Implicit causality and consequentiality of action verbs

Torgrim Solstad* and Oliver Bott

Fakultät für Linguistik und Literaturwissenschaft, Universität Bielefeld, Bielefeld, Germany

Investigating Implicit Causality (I-Caus) and Implicit Consequentiality (I-Cons) biases associated with action verbs (e.g., *Peter praised/healed Mary because/and so* …), this paper sheds light on the nature of the coreference and coherence biases associated with Implicit Causality verbs. We provide evidence in support of the Two-Mechanism Account, according to which I-Caus and I-Cons are driven by two different mechanisms: While I-Caus derives from empty explanatory slots for explanations in verb semantics, I-Cons follows from the general discourse principle of Discourse Contiguity. Evidence is provided by three production experiments in German investigating the coreference and coherence properties of agent-evocator and causative agent-patient verbs (e.g., *praise* vs. *heal*), which differ with regard to the availability of explanatory slots for I-Caus. Experiment 1 established I-Caus and I-Cons coreference biases for the two verb classes, while Experiment 2 investigated their corresponding coherence biases, showing that they pattern as predicted on the Two-Mechanism Account. Finally, Experiment 3 provided empirical evidence on the fine-grained types of causal relations associated with I-Caus and I-Cons for the two verb types.

1. Introduction

Causal relations like explanations or consequences play a constitutive role in the structuring of discourse. On the one hand, they have been argued to play a central role in the creation of mental representations of discourse that are retrievable from short- and long-term memory (Trabasso and van den Broek, 1985; Zwaan and Radvansky, 1998). Furthermore, identifying causal (and other) relations in texts has been argued to be an integral part of establishing discourse coherence also at the level of coreference (Hobbs, 1979; Kehler, 2002).

While much research on the linguistic properties of coherent discourse has focused on connectives such as *because* or *and so*, this paper discusses the possible role of verbs in the establishment of discourse coherence (Kehler et al. 2008, see also Das and Taboada 2018). More specifically, we investigate in which respect Implicit Causality verbs contribute to coherence at the level of discourse relations and coreference.

Implicit Causality verbs have figured prominently in psycholinguistic research on discourse expectations since the early 1970s (cf. e.g. Garvey and Caramazza, 1974; Brown and Fish, 1983; Au, 1986; Rudolph and Försterling, 1997; Hartshorne et al., 2015; Solstad and Bott, 2022). In general, Implicit Causality verbs can be used to describe interpersonal relations between two humans, as in (1). Most prominently, these verbs have been investigated with regard to *coreference* preferences in explanation and consequence relations in subsequent discourse. For instance, *annoy* as a member of the stimulus-experiencer subclass of Implicit Causality verbs has been found to typically trigger subject/stimulus continuations for Implicit Causality (after *because*) and object/experiencer continuations

for Implicit Consequentiality (after *and so*) in sentence completion tasks. For *praise* from the agent-evocator subclass, both biases have been found to be oriented towards the object/evocator argument:

(1) a. **Peter** annoyed Mary because … ✍ he was making a lot of noise.
b. Peter annoyed **Mary** and so … ✍ she decided to leave the room.
c. Peter praised **Mary** because … ✍ she had done a good job.
d. Peter praised **Mary** and so … ✍ she was very proud.

Intriguingly, subsequent research has shown that Implicit Causality verbs are also associated with a *coherence bias* (Kehler et al., 2008; Kehler and Rohde, 2019; Bott and Solstad, 2021; Solstad and Bott, 2022): When a full stop is inserted instead of the connectives in (1), participants predominately provide *explanations* over other types of discourse relations. Consequently, Implicit Causality verbs can be taken to be cues of both coherence as well as coreference relations.

