, 1983), but both types show qualitatively similar processing patterns when presented in a supportive context. Furthermore, contextualized metaphors elicit a different neural response compared to decontextualized ones (Bambini et al., 2016): In the absence of context, nominal metaphors elicit both an N400 and a P600, whereas contextualized metaphors elicit only an N400. Bambini et al. (2016) suggest that, when understanding a metaphor, a discourse context supports comprehension by facilitating lexical access and supporting the integration of incoming input. Relative to literal equivalents, however, metaphors still require the additional inferential step of interpreting the speaker's intended meaning, regardless of the presence of a supportive context.

Considering how metaphor sequence effects have only been studied for decontextualized nominal metaphors, it is unclear how sequential order effects would play out if a metaphor were embedded in a rich supporting context. Is, for example, the presence or absence of any potential sequence effects related to contextual integration, or to the processing of the metaphor proper? This question is relevant, since sequential order effects could be informative regarding the underlying cognitive mechanism involved in metaphor comprehension.

1.2. The sequential order of nominal metaphors

An important finding regarding nominal metaphors is that they are rated significantly higher for comprehension when the topic precedes the vehicle than the other way around, whereas literal comparisons (e.g., *a goblet is like a cup*) are not (Glucksberg et al., 1997). Glucksberg et al. (1997) therefore argue that while literal comparisons are reversible, metaphors and similes are not, in line with the Category Inclusion view (see also Chiappe et al., 2003).

Wolff and Gentner (2011) argue that rating tasks are not enough to study the effects of sequence, and advocate for the need of an online measure (see also Wolff & Gentner, 2000). They conducted a speeded comprehension task where participants read directional (forward) metaphors (*a rumor is a virus*) and their reversed counterparts (*a virus is a rumor*), which were presented at short and long time intervals. At the earliest intervals (500 and 600 milliseconds in Experiments 2 and 3, respectively), participants' comprehensibility judgments of forward and reversed metaphors did not differ significantly (but they did differ from a baseline of scrambled sentences). The authors took the absence of a difference between forward and reversed metaphor comprehension in the earliest intervals as evidence for an initial stage of alignment for which the order of elements in a metaphor is not relevant.

Several points speak in favor of investigating sequential order effects outside of decontextualized English nominal metaphors. First, it is unclear whether sequential order effects would also be visible for metaphors that appear embedded in a context. Second, it remains to be seen whether sequential order plays a role during the integration of the elements (i.e., during incremental metaphor processing) and not just in deriving an end-result interpretation. Third, reversing the sequence of the elements of nominal metaphors typically results in a drastic change in the interpretation of the sentence (consider *a rumor is a virus* and *a virus is a rumor*). This makes it difficult to disentangle the effect of sequential order from potential effects caused by the differences in interpretation. Fourth, not all metaphors necessarily have a topic-vehicle structure. What role does sequential order play for such metaphors, and how can it inform our theories of metaphor comprehension? To address these points, we propose investigating German verb–object metaphoric constructions.

1.3. German verb–object metaphors

The case of German verb–object metaphors provides us with an opportunity to study how metaphor processing takes place under very different conditions to those previously studied. Consider the following discourse:

> *(1) Stefan is a journalist and he travels to Frankfurt to investigate tax fraud. When he gets there, he finds an amoral broker in the bank who was defrauding the state and had even laundered money. Stefan comes closer to him and wants to record the boasting of the capitalist on tape. This encounter will stay in his memory for a long time. Stefan interviews a hyena and will portray the broker unforgivingly.*

In the last sentence, we encounter a metaphoric vehicle (*hyena*) as the object of a verb (*interviews*), but no explicit metaphoric topic. However, the verb does provide specific clues regarding what the topic is. This is because the verb has a (relatively) narrow set of selectional restrictions (Katz & Fodor, 1963; Wilks, 1975), which generally require its object (i.e., the interviewee) to be human. It is likely that, upon encountering the verb, the verb's most likely object given the discourse context (*the amoral broker*) will be activated. This, in turn, should prompt the reader to understand the verb's object (*hyena*) metaphorically (i.e., as the vehicle), as a reference to *the broker*. Now, imagine that you encounter the final sentence in (1) without a discourse context. You might be inclined to understand the sentence literally, that is, as Stefan interviewing a literal hyena. This illustrates that these metaphors are rather context-dependent.

Finally, imagine that (1) were written in German. German syntax alternates from a subject–verb–object to a subject–object–verb surface structure in the presence of an auxiliary verb. The last sentence of the German version of (1) could then be *Stefan wird eine Hyäne interviewen und wird unerbittlich das Raubtier porträtieren* (literal translation: '*Stefan will a hyena interview and will unforgivingly the predator portray*'). Here, the position of the vehicle ('hyena') changes relative to the verb

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

('to interview'). In short, metaphors that appear in German verb–object constructions allow us to examine a case in which there is no explicit metaphoric topic, the sequence relationship between elements is flexible, and metaphor comprehension critically depends on context.

What could we expect to happen during processing of these metaphors? First of all, we would expect them not to be understood as metaphors in the absence of context. Second, we can expect that, if the sequential order of the elements of these metaphors affects processing, there should be differences between the verb–object and the object–verb sequences. Third, if any sequential order effects emerge, and if they are a consequence of metaphoric processing, we should expect them not to appear when the sentences are understood literally or in isolation. These expectations are made explicit in the predictions section of Experiment 1. In Section 4, we explore the potential consequences of these predictions for theories on metaphor processing.

1.4. What drives the anticipation of postverbal objects?

A critical part of our investigation is that hearing the verb *interviewt* will activate a mental representation of its most likely object *Makler* ('broker'). This is based on research on the anticipation of postverbal objects. Altmann and Kamide (1999) found that when participants hear sentences that include verbs with narrow argument selection restrictions (such as *eats* in the sentence *the boy eats cake* in a context with only one edible object), participants' eye movements anticipated the edible object upon hearing the verb. This effect has been replicated successfully with larger samples (Hintz et al., 2017) and even 2-year-old children (Mani & Huettig, 2012). Importantly, Kamide et al. (2003a) found that when a verb does not provide enough constraining information on its own (such as *ride*), participants incorporate their knowledge about the subject (e.g., *the girl will ride…* vs. *the man will ride…*) to anticipate an appropriate object (e.g., a motorbike or a carousel). Similarly, listeners can incrementally use the combination of object and verb to anticipate a likely upcoming subject (Guerra et al., 2021; Kamide et al., 2003b).

These findings raise the question of what exactly drives the anticipation of postverbal objects. Nieuwland and Van Berkum (2006), for example, found that when an object mismatches its verb's selectional restrictions, hearing the object does not elicit an N400 effect if a supportive discourse precedes it. Does this mean that a discourse context is stronger than the verb's selectional restrictions in terms of facilitating anticipation? Consider (2) below:

> *(2) Stefan is a journalist and travels to Africa to investigate animal cruelty. When he gets there, he finds an unusual predator in the desert that has been severely mistreated and even shot. Stefan comes closer to it and is going to record the animal's sad groaning on tape. This encounter will stay in his memory for a long time. Stefan interviews a hyena and will portray the predator unforgivingly.*

Upon hearing the verb in the final sentence (if one were hearing the last sentence word by word), its selectional restrictions [+human] are likely perceived to be at odds with the contextually plausible referent (the hyena). What object – if any – would a comprehender anticipate? Our study addresses this question together with the

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

central questions regarding the effect of context and of element sequence on metaphor comprehension.

2. Experiment 1

In Experiment 1, participants read either a literal or a metaphoric discourse context. The literal context introduced a journalist (Stefan) and a wild animal (a hyena), whereas the metaphorical context introduced a journalist (Stefan) and his interviewee (a broker). Following the written context, participants listened to either a literal or metaphoric target verb–object sentence (see Fig. 1), whereas they inspected a visual context with four photographs (a hyena, a broker, and two distractors). Thus, the context set up a bias toward interpreting the postverbal object noun (hyena) in the target sentence either literally (as a wild animal) or metaphorically (an amoral broker), whereas the verb (to interview) always biased toward the metaphoric interpretation of the postverbal object noun (the broker).

Critically, the target sentences either had a Verb–Object (*Stefan interviewt eine Hyäne*) or an Object–Verb (*Stefan wird eine Hyäne interviewen*) sequence. We analyzed participants' gaze patterns to draw conclusions about how they anticipated postverbal objects (do they look at the hyena or the broker when hearing *interviewt* prior to the object?), about the importance of sequential order (are the gaze patterns in the Verb–Vehicle and Vehicle–Verb sequences similar when participants hear *eine Hyäne*?), and about the interaction between context effects and sequential order. (Does the effect of sequential order differ when the sentence is interpreted literally relative to when the sentence is interpreted metaphorically?)

Literal Discourse Context *Stefan ist Journalist und fährt nach Afrika, um das Thema Tierquälerei zu recherchieren. Als er da ist, findet er in der Wüste ein ungewöhnliches Raubtier, das stark misshandelt und sogar angeschossen wurde. Stefan kommt ihm näher und wird das traurige Stöhnen des Tieres auf Tonband aufnehmen. Diese Begegnung wird ihm lange im Gedächtnis bleiben.* English Translation: 'Stefan is a journalist and travels to Africa to investigate animal cruelty. When he gets there, he finds an unusual predator in the desert that has been severely mistreated and even shot at. Stefan comes closer to it and is going to record the animal's sad groaning on tape. This encounter will stay in his memory for a long time.'	**Metaphoric Discourse Context** *Stefan ist Journalist und fährt nach Frankfurt, um das Thema Steuerbetrug zu recherchieren. Als er da ist, findet er in der Bank einen amoralischen Makler, der den Staat betrügt und sogar Geldwäscherei betreibt. Stefan kommt ihm näher und wird das Angeben des Kapitalisten auf Tonband aufnehmen. Diese Begegnung wird ihm lange im Gedächtnis bleiben.* English Translation: 'Stefan is a journalist and travels to Frankfurt to investigate tax fraud. When he gets there, he finds an amoral broker in the bank who is defrauding the state and even laundering money. Stefan comes closer to him and will record the boasting of the capitalist on tape. This encounter will stay in his memory for a long time'
Target Literal Utterance Verbal-topic → Vehicle *Stefan **interviewt** eine **Hyäne** und wird unerbittlich das Raubtier porträtieren.* English Translation: 'Stefan interviews a hyena and will portray the predator unforgivingly.' Vehicle → Verbal-topic *Stefan wird eine **Hyäne interviewen** und wird unerbittlich das Raubtier porträtieren.* English Translation: 'Stefan will interview a hyena and will portray the predator unforgivingly.'	**Target Metaphoric Utterance** Verbal-topic → Vehicle *Stefan **interviewt** eine **Hyäne** und wird unerbittlich den Makler porträtieren.* English Translation: 'Stefan interviews a hyena and will portray the broker unforgivingly.' Vehicle → Verbal-topic *Stefan wird eine **Hyäne interviewen** und wird unerbittlich das Raubtier porträtieren.* English Translation: 'Stefan will interview a hyena and will portray the broker unforgivingly.'

Fig. 1. Example of a target utterance in Experiments 1 and 2 in the four conditions resulting from crossing the factors CONTEXT BIAS (Experiment 1 only) and SEQUENCE.

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

2.1. Participants

A sample of 32 native speakers of German (aged 18–31) with normal or corrected-to-normal vision participated in Experiment 1. They gave their informed consent and received 12 Euros each for their participation after completing the experiment (as did participants in Experiment 2). The number of participants was determined via an a priori power analysis through simulations based on data from a pilot study with the help of the R package SimR (Green & MacLeod, 2016). The power analysis determined that, with 32 participants, statistical power would be above 80% assuming a true effect size of Cohen's $d = 0.2$ for the difference between Metaphoric Verb–Object and Metaphoric Object–Verb conditions in the vehicle region (see Fig. 1 and Section 2.3 for an explanation of these conditions). This represents a 'small' effect size, following Cohen (1992). Both experiments were covered by the ethics vote of the psycholinguistics lab of the Humboldt-Universität zu Berlin granted by the German Linguistic Society.

2.2. Materials

2.2.1. Linguistic stimuli

We created 36 verb–object metaphors, which were paired with a literally biasing and a metaphorically biasing context (see Fig. 1). The 36 items were selected from an original pool of 38 following the results of a ratings task norming the metaphoric conditions (see Norming Study 1 in the Supplementary Material). Both contexts and target utterances were matched for length within every item (±2 characters) as well as for syntactic structure. The target sentences all had verbs with narrow selectional restrictions (see Norming Study 2 in the Supplementary Material). The last sentence in each context (within items) was identical across conditions, as well as the last sentence in the critical utterance except for the disambiguating word: In the literal conditions, participants heard the literal disambiguating word (e.g., *Raubtier*, 'predator'). In the metaphoric conditions, they heard the metaphoric disambiguating word (*Makler*, 'broker'). This word was the same one used in the written context for the given referent. Sentences were recorded by a female native speaker of German.

We normed the target metaphors for aptness and familiarity prior to conducting the experiment, as we report in the Supplementary Material. Every metaphor in the final set was rated to be above-average apt. In the norming study, we had participants select the correct interpretation of the metaphor in a multiple-choice task. In a further task, participants used a Likert scale from 1 to 7 to indicate how well they thought the sentence conveyed its metaphoric meaning. The multiple-choice norming study corroborated that their metaphoric meaning was correctly identified over 80% of the time for each item, with the exception of Item 1 (52%) and Item 24 (75%). The aptness task revealed that these two items were also the only to have a mean aptness score below 4 (Item 1: 2.63; Item 24: 3.35) and were excluded from the study. Based on these results, we think that the materials represent a sufficiently natural and comprehensible set of metaphors.

When constructing our materials, we chose to use the indefinite article for the metaphoric vehicle (e.g., *eine Hyäne*). We had in mind a generic use of the indefinite article, as is used in (for example) categorical statements such as *an apple is a fruit.* This is different from the specific indefinite article use, such as *an apple fell on my head.* The former type of sentence can be used to introduce a new topic, whereas the

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

latter cannot (see Burton-Roberts, 1976). Since the word *Hyäne* has not been previously introduced in the context, and it arguably introduces a new way of conceptualizing 'the broker', we believe it is appropriate to use the generic form. In contrast, using the definite article (*the hyena*) would result in a so-called 'bridging inference' that requires a presupposition accommodation: The comprehender must infer that there exists a 'hyena' in the discourse (existence presupposition) and that there is only a single 'hyena' (uniqueness presupposition). Presupposition accommodation has been shown to result in added processing effort (e.g., Domaneschi & Di Paola, 2018). Though interesting, investigating how metaphor comprehension interacts with the processing of presuppositions is beyond the scope of the current work.

2.2.2. *Visual stimuli*

Each item contained four photographs: One photograph depicted an object consistent with the literal meaning of the metaphoric vehicle (e.g., a picture of a hyena, for the example item in Fig. 1), and another photograph depicted an object consistent with its metaphoric meaning (e.g., a picture of a broker). Two further photographs served as unrelated distractors. The images were chosen from a pool of available photographs found on a popular search engine. The position of the images was randomized across items and participants.

2.2.3. *Filler items*

We created 72 additional combinations of written contexts and spoken utterances and used them as filler items. These included metaphoric utterances (that were not verb–object metaphors), idiomatic, and literal sentences. For the filler trials, there was always one target image and three distractors. All fillers are included in the Supplementary Material.

2.3. Design

Experiment 1 had a 2×2, repeated-measures design with the factors CONTEXT BIAS (Literal vs. Metaphoric) and SEQUENCE (Verb–Object vs. Object–Verb). CONTEXT BIAS refers to the type of linguistic context that participants read prior to hearing the target utterance. SEQUENCE indicates whether the main verb appeared before or after the direct object, which amounts to reversing the order of verbal topic and vehicle. This resulted in four versions of every item for each experimental condition.

2.4. Procedure

Participants' eye movements were recorded using an Eyelink 1000 plus, produced by SR Research. At the beginning of each experimental session, the eye-tracker was calibrated with a nine-point calibration procedure to ensure accurate monitoring of the right eye, while participants rested their head on a chin rest. The procedure was performed and repeated until there was less than a maximum error of 1°. If it was not possible to meet this criterion, the experiment was aborted, and participants were replaced ($N = 2$). Re-calibration was performed after every pause in the experiment,

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

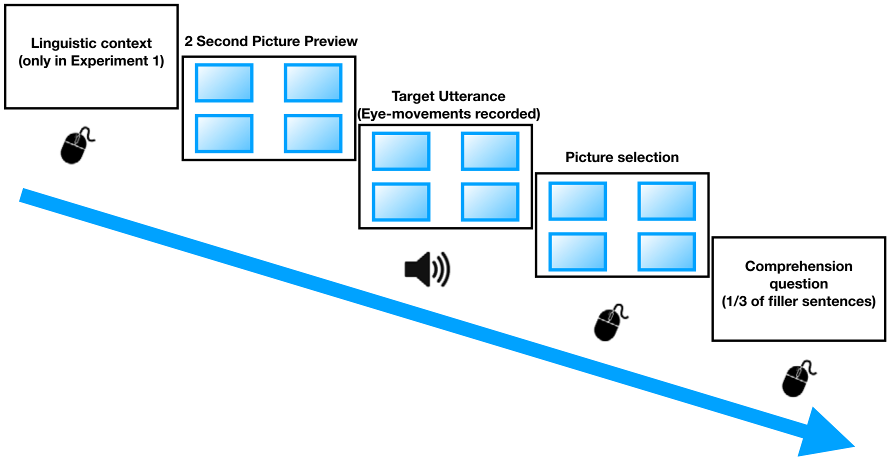

Fig. 2. Example of the progression of a trial in Experiments 1 and 2.

that is, twice more. After initial calibration, participants saw three practice trials before the experiment began.

On each trial, participants first read a four-sentence context and clicked the mouse key to continue. Then, they saw the visual context with four pictures. After 2 seconds of image preview, participants heard the target utterance as pictures remained on the screen. Participants were instructed to click on the image that they thought best fit the written context and the spoken sentence. They could only move the mouse once the spoken utterance had been played in its entirety. On 24 of the filler trials, participants were required to answer multiple-choice questions about either the written text (eight trials), the pictures (eight trials), or the spoken utterance (eight trials). The entire procedure is illustrated in Fig. 2.