Based on the coreference patterns in (1), previous theoretical approaches have attempted to explain both biases in terms of argument structure (see, in particular Crinean and Garnham, 2006; Hartshorne et al., 2015). Investigating action verbs of agent-evocator and agent-patient type, this paper provides further experimental evidence for an alternative theory, the *Two-Mechanism Account* (Solstad and Bott, 2022), according to which Implicit Causality (henceforth, I-Caus) and Implicit Consequentiality (henceforth, I Cons) biases are governed by different mechanisms.[1] The I-Caus coreference bias and the overall coherence bias towards explanations are accounted for in terms of Empty Slots in verb semantics triggering particular types of explanations. Contrary to this, the I-Cons coreference bias is taken to be based in the *Contiguity Principle*, a general discourse-structural mechanism, according to which discourse should continue from the last temporally available state (Kehler, 2002). Thus, both verb semantic and discourse-structural principles play a role in the coreference and coherence biases associated with Implicit Causality verbs. The upshot for the interaction between verb semantics and connectives in establishing discourse coherence is that not all phenomena that look the same—in particular, coreference biases for explanations and consequences—have the same foundations.

1.1. Implicit causality and consequentiality: offline and online processing

For explanations (e.g., after *because*), Implicit Causality verbs induce an I-Caus **coreference bias** to one of their arguments (with varying preferences for other discourse relations, cf. e.g. Ehrlich, 1980). The agent-evocator verb *praise* displays a strong I-Caus bias

towards the object (1c), while other verbs, like the psychological verb *annoy* display an I-Caus subject bias (1a). This has been shown for a number of production and comprehension tasks for several languages (Garvey and Caramazza, 1974; Brown and Fish, 1983; Au, 1986; Rudolph and Försterling, 1997; Goikoetxea et al., 2008; Ferstl et al., 2011; Hartshorne et al., 2013, 2015; Bott and Solstad, 2014; Garnham et al., 2020b; Solstad and Bott, 2022). Explanations aligned with the coreference bias as in (1c) are characterized as *bias-congruent*, whereas continuations in violation of it, like, for instance, a continuation about the subject of *praise*, are commonly referred to as *bias-incongruent*, cf. (2).

(2) Peter praised Mary because **he** felt she really deserved it.

I-Caus coreference biases have been discussed for four major verb classes: Psychological stimulus-experiencer and experiencer stimulus-verbs like *annoy* and *admire* are subject- and object-biased, respectively, while agent-evocator verbs like *praise* are predominantly object-biased. The fourth class, including agent-patient verbs like *telephone*, *betray* or *fool*, displays an overall balanced bias, with individual verb biases ranging between pronounced subject- and object-biases.

Implicit Causality verbs have been investigated for one further coreference bias, **Implicit Consequentiality**. I-Cons is found with result/consequence discourse relations as marked by *and so*, or similar (Au, 1986; Stewart et al., 1998; Crinean and Garnham, 2006; Commandeur, 2010; Hartshorne et al., 2015; Garnham et al., 2020b; Solstad and Bott, 2022). As illustrated in (1b) and (1d), both *annoy* and *praise* display an I-Cons object bias.

Verb class-internal I-Cons biases are also highly consistent. For experiencer-stimulus verbs (*admire*) and stimulus-experiencer verbs (*annoy*), I-Cons biases are reversed as compared to I-Caus, compare (1a) and (1b). Agent-evocator verbs like *praise*, on the contrary, display comparably strong object biases for both I-Caus and I-Cons, as shown in (1c) and (1d). Finally, agent-patient verbs display an object I-Cons bias (Garnham et al., 2020b), as opposed to their overall balanced I-Caus bias.

The **coherence** bias associated with Implicit Causality verbs, that is, the preference for providing explanations after a full stop as in *"Peter praised Mary."* has been less extensively studied. The few existing studies have shown that verbs with a pronounced coreference bias also tend to display a strong coherence bias towards explanations (Kehler et al., 2008; Bott and Solstad, 2014, 2021; Solstad and Bott, 2022). Interestingly, as first shown by Kehler et al. (2008), explanations after a full stop display the same coreference bias as explicitly elicited explanations after *because* (a result that was replicated in Bott and Solstad, 2014; Solstad and Bott, 2022). Consequently, a theory of I-Caus should account for why and how these two features would be interrelated.

It is important to note that I-Cons biases are strongly related to the presence of an explicit connective like *and so*. After all, continuations after a full stop overwhelmingly constitute explanations (Kehler et al., 2008). Thus, although both explanatory and consequential connectives are associated with a coreference bias, I-Caus and I-Cons cannot be claimed to be parallel with regard to both coreference and coherence. Based on this observation, Solstad and Bott (2022) argued that two different mechanisms are

---

1   The term "Implicit Causality verb" is used as a general cover term for all verbs displaying an Implicit Causality and/or Consequentiality bias. I-Caus and I-Cons are used as abbreviations to refer to those particular biases, respectively.

needed to derive I-Caus and I-Cons biases, a point to which we will return below.

Supporting the assumption that I-Caus involves (discourse) expectations, several online comprehension studies have revealed early effects right at the pronoun. These effects, often referred to as *focusing effects* in research on Implicit Causality, have been found for self-paced reading and eye-tracking during reading (Koornneef and van Berkum, 2006; Featherstone and Sturt, 2010; Koornneef et al., 2016), ERPs (van Berkum et al., 2007), probe tasks (Greene and McKoon, 1995; McDonald and MacWhinney, 1995), and eye-tracking in the visual world paradigm (Pykkönen and Järvikivi, 2010; Cozijn et al., 2011; van den Hoven and Ferstl, 2018b; Garnham et al., 2020a). Evidence is not clear-cut, though, as other studies have failed to find early effects and argued for (late) integration (e.g., Garnham et al., 1996; Stewart et al., 2000). Also, as stated by Garnham et al. (2020a), a number of the paradigms and designs applied in the studies advocating for focusing effects are not ideally suited to identify predictive processing (for a general discussion, cf. e.g. Pickering and Gambi, 2018).

So far, only two studies have been published on the online processing of I-Cons. In the visual-world paradigm, Garnham et al. (2020a) found evidence for the early influence of both I-Caus and I-Cons. No statistically reliable difference was found for the relative time course of the two coreference biases. Kim and Chun (2022) conducted a self-paced reading study on I-Cons in Korean, manipulating coreference and topichood. However, in their experiment only I-Cons object bias verbs were investigated, making it hard to relate their results to those of Garnham et al. (2020a).

Finally, a small number of online studies have investigated the processing consequences of the coherence bias. Rohde and Horton (2014) used an implicit learning paradigm to show that I-Caus stimuli trigger the expectation of an explanation relation. Furthermore, an eye-tracking during reading study by Hoek et al. (2021a) investigated processing effects at connectives marking cause and consequence relations. Their results revealed an I-Caus coherence bias effect on the reading times of a connective preceding the pronoun depending on whether the explanation was "pre-empted" in the matrix clause by means of a relative clause (*Diane fired the guy who was embezzling money*) or not (*Diane fired the guy who was here last month*). Based on this existing work, it is thus plausible to assume that the explanatory coherence bias also constitutes an expectation phenomenon— and that it may even be the driving force underlying the next-mention coreference bias (Bott and Solstad, 2014; Solstad and Bott, 2022).

1.2. Theoretical accounts of I-Caus and I-Cons

The theoretical implications of the above findings are still under debate. Previous research can be divided into two broad classes. *World-knowledge accounts* assume coreference biases to derive primarily from event knowledge schemata or social and affective properties of the events in question (Corrigan, 2001; Pickering and Majid, 2007; van den Hoven and Ferstl, 2018a; Kuehnast and Meier, 2019). In contrast, *verb-semantic approaches* explain the bias

patterns by applying to argument structure (Crinean and Garnham, 2006) or verb-semantic decomposition (Bott and Solstad, 2014, 2021; Hartshorne et al., 2015; Solstad and Bott, 2022).