2.5. Analysis

Prior to analysis, filler trials and critical trials in which the participants clicked on the incorrect picture were removed. (We also intended to remove participants who scored less than 80% accuracy on the comprehension questions, but none was below this threshold.) The remaining data were pre-processed using the R programming language (R Core Team, 2020) and R-Studio (RStudio Team, 2020). For data processing, visualization, and analysis, we used the following packages: VWPre (Porretta et al., 2017), ggplot2 (Wickham, 2016), lme4 (Bates et al., 2007), Rmisc (Hope, 2013), MASS (Ripley et al., 2013), dplyr (Wickham et al., 2015), DoBy (Højsgaard, 2012), ggpubr (Kassambara & Kassambara, 2020), papaja (Aust & Barth, 2017), here (Müller, 2017), and lmerTest (Kuznetsova et al., 2015). We first down-sampled the data to 500 Hz. We then calculated the proportion of fixations on each area of interest for every 20-millisecond time bin (time-locked to the beginning of each sentence region seen in Table 1). To analyze the eye-tracking record, we quantified participants' viewing preference by measuring the log ratio (Arai et al., 2007) between proportion of looks to the metaphoric picture divided by the proportion of looks to the literal picture. Log-ratio values are centered around 0, where

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

Table 1. Regions of interest for a critical item in Experiments 1 and 2

Region	Example item	Comment
VEHICLE	*eine Hyäne* ('A hyena')	The position of this region varied between conditions.
VERB	*interviewt* (Verb–Object conditions), or *interviewen* (Object–Verb conditions) ('interviews')	The position of this region varied between conditions.
UND	*und wird* ('and will')	This region was identical across all critical items, and its position in sentence identical within every item.
ADVERB	*unerbittlich* ('unforgivingly')	This region was always an adverb, and its position in sentence was identical within every item.
DISAMBIGUATION	*den Makler* (metaphoric conditions) ('the broker') or *das Raubtier* (literal conditions) ('the predator')	Word is identical to the word in the written context, its position in the sentence was identical within every item; the specific word changes based on the discourse context. This word disambiguates the intended referent.

positive values indicate a preference for the metaphoric picture and negative values indicate a preference for the literal picture.

We fitted linear mixed-effects regression models to each region of interest shown in Table 1. The VEHICLE and VERB regions are the critical regions for our study. The remaining regions were analyzed for the purpose of completeness, and their results are reported in the Supplementary Material. All gaze-data models included the factors CONTEXT BIAS, SEQUENCE, and their interaction as fixed effects as well as trial number as a control variable. Fitted models were 'maximal' (Barr et al., 2013), including random intercepts by items and participants, as well as random slopes for both factors (CONTEXT BIAS and SEQUENCE) and their interaction both by items and by participants. Non-convergence issues were handled by using the 'bobyqa' optimizer, allowing us to fit 'maximal' models for the eye-tracking data of both Experiments 1 and 2. Significance was assessed using the Satterthwaite approximation for computing p-values. The significance threshold was set at alpha $= 0.05$.

Models were coded using a treatment contrast scheme. We did this in order to tailor the contrasts to the specific hypotheses of the experiment – as recommended by Schad et al. (2020) – instead of relying on post-hoc pairwise comparisons. With treatment contrast, the coefficient of the intercept always tests the null-hypothesis of whether the outcome value (in our case, log ratios) of the baseline condition is equal to zero. The model's coefficients then test for 'simple' effects, that is, differences between individual conditions. This means that we can simultaneously test whether there are differences between conditions and whether the condition coded as the baseline is significantly different from zero, that is, whether there is an overall preference for the metaphoric or the literal picture throughout the region.

The models for the VEHICLE region and the VERB region were each fitted three times. The first model had the Metaphoric Verb–Object condition as the intercept, the second one had the Metaphoric Object–Verb condition as intercept, and the third one had the Literal Verb–Object condition as the intercept. Each model therefore tests whether each of these three conditions showed a preference for metaphoric or

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

literal picture in the corresponding time window. Since it takes about 180 milliseconds to plan and launch a saccadic movement in a visual-world set-up (Altmann & Kamide, 2004), we fitted an additional post-hoc model to the VERB region, shifting the time window 180 milliseconds after onset of the respective word. For this post-hoc model, we Bonferroni-corrected our significance threshold (alpha/2).

As supplementary measures, we analyzed reading times of the linguistic contexts and picture-selection times. We did this by fitting linear mixed-effects models on a square root transformation (context reading times) and an inverse square root transformation (picture-selection times) of the data. These transformations were made following the results of a Box–Cox test (Box & Cox, 1964) given that the residuals of the respective models were not normally distributed. These supplementary models did not include a 'maximal' random effects structure due to convergence issues: They excluded random correlations by items and by participants, as well as random intercepts by items.

All our linguistic materials, data, and analysis scripts are available under the following publicly accessible Open Science Framework repository: https://osf.io/85zwy/.

2.6. Predictions

2.6.1. VEHICLE region

The first set of predictions for Experiment 1 refers to both the potential effects of context and of sequential order on metaphor comprehension. First, we expected participants to generate different interpretations of the verb–object constructions (literal or metaphoric) as a function of context. We predict that in both literal CONTEXT BIAS conditions, participants will preferentially inspect the literal image (the hyena) when hearing the VEHICLE region (*Hyäne*) (reflecting a literal interpretation). In the metaphoric CONTEXT BIAS conditions, on the other hand, participants should prefer to look at the metaphoric picture (the broker), signifying that they are understanding the object of the verb metaphorically. This should result in significant differences in viewing patterns between both metaphoric conditions and their literal counterparts.

Regarding sequence: One way of studying the incremental effect of sequential order effects on metaphor comprehension is to examine how sequential order affects lexical processing. For example, in verb–object constructions (where there is not explicit metaphoric topic), will a metaphoric vehicle be processed differently depending on whether it is encountered before or after the verb? We predict that, if the position of the verb relative to the object impacts the way in which the object is processed, there should be significant differences in the log-gaze ratios between the Verb–Object and Object–Verb conditions in the vehicle region. Critically, we predict this to be the case for the metaphoric, but not for the literal conditions: If sequential order effects are metaphor-specific, there should be no effect of sequential order for the literal conditions in the vehicle region. This should result in a significant interaction between SEQUENCE and CONTEXT BIAS.

2.6.2. VERB region

The second prediction for Experiment 1 relates to the anticipation of postverbal objects. Altmann and Kamide (1999) showed that when hearing a verb, participants

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

preferentially directed their gaze to a picture of an object that is consistent with the verb's selectional restrictions. This is likely to happen in the Metaphorical context conditions, as far as the participants' interpretation of the vehicle is metaphorical. However, in the Literal Verb–Object condition, the verb's selectional restrictions are at odds with the discourse context. The linguistic context guides participants to expect the visual representation of the literal hyena to be the upcoming referent, but the verb's ('to interview') selectional restrictions are only compatible with a human as the object. There are (at least) three possible scenarios: Participants could rely on (1) the verb or (2) on the context to anticipate an upcoming object, or they could (3) not anticipate any object whatsoever. Accordingly, in the Literal Verb–Object condition, we would either expect (1) a preference for looking at the broker (compared to the hyena), (2) a preference for looking at the hyena (compared to the broker), or (3) no preference for either one when hearing the verb.

Finally, in order to make the case that the verb acts as a 'stand in' for the implicit metaphoric topic, it is important to show that participants prefer to inspect the image compatible with the metaphoric topic ('the broker') when hearing the verb. We predict that the Metaphoric Verb–Object condition will have a positive log-gaze ratio that is significantly different from zero.

2.7. Results

2.7.1. Context-reading times, picture-selection, and comprehension questions

There were no significant differences between reading times of the two types of contexts. There were also no significant differences in picture-selection times, although there was a numerical advantage in the Literal versus Metaphoric conditions. In terms of the picture selected, participants selected the literal picture in 99% of the trials in the Literal Conditions. Conversely, they selected the metaphoric picture in 98% of the trials in the Metaphoric conditions.

Participants were consistently accurate at answering the 24 comprehension questions on the filler items. The mean response accuracy was 93%, and the median accuracy was 94%. The minimum score for an individual participant was 84%, and the maximum was 100%.

2.7.2. Eye movements during the VERB Region

Model output is summarized in Tables A.1–A.4. (All tables are in the Appendix.) Fig. 3 shows the timecourse of log-gaze ratios. The first version of the model (Metaphoric–Verb–Object condition as intercept) showed a significant interaction between the factors CONTEXT BIAS and SEQUENCE, as well as a significant difference between Metaphoric–Verb–Object and Literal–Verb–Object. The intercept of the model was positive but not significantly different from zero. However, visual inspection of the data showed that participants preferentially inspected the metaphoric picture shortly after the onset of the verb. This was confirmed by a post-hoc analysis shifting the time window to 180 milliseconds after word onset, showing a significantly positive intercept. This suggests that when hearing the verb prior to the vehicle (after having read a metaphorically biasing context), participants anticipated the object that was compatible with both context and the verb's selectional restrictions (the broker).

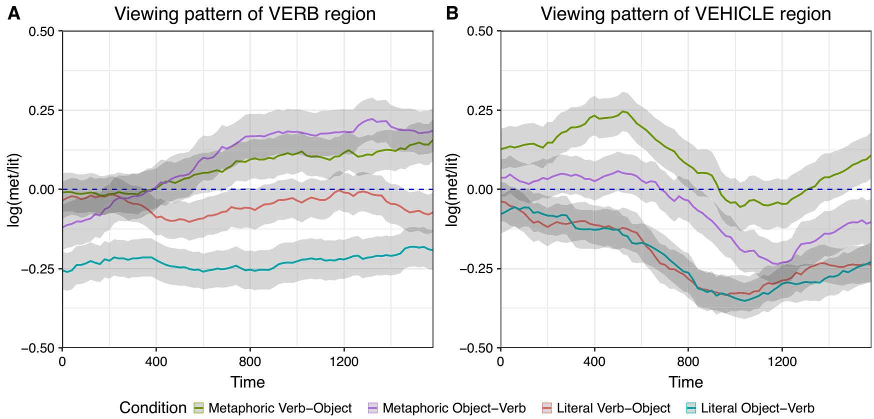

Fig. 3. Timecourse of VERB (Panel A) and VEHICLE (Panel B) regions (Experiment 1). The error bars show 95% confidence intervals.

The second version of the model (Metaphoric–Object–Verb as intercept) showed a significant difference between Metaphoric–Object–Verb and Literal–Object–Verb conditions. The intercept of the model was significantly positive, suggesting that participants preferred the ‘broker’ as the most likely referent.

Finally, the third model (Literal–Verb–Object condition as intercept) showed a significant difference between Literal–Verb–Object and Literal–Object–Verb conditions. The intercept of the model was not significantly different from zero, suggesting that participants reliably anticipated neither the object that was compatible with context (the hyena) nor the object compatible with the verb’s selectional restrictions (the broker). They only preferred to look at the hyena when they heard the verb after the object (Literal–Object–Verb conditions).

2.7.3. Eye movements during the VEHICLE Region

Tables A.5–A.7 show the output of the models, and Fig. 3 shows the timecourse of log-gaze ratios. First and foremost, there was a significant interaction between SEQUENCE and CONTEXT BIAS. The first version of the model (Metaphoric–Verb–Object condition as intercept) showed a significant difference between Metaphoric–Verb–Object and Metaphoric–Object–Verb conditions. Additionally, the intercept of the model was positive and significantly different from zero. This suggests both a rapid preference for a metaphoric interpretation in the Metaphoric–Verb–Object condition and a difference in processing depending on whether the vehicle appeared after or before the verb.

The second version of the model (Metaphoric–Object–Verb condition as intercept) showed a significant difference between Metaphoric–Object–Verb and Literal–Object–Verb conditions. The intercept of this model was negative but not significantly different from zero. However, visual inspection of Fig. 3 seems to suggest that participants did prefer to view the literal picture around 700 milliseconds after onset of the vehicle.

Finally, the third model showed no significant difference between Literal–Verb–Object and Literal–Object–Verb conditions. This suggests that the gaze preference

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

differences between Metaphoric–Verb–Object and Metaphoric–Object–Verb conditions were specific to metaphor comprehension.

2.8. Discussion

Experiment 1 had three major takeaways. First, sequential order affects how a verb's object is processed when understood metaphorically, but not literally: In both literal conditions, there was a marked preference for inspecting the literal (and not the metaphoric) picture in the VEHICLE region. Participants preferred to inspect the metaphoric picture (and not the literal picture) in this region only when it was mentioned after the VERB (Metaphoric–Verb–Object condition). When the vehicle preceded the verb, participants instead likely derived a literal interpretation of the vehicle first. This suggests a processing strategy mediated by sequential order.

Second, hearing the verb before the object in the metaphoric conditions likely activated a mental representation of the metaphoric topic. This follows from the fact that, when hearing the verb before the object, participants preferred to look at the metaphoric picture over the literal one (and over any of the other available images on display).

Third, participants did not anticipate any object in particular when the verb's selectional restrictions were at odds with the discourse context: There was no preference for the literal or metaphoric picture when hearing the verb in the Literal–Verb–Object condition.

In Section 4, we will revisit these findings and suggest how the theoretical views on metaphor comprehension presented in the Introduction might accommodate them. First, however, it is necessary to probe the source of the sequential order effects. It could be that differences between the Verb–Object and Object–Verb conditions are brought on by differences in sequence alone, and not by the context biases influencing metaphor processing. This makes it important to investigate whether said differences would persist when participants do not read a context encouraging a metaphoric interpretation of the utterance (and are therefore unlikely to understand the metaphor). We thus conducted Experiment 2, which investigates incremental processing of verb–object constructions in the absence of a discourse context.

3. Experiment 2

3.1. Participants

A further sample of 32 native speakers of German (aged 18–31) with normal or corrected-to-normal vision participated in Experiment 2.

3.2. Materials, design, procedure, and analysis

For Experiment 2, we used the same linguistic and visual materials as for Experiment 1, but omitted the discourse contexts. Experiment 2 resulted in a design with SEQUENCE as the only factor (levels: Verb–Object vs. Object–Verb). However, since the target sentences maintained the differences in disambiguating word ('predator' in the literal and 'broker' in the metaphoric utterances), the 2×2 design was maintained for the analysis of picture selection time and accuracy.

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

The procedure was identical to that described for Experiment 1, except that trials began with the presentation of the visual context, rather than the discourse context. Consequently, we changed the comprehension questions such that they were only about the spoken utterances or the pictures.

Experiment 2 was analyzed in a similar way to Experiment 1. Models including SEQUENCE and trial order as a fixed effect were fitted to the log-gaze probability ratios of looks to metaphoric picture over looks to literal picture in the VEHICLE and VERB regions. All models used a treatment contrast coding scheme. Models of gaze data were each fitted twice, changing the intercept of the model from the Verb–Object to Object–Verb condition. These analyses were planned a priori. Additionally, two post-hoc models were fitted to the gaze data of the VERB region with different dependent variables. One model used log-gaze probabilities of looks to metaphoric picture divided by looks to one of the distractor images, and the other model used log-gaze probabilities of looks to the metaphoric picture divided by looks to the other distractor image. As a final analysis, we conducted a between-experiment comparison, joining the data from Experiments 1 and 2 and fitting a new regression model including EXPERIMENT as a factor. This was done post hoc to assess differences in processing between experiments.

3.3. Predictions

We predicted that if the differences in the VEHICLE region of Experiment 1 between metaphoric Verb–Object and Object–Verb conditions were the consequence of a contextually triggered metaphoric interpretation, no such difference should appear in Experiment 2. This should also be accompanied by an interaction between SEQUENCE and EXPERIMENT in the between-experiment comparison. Alternatively, if these differences were not caused by metaphoric interpretation, we would expect a similar pattern to appear in the VEHICLE region of Experiment 2 relative to the metaphoric conditions of Experiment 1, and no interaction between SEQUENCE and EXPERIMENT.

Additionally, if participants rely on a verb's selectional restrictions to anticipate objects, there should be a significant difference between Verb–Object and Object–Verb conditions in the VERB region, with a larger log-gaze probability in the Verb–Object compared to the Object–Verb condition. Furthermore, the log-gaze ratio of the Verb–Object condition should be positive and significantly different from zero, which would represent a preference for the verb's ('interviews') preferred argument ('the broker') compared to the alternative argument represented by the competitor image ('the hyena').

3.4. Results

3.4.1. Picture selection and comprehension questions

Participants were faster at selecting a picture in the literal (i.e., after hearing the literal disambiguating word) compared to the metaphoric conditions (i.e., after hearing the metaphoric disambiguating word). They preferentially selected the literal picture as the referent over 90% of the times in the literal conditions and around 45% of the times in the metaphoric conditions. This suggests that without a context, it was difficult for participants to select the target representing the metaphoric interpretation, even after hearing the disambiguating word. Participants were very accurate in answering the comprehension questions. Mean response accuracy by participant was 95% (median: 94%). The lowest score was 89%, and the highest score was 100%.

3.4.2. Eye movements during the VERB region

As shown in Fig. 4, there was a significant difference between Verb–Object and Object–Verb conditions. Participants looked more at the picture of a broker (i.e., the picture of an object matching the verb's selectional restrictions) than at the picture of a hyena when hearing the verb 'interviews' before (compared to after) the object. We were particularly interested in whether the Verb–Object condition (i.e., the condition coded as the intercept) was significantly different from zero – knowing this would tell us whether participants were able to anticipate a postverbal referent when hearing the verb before the object. The results showed a positive intercept that was not significantly different from 0. There was no overall preference for looking at the metaphoric compared to the literal picture. This is shown in Fig. 4. Table A.8 shows the output of the model. However, visual inspection of the data does show that a preference for the metaphoric picture arises as time in this region progresses, which is why we fitted a post-hoc model analyzing the data 180 milliseconds after onset of the verb, analogously to the procedure in Experiment 1. This model showed a positive intercept significantly different form zero, and is shown in Table A.9.