Among verb-semantic approaches, there is less agreement as to what properties of the verb should be made responsible for coreference (and coherence) biases and how I-Caus and I-Cons can be related. Most verb-based approaches can be characterized as *One-Mechanism Accounts*: They have taken I-Caus and I-Cons to follow from the same principles (cf. e.g., Crinean and Garnham, 2006; Hartshorne et al., 2015). In general, these approaches make reference to the counterfactual nature of causal relations: There is no effect without a cause and if the verb is causal, we may focus on either the cause (I-Caus) or the effect (I-Cons) part of that relation. This seems to neatly account for the mirrored I-Caus and I-Cons biases of stimulus-experiencer and experiencer-stimulus verbs, where explanations refer to the causing stimulus argument and consequences are associated with the affected experiencer argument. However, this account runs into problems with agent-evocator verbs, which display an object bias for both I-Caus and I-Cons, and causative agent-patient verbs like *kill*, which mostly display a perfectly balanced I-Caus bias. Solstad and Bott (2022) have recently argued against One-Mechanism Accounts. Instead, they proposed that the two bias types are triggered by two different mechanisms.

1.3. A two-mechanism account of I-Caus and I-Cons

To account for **I-Caus**, Solstad and Bott (2022) proposed a mechanism based on fine-grained verb-semantic representations. Characterized as the *Empty Slot Theory*, this mechanism provides an integrated account of the coreference and coherence phenomena observed thus far (Solstad and Bott, 2013, 2022; Bott and Solstad, 2014, 2021). For **I-Cons**, a general discourse coherence principle, called the *Contiguity Principle* (Kehler, 2002), is assumed to drive coreference preferences.

The Empty Slot Theory assumes that I-Caus coreference as well as coherence biases are evoked by explanatory slots, or semantically underspecified entities associated with the biased arguments. For instance, the evocator object of *Peter praised Mary* is assumed to come with a presupposition as to a preceding eventuality involving *Mary* (for instance, Mary may have done an excellent job, see Au, 1986; Bott and Solstad, 2014, 2021, 2022; Solstad and Bott, 2023). This presupposition constitutes an external reason for Peter's action, that is, a reason external to his attitudinal state: If Peter praises Mary, the occasion on which he praises her also constitutes his external reason for praising her.

The biases are assumed to come about because we preferably avoid leaving it to interlocutors to accommodate underspecified content (e.g., Altmann and Steedman, 1988). Thus, the coherence and coreference biases for I-Caus can be considered to be grounded in a two-pronged strategy. First, the empty slot will trigger an explanation because it evokes a *why* question (an implicit Question Under Discussion, cf. Klein and von Stutterheim, 1987; Roberts, 1996/2012; Onea, 2016). Second, this explanation is biased towards

the argument associated with the slot. Thus, when participants provide an explanation about the biased evocator argument *Mary* in *Peter praised Mary because . . .*, they follow a strategy of filling the slot that is given by *praise*. Since this slot is causally related to the main eventuality—the agent's reason for praising the evocator is a presupposed state-of-affairs (e.g., Mary's excellent job), which causes the agent's intention to act (cf. Solstad, 2010), continuations tend to constitute an explanation even in the absence of a causal connective such as *because*.

Notably, agent-patient verbs are assumed to differ from agent-evocator (and also psychological verbs): They are not taken to involve any comparable underspecified entity that could be specified in a subsequent explanation. Take the causative agent-patient verb *poison*, which we do not assume to be presuppositional (contrary to *praise*). There may be an occasion for the act of poisoning, but it is not "hard-wired" into the semantics of the verb as it is for *praise* (see, in particular, Bott and Solstad, 2014, 2021).

Importantly, although the I-Caus bias is derived from an expectation for an explanation, it is not dependent on causality in the verb itself. If causality would be the decisive factor, causative verbs like *poison* should display a subject bias, since the subject is the agent causing a change of state in the patient. Quite to the contrary, there are a number of causative agent-patient verbs like *poison* or *kill* that do not display a clear coreference bias (Ferstl et al., 2011) and also have no strong coherence bias towards explanations (Bott and Solstad, 2014, 2021).