3.4.3. Eye movements during the VEHICLE region

Fig. 4 shows the average log-ratio over time, and Tables A.10 and A.11 show the output of the statistical models. The regression analysis showed no significant difference between Verb–Object and Object–Verb conditions in this region. Both the first (Verb–Object as intercept) and the second (Object–Verb as intercept)

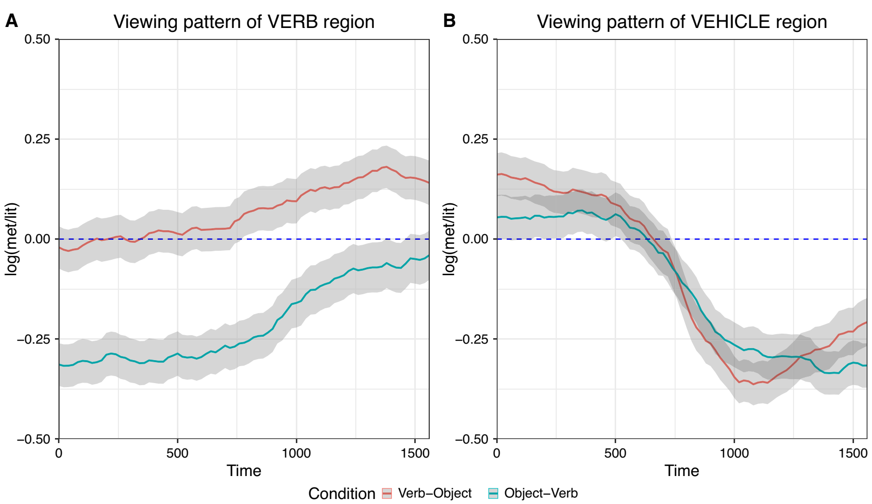

Fig. 4. Timecourse of VERB (Panel A) and VEHICLE (Panel B) regions (Experiment 2). The error bars show 95% confidence intervals.

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

regression models had a negative intercept coefficient that was significantly different from zero. Overall, participants displayed a preference for fixating the literal compared to the metaphoric picture. Finally, there was an interaction effect between EXPERIMENT and SEQUENCE, confirming the differences between Experiments 1 and 2, which is shown in Table A.12.

3.5. Discussion

Experiment 2 had two findings. First, sequential order effects on metaphor comprehension do not seem to be caused by sequence alone, but by the interaction between sequence and contextual bias. Second, when hearing the verb, participants preferred to inspect the picture compatible with the verb's selectional restrictions relative to the distractor images. A preference relative to the literal image seems to appear later in the region.

4. General discussion

In this study, we investigated the time course of comprehension of German verb–object constructions such as *Stefan interviewt eine Hyäne* ('Stefan interviews a hyena') in the presence (Experiment 1) or absence (Experiment 2) of a linguistic context. The context in Experiment 1 biased either toward a literal or toward a metaphoric interpretation of the target utterances. German verb–object metaphors allow for the position of their elements to be reversed without altering the interpretation beyond a change in tense (*Stefan wird eine Hyäne interviewen*, 'Stefan will a hyena interview'). Our main goal was to study both the effects of contextual bias and of the sequential order of the metaphoric elements on metaphor processing in order to evaluate how competing theoretical views might be able to account for them. We now turn to this critical point.

4.1. Extending the theories to account for German verb–object metaphors

In this article, we have argued for the need of studying metaphors beyond English nominal metaphors. One critical point in this regard is that different types of metaphors allow us to test different types of predictions. German verb–object metaphors, for example, allow us to test whether altering the sequence of elements in a metaphor changes the way in which the metaphor is processed, while keeping its meaning constant (except for changes in tense). For nominal metaphors, by contrast, the meaning changes in terms of who-is-what when reversing the elements in the metaphor. In German verb–object metaphors, there is no explicit mention of the metaphoric topic. Instead, the verb links to the topic and can elicit expectations of the vehicle. Because theories on metaphor comprehension have only examined cases where the topic is explicit (nominal metaphors, 'X is a Y'), it would be necessary to extend the theories in order to account for verb–object metaphors. What could such an extension look like? To start, let us consider how the theories predict lexical processing to unfold during nominal metaphor comprehension, and how this might be influenced by sequential order.

In this regard, the Structure Mapping Theory of Gentner and collaborators is fairly explicit. They state that the Structure Mapping Engine "begins blind and local by

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

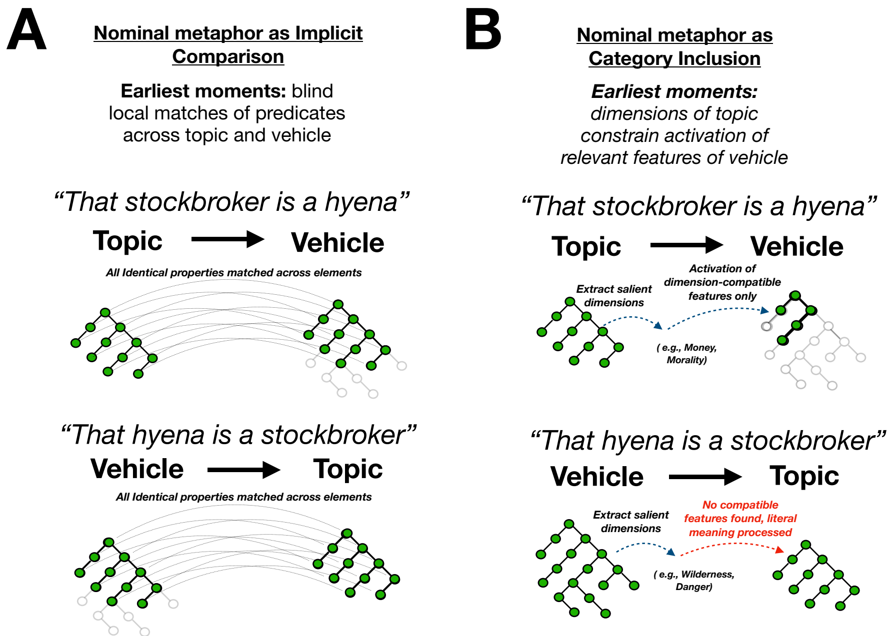

Fig. 5. Theoretical predictions for early stages of nominal metaphor processing.

matching all identical predicates in the two representations" (Gentner et al., 2001, p. 217; i.e., topic and vehicle). This initial stage is illustrated in Panel A of Fig. 5, adapted from Fig. 6.1 of Gentner et al. (2001). In Fig. 5, each structure tree represents the lexical entry of topic and vehicle, and each node in the tree represents a predicate of the lexical structure. The nodes colored green represent what each theory would predict to be activated in the first moments of metaphor comprehension, whereas the transparent nodes represent lexical features that are not activated. In Structure Mapping Theory, this early stage is blind and role-neutral. This means that the retrieval and activation of lexical information of topic and vehicle (the predicates within the individual representations; Gentner et al., 2001) must remain constant regardless of the sequence of the elements. In other words, to determine which lexical information within topic and vehicle has to be matched, said lexical information has to be activated before the 'matching' begins: One cannot decide which predicates are identical if a large amount of predicates has not been previously activated. One would therefore expect, if the Implicit Comparison view holds, that lexical processing of topic and vehicle would proceed similarly regardless of their sequential order (during early stages of comprehension). Importantly, for novel metaphors, the initial mental representations of topic and vehicle are identical to those elicited by a literal usage of the same words (Gentner et al., 2001, p. 228). Under the assumption that Structure Mapping Theory could be applicable to verb–object constructions, it is reasonable to state that regardless of the verb–object sequence, lexical information activated when processing the vehicle should remain constant. This is illustrated in Fig. 6.

In contrast, the Category Inclusion model, as framed by Glucksberg et al. (1997), sees metaphor comprehension as an interactive process from the earliest stages

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

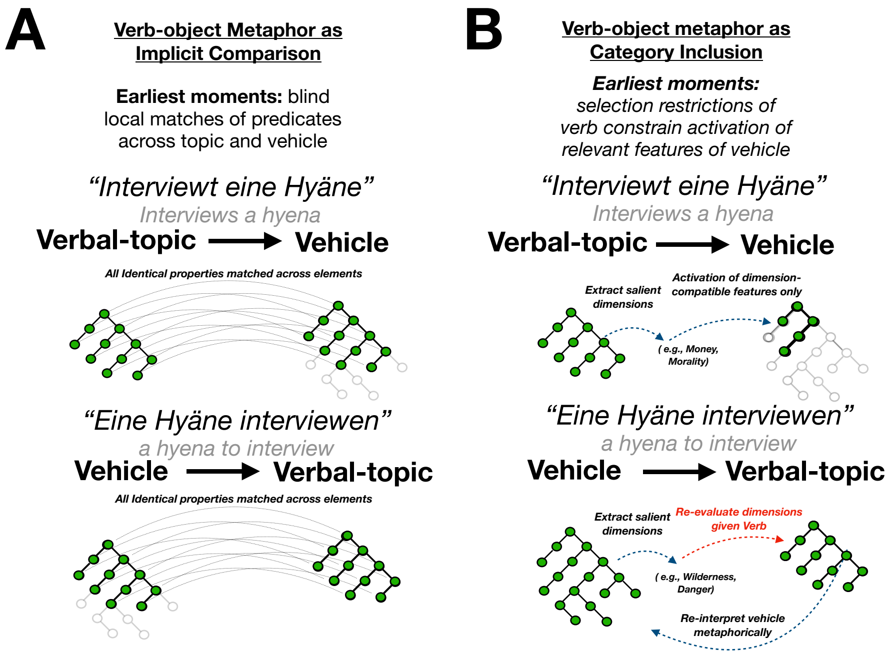

Fig. 6. Potential theoretical predictions for early stages of verb–object metaphor processing.

onward. The topic provides a set of interpretative dimensions that constrains the candidate properties of the vehicle that are then used to create an ad-hoc category of which the topic is identified as a member. Interpretative dimensions, according to Glucksberg (2001), are analogous to the notion of relevance in the conceptual combination literature (Murphy, 1988, 1990). The Category Inclusion model has the limitation of not being computationally instantiated (in contrast to Structure Mapping Theory), making it hard to pinpoint exactly what would be predicted to occur in early stages. In Panel B of Fig. 5, we offer a schematic instantiation of what the theory would predict for nominal metaphors: When the topic precedes the vehicle, dimensions for attribution are extracted. Based on these dimensions, only the most salient features of the vehicle are activated that can map onto said dimensions (instead of activating all predicates of the vehicle with a structural match to predicates of the topic, as the Structure Mapping Engine does). As argued by proponents of this theory, metaphor comprehension (for nominal metaphors) fails when the sequence is reversed (Glucksberg et al., 1997).

Because German verb–object metaphors are felicitously reversible, the Category Inclusion view would have to be amended to account for their comprehension. Our suggestion is spelled out in Fig. 6. Note that – for verb–object metaphors – we assume that the Category Inclusion Model would predict an initial activation of the literal meaning of the vehicle if it were encountered before the verb. After the verb is processed, the verb's selectional restrictions could allow dimensions to be highlighted, which retroactively allow for features of the vehicle to be constrained. This makes it clear that, in this model, activation of lexical properties of the vehicle is *contingent* upon extracting dimensions for attribution from the topic (in the nominal

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

metaphor case) or the verb (in the verb–object case). One would therefore expect, if the Category Inclusion model can be extended to verb–object constructions, that lexical processing of topic and vehicle will be different depending on which of the elements is processed first.

Our study suggests that the processing of German verb–object metaphors is contingent upon sequential order in context. Understanding the vehicle metaphorically was affected by whether the vehicle was heard before or after the verb. We interpret this as being more compatible with the extended Category Inclusion view that we have presented. This view critically assigns different roles to each element in a metaphor and predicts that the position of the elements will affect processing. Specifically, as we illustrated in Fig. 6, our results are compatible with the notion of lexical activation of the vehicle being contingent on prior activation of the verb: Hearing the verb triggers a search for features compatible with the verb's selectional restrictions. This facilitates processing of the vehicle and limits activation to only the relevant features needed to construct the ad-hoc category. When the vehicle is processed prior to the verb, more lexical information is accessed, since no dimensions are available to constrain activation. The critical cognitive mechanism in this process therefore seems to be category inclusion (as a special case of conceptual combination).

Our results are less straightforwardly compatible with our suggested extension of the Implicit Comparison view. Such an extension would suggest that processing a metaphor requires structural alignment of its elements prior to projecting inferences. This alignment process should be role-neutral, and the same amount of the vehicle's lexical information should be retrieved and activated whether it appears prior to or after the verb, as seen in Panel A of Fig. 6. In other words, it should be necessary to know the vehicle's full lexical structure before comparing it to the structure of the implicitly activated metaphoric topic. To accommodate the present results, it should be possible for the processing of the vehicle's meaning to vary as a function of its position relative to the verb, somewhat loosening the theory's stance on sequential order effects.

4.2. Context dependency of German verb–object metaphors

The existing literature on context effects on metaphor processing shows that processing can differ between contextualized and decontextualized nominal metaphors. For example, metaphors that are hard to understand or even incomprehensible in the absence of context can be swiftly understood when embedded in a supporting context (Gildea & Glucksberg, 1983). Our study extends this finding to verb–object metaphors. In the absence of a context (Experiment 2), participants did not seem to understand the metaphor. They likely activated a representation of the metaphoric topic ('the broker') when hearing the verb ('interviews'), but this activation was not enough to overturn a literal interpretation of the vehicle ('hyena'), as evidenced by participants' gaze record when they heard the vehicle and as evidenced by their picture selection at the end of the trial. We take this to mean that, in a verb–object metaphor of the type discussed in this article, context is not only influential but essential for the construction of metaphoric meaning. At least for the present stimuli, the verb's selectional restrictions were not enough on their own to trigger a figurative interpretation.

4.3. Anticipating postverbal objects

We draw the following conclusions regarding the anticipation of postverbal objects. First, it seems that a verb's selectional restrictions were not enough to override the influence of the linguistic context. This was not only visible in the metaphoric conditions, but in the literal conditions as well. In Experiment 1, participants quickly anticipated the referent that was compatible with both the context and the verb (metaphoric bias, Verb–Object condition). However, when context was pitted against the verb's selectional restrictions (literal bias, Verb–Object condition), participants did not anticipate any referent whatsoever. This finding is consistent with the results of Experiment 1 of Nieuwland and Van Berkum (2006). They found that hearing *the yacht* after a verb that requires an animate object (*consoled*) did not elicit an N400 relative to an animate object (*the sailor*) when the discourse context set up a 'cartoon-like' story in which a yacht goes to see a therapist. In that study, as in our own Experiment 1, it seems that a strong discourse context can 'neutralize' the verb's selectional restrictions.

Second, our results strongly suggest that faced with a verb–object pair with mismatching semantic features (e.g.,'interviews' and 'hyena') and no context (Experiment 2), participants chose to loosen the verb's selectional restrictions (e.g., they dropped the [+human] feature from the verb 'interviews'). This resulted in a literal interpretation of the word 'hyena' (significant preference for literal over metaphoric picture in the VEHICLE region). This finding is consistent with what has been dubbed *the verb mutability effect* (Gentner & France, 1988; King & Gentner, 2022). Under semantic strain (i.e., when a verb's selectional restrictions are not fully compatible with the lexical features of the subject), a verb's semantic features are more likely to be loosened than the semantic features of the verb's subject. Our Experiment 2 shows that the verb mutability effect could potentially be extended to verb–object combinations.

Experiment 2 also suggests that participants took, on average, longer to display postverbal anticipation effects relative to Experiment 1. This suggests that anticipation effects based on a verb's selectional restrictions alone are somewhat delayed in comparison to anticipation effects based on a combination of selectional restrictions together with a matching, biasing context.

This seems plausible considering the literature on anticipation of postverbal referents. In the hallmark study, Altmann and Kamide (1999) reported significant effects of anticipation prior to the onset of the postverbal noun. However, these effects were not significant prior to the offset of the verb (Altmann & Kamide, 1999, p. 253). In Kamide et al. (2003a), on the other hand, anticipation effects were significant already prior to verb offset (Kamide et al., 2003a, pp. 144–145). The main difference here was that in Altmann and Kamide (1999), anticipation was triggered by verb information, whereas in Kamide et al. (2003a) participants anticipated a postverbal referent based on cues given by the subject together with the verb. Perhaps then, an event representation built up via multiple cues (as in Kamide et al., 2003a) may enable more rapid anticipation of postverbal objects (but see Kamide et al., 2003b for evidence to the contrary).

5. Conclusion

The present study investigated how metaphors realized in German verb–object constructions are incrementally processed. We conclude that the interaction of

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

context bias and sequential order of the elements of a metaphor critically changes how metaphors – but not their literal counterparts – are processed. We see this finding as being more compatible with an extension of the Category Inclusion view than with an extension of the Indirect Comparison View of metaphor processing. We encourage researchers working on metaphor processing to further explore the way in which comprehension of non-nominal metaphors can be accounted for by existing theories.

Acknowledgments. We would like to thank Esma Tanis, Lea-Sophie Adam, Emanuelle Borchert, Thao Tran, Melis Odabaş, and Olga Buchmüller for their assistance in creating the materials and conducting the experiments.

Data availability statement. All data, analysis scripts, and linguistic materials for Experiments 1 and 2 are available in the project's OSF repository (https://osf.io/85zwy/).

Funding statement. This work was supported by the Agencia Nacional de Investigación *y* Desarrollo (ANID, Government of Chile) under the individual grant FONDECYT 1221792 (E.G.). Funding from ANID/PIA/Basal Funds for Centers of Excellence Project FB0003 is also gratefully acknowledged (E.G.).

References

Altmann, G. & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, 73(3), 247–264. https://doi.org/10.1016/S0010-0277(99)00059-1

Altmann, G. & Kamide, Y. (2004). Now you see it, now you don't: Mediating the mapping between language and the visual world. In J. Henderson & F. Ferreira (Eds.), *The interface of language, vision, and action: Eye movements and the visual world* (pp. 347–386). Psychology Press.

Arai, M., van Gompel, R. P. G., & Scheepers, C. (2007). Priming ditransitive structures in comprehension. *Cognitive Psychology*, 54(3), 218–250. https://doi.org/10.1016/j.cogpsych.2006.07.001

Aust, F. & Barth, M. (2017). Papaja: Prepare reproducible APA journal articles with R Markdown. *R package version 0.1. 0.9997.*

Bambini, V., Bertini, C., Schaeken, W., Stella, A., & Di Russo, F. (2016). Disentangling metaphor from context: An ERP study. *Frontiers in Psychology*, 7, 559.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Sarkar, D., Bates, M. D., & Matrix, L. (2007). The Lme4 package. *R Package Version*, 2(1), 74.