While the Empty Slot Theory claims that verb semantics is the major determinant of I-Caus, it does not exclude the influence of world knowledge (cf. e.g., Semin and Fiedler, 1988; Corrigan, 2001; van den Hoven and Ferstl, 2018b) or of other linguistic factors (such as passive voice; Au, 1986). Also, since biases are non-deterministic and even vary within classes, other factors than semantic underspecification must be assumed to be of relevance, possible candidates being the valence or arousal involved in an event (cf. e.g., Corrigan, 2001; Kuehnast and Meier, 2019).

Although the Empty Slot Theory has much in common with the proposals put forward by, for instance, Crinean and Garnham (2006), Hartshorne et al. (2013), and Hartshorne et al. (2015), one important difference is that the more fine-grained semantic analysis allows for a detailed semantic-pragmatic analysis of the particular explanation and consequence relations that can be found for Implicit Causality (Bott and Solstad, 2014, 2021; Solstad and Bott, 2022, Exp. 4).

What really sets the Two-Mechanism Account apart from those other approaches, however, is that it assumes a wholly different mechanism for I-Cons. I-Cons does not rely on the presence of a slot provided by verb semantics, according to Solstad and Bott (2022). Instead, they argue that I-Cons follows from what they call the *Contiguity Principle*, whereby a continuation from the end point of the previous eventuality is provided (following general assumptions in Kehler, 2002). The duality of the Empty Slot Theory and the Contiguity Principle can be illustrated for *praise*. As stated above, we take the presupposition of *praise* to constitute a slot that can be filled by an explanation. However, since *praise* is not causative, there is no causal end-state "slot" which could be targeted by an *and so* clause. Instead *and so* can only introduce a new eventuality subsequent to the one introduced by the Implicit

Causality verb in the prompt. Even causative agent-patient verbs like *poison* or *kill*, which do involve an end-state, do not (in cases that we are familiar with) provide a suitable end-state slot that can be filled by an *and so* clause. Thus, for *kill*, the end-state is already specified (as the patient being not alive) and does not offer itself for further elaboration. We see it as further evidence of this approach that the I-Cons coreference bias can only be found in the presence of an explicit connective like *(and) so* and that explanations are clearly dominant as continuations after full stop prompts for strongly biased verb classes (see above), but not for "non-biased" verbs (Kehler et al., 2008; Bott and Solstad, 2014).

Solstad and Bott (2022) provided evidence for the Two-Mechanism Account by investigating psychological Implicit Causality verbs of stimulus-experiencer and experiencer-stimulus type. In an offline discourse production study, Solstad and Bott (2022) looked beyond coreference and coherence, annotating some rather subtle subcategories among explanations and consequences. In previous research, the mirror biases for I-Caus and I-Cons for these verb classes has been taken as evidence for One-Mechanism Accounts. Solstad and Bott (2022) showed that although the coreference biases mirror each other, with I-Caus biases towards the stimulus argument and I-Cons biases towards the experiencer for both verb classes, there is a strong asymmetry with regard to coherence bias. Thus, in their Experiment 2 Solstad and Bott (2022) found these verbs to trigger three times as many explanations as consequences after a full stop. Crucially, Experiment 4 in that study provided evidence that the explanations and consequences for bias-congruent and bias-incongruent continuations follow distinct patterns, with only the bias-congruent *explanations* filling a slot in the predicate. Contrary to this, almost all consequences introduced eventualities subsequent to that introduced by the Implicit Causality verb in the prompt, as predicted by the Contiguity Principle.