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition*, 75, 1–28. https://doi.org/10.1016/S0010-0277(99)00073-6

Box, G. E. P. & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society. Series B (Methodological)*, 26(2), 211–252.

Burton-Roberts, N. (1976). On the generic indefinite article. *Language*, 52, 427–448.

Chiappe, D., Kennedy, J. M., & Smykowski, T. (2003). Reversibility, aptness, and the conventionality of metaphors and similes. *Metaphor and Symbol*, 18(2), 85–105.

Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112(1), 155.

Coulson, S. & Oakley, T. (2005). Blending and coded meaning: Literal and figurative meaning in cognitive semantics. *Journal of Pragmatics*, 37(10), 1510–1536. https://doi.org/10.1016/j.pragma.2004.09.010

Domaneschi, F. & Di Paola, S. (2018). The processing costs of presupposition accommodation. *Journal of Psycholinguistic Research*, 47(3), 483–503.

Estes, Z. & Glucksberg, S. (2000). Interactive property attribution in concept combination. *Memory & Cognition*, 28(1), 28–34. https://doi.org/10.3758/BF03211572

Ferreira, F. & Chantavarin, S. (2018). Integration and prediction in language processing: A synthesis of old and new. *Current Directions in Psychological Science*, 27(6), 443–448. https://doi.org/10.1177/0963721418794491

Gentner, D. & Boronat, C. (1992). Metaphor as mapping. In *Workshop on Metaphor, Tel Aviv, Israel.*

Gentner, D. & Bowdle, B. (2008). Metaphor as structure-mapping. In R. Gibbs (Ed.), *The Cambridge handbook of metaphor and thought* (pp. 109–128). Cambridge University Press. https://doi.org/10.1017/CBO9780511816802.008

Gentner, D., Bowdle, B. F., Wolff, P., & Boronat, C. (2001). Metaphor is like analogy. In *The analogical mind: Perspectives from cognitive science* (pp. 199–253). The MIT Press.

Gentner, D. & France, I. M. (1988). The verb mutability effect: Studies of the combinatorial semantics of nouns and verbs. In S. I. Small, G. W. Cotrell, & M. Tanenhaus (Eds.), *Lexical ambiguity resolution* (pp. 343–382). Morgan Kaufman.

Gerrig, R. J. (1989). The time course of sense creation. *Memory & Cognition*, 17(2), 194–207.

Gildea, P. & Glucksberg, S. (1983). On understanding metaphor: The role of context. *Journal of Verbal Learning and Verbal Behavior*, 22(5), 577–590.

Glucksberg, S. (2001). *Understanding figurative language*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195111095.001.0001

Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences*, 7(2), 92–96. https://doi.org/10.1016/S1364-6613(02)00040-2

Glucksberg, S. (2008). How metaphors create categories–quickly. In R. Gibbs (Ed.), *The Cambridge handbook of metaphor and thought* (pp. 67–83). Cambridge University Press. https://doi.org/10.1017/CBO9780511816802.006

Glucksberg, S., McGlone, M. S., & Manfredi, D. (1997). Property attribution in metaphor comprehension. *Journal of Memory and Language*, 36(1), 50–67. https://doi.org/10.1006/jmla.1996.2479

Green, P. & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, 7(4), 493–498. https://doi.org/10.1111/2041-210X.12504

Guerra, E., Bernotat, J., Carvacho, H., & Bohner, G. (2021). Ladies first: Gender stereotypes drive anticipatory eye-movements during incremental sentence interpretation. *Frontiers in Psychology*, 12, 589429. https://doi.org/10.3389/fpsyg.2021.589429

Hintz, F., Meyer, A. S., & Huettig, F. (2017). Predictors of verb-mediated anticipatory eye movements in the visual world. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 43(9), 1352–1374. https://doi.org/10.1037/xlm0000388

Højsgaard, S. (2012). The doBy package. *R Package Version*, 4(3).

Holyoak, K. J. & Stamenković, D. (2018). Metaphor comprehension: A critical review of theories and evidence. *Psychological Bulletin*, 144(6), 641–671. https://doi.org/10.1037/bul0000145

Hope, R. M. (2013). Rmisc: Ryan miscellaneous. *R Package Version*, 1(5).

Huettig, F., Rommers, J., & Meyer, A. S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologica*, 137(2), 151–171. https://doi.org/10.1016/j.actpsy.2010.11.003

Inhoff, A. W., Lima, S. D., & Carroll, P. J. (1984). Contextual effects on metaphor comprehension in reading. *Memory & Cognition*, 12(6), 558–567.

Kamide, Y., Altmann, G., & Haywood, S. L. (2003a). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language*, 49(1), 133–156. https://doi.org/10.1016/S0749-596X(03)00023-8

Kamide, Y., Scheepers, C., & Altmann, G. (2003b). Integration of syntactic and semantic information in predictive processing: Cross-linguistic evidence from German and English. *Journal of Psycholinguistic Research*, 32(1), 37–55.

Kassambara, A. & Kassambara, M. A. (2020). Package 'ggpubr'. *R Package Version*, 0.1, 6.

Katz, J. J. & Fodor, J. A. (1963). The structure of a semantic theory. *Language*, 39(2), 170–210.

King, D. & Gentner, D. (2022). Verb metaphoric extension under semantic strain. *Cognitive Science*, 46(5), e13141.

Knoeferle, P. (2019). Predicting (variability of) context effects in language comprehension. *Journal of Cultural Cognitive Science*, 3, 141–158. https://doi.org/10.1007/s41809-019-00025-5

Knoeferle, P. & Guerra, E. (2016). Visually situated language comprehension. *Language and Linguistics Compass*, 10(2), 66–82. https://doi.org/10.1111/lnc3.12177

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2015). Package 'lmertest'. *R Package Version*, 2, 734.

Mani, N. & Huettig, F. (2012). Prediction during language processing is a piece of cake – But only for skilled producers. *Journal of Experimental Psychology: Human Perception and Performance*, 38(4), 843.

McGlone, M. S. & Manfredi, D. A. (2001). Topicvehicle interaction in metaphor comprehension. *Memory & Cognition*, 29(8), 1209–1219. https://doi.org/10.3758/BF03206390
Müller, K. (2017). *Here: A simpler way to find your files* [Manual].
Murphy, G. L. (1988). Comprehending complex concepts. *Cognitive Science*, 12(4), 529–562.
Murphy, G. L. (1990). Noun phrase interpretation and conceptual combination. *Journal of Memory and Language*, 29(3), 259–288.
Nieuwland, M. S. & Van Berkum, J. J. (2006). When peanuts fall in love: N400 evidence for the power of discourse. *Journal of Cognitive Neuroscience*, 18(7), 1098–1111.
Ortony, A., Schallert, D. L., Reynolds, R. E., & Antos, S. J. (1978). Interpreting metaphors and idioms: Some effects of context on comprehension. *Journal of Verbal Learning and Verbal Behavior*, 17(4), 465–477. https://doi.org/10.1016/S0022-5371(78)90283-9
Porretta, V., Kyröläinen, A., Van Rij, J., & Järvikivi, J. (2017). VWPre: Tools for preprocessing visual world data. *R Package Version*, 1(0).
Pouscoulous, N. & Dulcinati, G. (2019). Metaphor. In C. Cummins & N. Katsos (Eds.), *Oxford Handbook of experimental semantics and pragmatics*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198791768.013.19
R Core Team. (2020). *R: A language and environment for statistical computing* [Manual]. R Foundation for Statistical Computing.
Ripley, B., Venables, B., Bates, D. M., Hornik, K., Gebhardt, A., Firth, D., & Ripley, M. B. (2013). Package 'mass'. *Cran R*, 538, 113–120.
Ronderos, C. R., Guerra, E., & Knoeferle, P. (2020). The processing of German verb-object metaphors. In S. Denison, M. Mack, Y. Xu, & B.C. Armstrong (Eds.), *Proceedings of the 42nd Annual Conference of the Cognitive Science Society* (pp. 3384–3391). Cognitive Science Society.
RStudio Team. (2020). *RStudio: Integrated development environment for r* [Manual]. RStudio, PBC.
Rubio Fernandez, P. (2007). Suppression in metaphor interpretation: Differences between meaning selection and meaning construction. *Journal of Semantics*, 24(4), 345–371. https://doi.org/10.1093/jos/ffm006
Schad, D. J., Vasishth, S., Hohenstein, S., & Kliegl, R. (2020). How to capitalize on a priori contrasts in linear (mixed) models: A tutorial. *Journal of Memory and Language*, 110, 104038. https://doi.org/10.1016/j.jml.2019.104038
Sedivy, J. C., Tanenhaus, M., Chambers, C., & Carlson, G. N. (1999). Achieving incremental semantic interpretation through contextual representation. *Cognition*, 71(2), 109–147.
Sperber, D. & Wilson, D. (2008). A deflationary account of metaphors. In R. Gibbs (Ed.), *The Cambridge handbook of metaphor and thought* (pp. 84–105). Cambridge University Press. https://doi.org/10.1017/CBO9780511816802.007
Tanenhaus, M., Spivey-Knowlton, M., Eberhard, K., & Sedivy, J. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, 268(5217), 1632–1634. https://doi.org/10.1126/science.7777863
Tanenhaus, M. & Trueswell, J. C. (2006). Chapter 22: Eye movements and spoken language comprehension. In M. J. Traxler & M. A. Gernsbacher (Eds.), *Handbook of psycholinguistics* (2nd edn., pp. 863–900). Academic Press. https://doi.org/10.1016/B978-012369374-7/50023-7
Wickham, H. (2016). *Ggplot2: Elegant graphics for data analysis*. Springer.
Wickham, H., François, R., Henry, L., & Müller, K. (2015). *Dplyr: A grammar of data manipulation, R package version 0.4, 3*, p156.
Wilks, Y. (1975). A preferential, pattern-seeking, semantics for natural language inference. *Artificial Intelligence*, 6(1), 53–74.
Wilson, D. & Sperber, D. (2012). *Meaning and relevance*. Cambridge University Press. https://doi.org/10.1017/CBO9781139028370
Wolff, P. & Gentner, D. (2000). Evidence for role-neutral initial processing of metaphors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26(2), 529.
Wolff, P. & Gentner, D. (2011). Structure-mapping in metaphor comprehension. *Cognitive Science*, 35(8), 1456–1488. https://doi.org/10.1111/j.1551-6709.2011.01194.x

A. Appendix: Tables with results of Experiments 1 and 2

Table A.1. Results for Model 1, VERB region, Experiment 1

Term	$\hat{\beta}$	95% CI	t	df	p
Met–Verb–Object	0.07	[0.00, 0.14]	1.94	62.63	0.057
v. Lit–Verb–Object	−0.12	[−0.23, −0.02]	−2.27	55.52	0.027
v. Met–Object–Verb	0.01	[−0.08, 0.11]	0.29	52.49	0.772
Trial order	0.00	[0.00, 0.00]	−0.42	83,014.45	0.678
SEQUENCE × CONTEXT	−0.18	[−0.33, −0.04]	−2.48	59.18	0.016

Note. The first row shows condition coded as intercept.

Table A.2. Results for Model 1, starting 180 milliseconds after VERB onset, Experiment 1

Term	$\hat{\beta}$	95% CI	t	df	p
Met–Verb–Object	0.09	[0.02, 0.16]	2.55	62.83	0.013
v. Lit–Verb–Object	−0.15	[−0.25, −0.05]	−2.82	59.17	0.006
v. Met–Object–Verb	0.02	[−0.08, 0.12]	0.46	56.21	0.649
Trial order	0.00	[0.00, 0.00]	−0.33	83,356.62	0.744
SEQUENCE × CONTEXT	−0.18	[−0.33, −0.02]	−2.27	61.30	0.027

Note. The first row shows condition coded as intercept. *p*-values are Bonferroni-corrected.

Table A.3. Results for Model 2, VERB region, Experiment 1

Term	$\hat{\beta}$	95% CI	t	df	p
Met–Object–Verb	0.08	[0.01, 0.16]	2.27	61.86	0.026
v. Lit–Object–Verb	−0.30	[−0.41, −0.20]	−5.63	60.15	<0.001
v. Met–Verb–Object	−0.01	[−0.11, 0.08]	−0.29	52.49	0.772
Trial order	0.00	[0.00, 0.00]	−0.42	83,014.43	0.678
SEQUENCE × CONTEXT	0.18	[0.04, 0.33]	2.48	59.20	0.016

Note: The first row shows condition coded as intercept.

Table A.4. Results for Model 3, VERB region, Experiment 1

Term	$\hat{\beta}$	95% CI	t	df	p
Lit–Verb–Object	−0.05	[−0.12, 0.02]	−1.51	57.45	0.137
v. Met–Verb–Object	0.12	[0.02, 0.23]	2.27	55.53	0.027
v. Lit–Object–verb	−0.17	[−0.27, −0.07]	−3.30	60.17	0.002
Trial order	0.00	[0.00, 0.00]	−0.42	83,014.43	0.678
SEQUENCE × CONTEXT	0.18	[0.04, 0.33]	2.48	59.19	0.016

Note: The first row shows condition coded as intercept.

Table A.5. Results for Model 1, VEHICLE region, Experiment 1

Term	$\hat{\beta}$	95% CI	t	df	p
Met–Verb–Object	0.088	[0.025, 0.151]	2.75	61.60	0.008
v. Lit–Verb–Object	−0.297	[−0.383, −0.212]	−6.80	59.80	<0.001
v. Met–Object–Verb	−0.156	[−0.231, −0.081]	−4.07	60.29	<0.001
Trial order	0.001	[0.001, 0.002]	6.05	81,686.27	<0.001
SEQUENCE × CONTEXT	0.146	[0.032, 0.261]	2.50	61.14	0.015

Note: The first row shows condition coded as intercept.

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

Table A.6. Results for Model 2, VEHICLE region, Experiment 1

Term	$\hat{\beta}$	95% CI	*t*	*df*	*p*
Met–Object–Verb	−0.068	[−0.140, 0.004]	−1.84	59.00	0.071
v. Lit–Object–Verb	−0.151	[−0.250, −0.052]	−2.99	60.59	0.004
v. Met–Verb–Object	0.156	[0.081, 0.231]	4.07	60.29	<0.001
Trial order	0.001	[0.001, 0.002]	6.05	81,686.29	<0.001
SEQUENCE × CONTEXT	−0.146	[−0.261, −0.032]	−2.50	61.05	0.015

Note: The first row shows condition coded as intercept.

Table A.7. Results for Model 3, VEHICLE region, Experiment 1

Term	$\hat{\beta}$	95% CI	*t*	*df*	*p*
Lit–Verb–Object	−0.209	[−0.265, −0.153]	−7.31	60.46	<0.001
v. Met–Verb–Object	0.297	[0.212, 0.383]	6.80	59.80	<0.001
v. Lit–Object–verb	−0.009	[−0.096, 0.077]	−0.21	60.85	0.832
Trial order	0.001	[0.001, 0.002]	6.05	81,686.29	<0.001
SEQUENCE × CONTEXT	−0.146	[−0.261, −0.032]	−2.50	61.15	0.015

Note: The first row shows condition coded as intercept.

Table A.8. Results for Model 1, VERB region, Experiment 2

term	$\hat{\beta}$	95% CI	*t*	*df*	*p*
Verb–Object	0.07	[0.00, 0.14]	1.96	53.84	.055
v. Verb–Object	−0.27	[−0.39, −0.16]	−4.79	32.68	< .001
Trial order	0.00	[0.00, 0.00]	8.31	54,848.64	< .001

Note: The first row shows condition coded as intercept.

Table A.9. Results for Model 2, starting 180 milliseconds after onset of VERB region, Experiment 2

Term	$\hat{\beta}$	95% CI	*t*	*df*	*p*
Verb–Object	0.08	[0.01, 0.15]	2.38	54.76	0.021
v. Object–Verb	−0.26	[−0.37, −0.15]	−4.47	31.21	<0.001
Trial order	0.00	[0.00, 0.00]	8.26	54,937.57	<0.001

Note: The first row shows condition coded as intercept.

Table A.10. Results for Model 1, VEHICLE region, Experiment 2

Term	$\hat{\beta}$	95% CI	*t*	*df*	*p*
Verb–Object	−0.12	[−0.20, −0.05]	−3.23	35.70	0.003
v. Object–Verb	0.00	[−0.09, 0.08]	−0.11	28.89	0.917
Trial order	0.00	[0.00, 0.00]	9.32	54,428.94	<0.001

Note: The first row shows condition coded as intercept.

https://doi.org/10.1017/langcog.2022.22 Published online by Cambridge University Press

Table A.11. Results for Model 2, VEHICLE region, Experiment 2

Term	$\hat{\beta}$	95% CI	*t*	*df*	*p*
Object–Verb	−0.13	[−0.19, −0.06]	−3.93	52.29	<0.001
v. Verb–Object	0.00	[−0.08, 0.09]	0.10	28.89	0.917
Trial order	0.00	[0.00, 0.00]	9.32	54,428.94	<0.001

Note: The first row shows condition coded as intercept.

Table A.12. Results for between-experiment comparison, VEHICLE region

Term	$\hat{\beta}$	95% CI	*t*	*df*	*p*
Exp2–Verb–Object	−0.12	[−0.19, −0.06]	−3.75	79.87	<0.001
v. Lit–Verb–Object	−0.09	[−0.17, 0.00]	−2.03	81.17	0.045
v. Met–Verb–Object	0.21	[0.13, 0.29]	5.04	79.39	<0.001
v. Exp2–Object–Verb	−0.01	[−0.08, 0.07]	−0.14	72.78	0.886
Trial order	0.00	[0.00, 0.00]	11.98	136,512.95	<0.001
Exp2 × Exp1(lit)	−0.01	[−0.11, 0.10]	−0.09	72.91	0.929
Exp2 × Exp1(met)	−0.14	[−0.24, −0.05]	−2.91	73.41	0.005

Note: The first row shows condition coded as intercept.

Cite this article: Ronderos, C. R., Guerra, E. & Knoeferle, P. (2023). When sequence matters: the processing of contextually biased German verb–object metaphors *Language and Cognition* 15: 1–28. https://doi.org/10.1017/langcog.2022.22