However, the empirical coverage of their study crucially lacked a comparison of these psychological verbs with action verbs also commonly investigated in I-Caus and I-Cons research (Brown and Fish, 1983; Au, 1986; Rudolph and Försterling, 1997; Crinean and Garnham, 2006; Ferstl et al., 2011; Hartshorne and Snedeker, 2013; Bott and Solstad, 2014; Hartshorne et al., 2015; Garnham et al., 2020b). It also lacked a comparison between verbs with a clear I-Caus bias such as agent-evocator verbs and other action verbs that lack a clear bias like (causative) agent-patient verbs (Bott and Solstad, 2014, 2021). After all, an alternative, perhaps even more simple, explanation of the asymmetry in coherence biases between I-Caus and I-Cons could be stated in terms of the *Causality by Default Hypothesis* by Sanders (2005) (see also Kuperberg et al., 2011, for evidence from ERPs), according to which explanations constitute default coherence relations.[2] The present

---

2   As one reviewer points out, there is a superficial similarity to the copredication account of Murphy (2021). For cases like *The school had unruly students and lots of graffiti*, Murphy (2021, p. 19) argues that the dual interpretation of *school* as an abstract institution or a concrete building is facilitated by the causal relation between unruly students (cause) and graffiti (consequence). However, the Empty Slot Theory does not presume a particular semantic relation between the Implicit Causality verb and the

paper addresses this issue, presenting the results of production experiments closely parallel to those in Solstad and Bott (2022), in which we compare verbs with a semantic slot that is assumed to trigger explanations (agent-evocator verbs) to action verbs with no such slot (causative agent-patient verbs).

1.4. The present investigation: the importance of slots and contiguity

The present paper elaborates on the Two-Mechanism Account by investigating the influence of the presence or absence of slots for two types of action verbs: on the one hand, agent-evocator verbs, which carry a presuppositional slot associated with the evocator argument, and which is assumed to trigger explanations about this argument. On the other hand, we also included causative agent-patient verbs that are slot-less in the sense of the Empty Slot Theory. The latter verbs were chosen to be able to additionally investigate the assumption in previous research that verb causality is an important determinant of I-Caus and I-Cons coreference biases (Hartshorne and Snedeker, 2013; Hartshorne et al., 2015). Consequently, the present paper complements the investigation in Solstad and Bott (2022) in terms of its empirical coverage.

The Two-Mechanism Account makes a number of predictions for agent-evocator and agent-patient verbs. These predictions pertain to both coreference and coherence biases. For this reason, our experiments will investigate not only coreference biases (**Exp. 1**), but also the distribution of coherence relations (**Exp. 2**) and a fine-grained typology of causal relations (for explanations and consequences; **Exp. 3**).

First, the Empty Slot Theory predicts that agent-evocator verbs, which carry a slot for explanatory content associated with the object, should display a strong I-Caus object bias. On the contrary, agent-patient verbs involve no such slot, and should thus display a (more) balanced bias. Given that neither verb class involves a slot for consequences, and since the end point of the event introduced by these verbs is associated with their object argument, we predict from the Contiguity Principle a strong I-Cons object bias for both verb classes.

As to discourse relations, we can derive the prediction that the respective presence and absence of an explanatory slot in the two verb classes should lead to a difference in the distribution of explanations and consequences. Whereas agent-evocator verbs should trigger explanations as predicted by the Empty Slot Theory, agent-patient verbs should, following the Contiguity Principle, trigger more consequences than agent-evocator verbs, and, possibly, more consequences than explanations.[3]

With regard to causal discourse relations, we predict explanations and consequences to display distinct patterns, and more interestingly, agent-evocator and agent-patient verbs to differ in their distribution of explanation types, deriving from the respective presence and absence of an explanatory slot, which triggers particular types of explanations in agent-evocator verbs. At the same time, no difference is predicted in the types of consequences for the two verb classes, since these are driven by factors more independent of verb class.

2. Experiment 1: coreference biases

Experiment 1 established I-Caus and I-Cons coreference biases for the verb classes under investigation. While the selected agent-evocator predicates involve an empty slot for explanatory content associated with their object argument, the agent-patient verbs were not assumed to include any such slot. On the other hand, the selected agent-patient verbs were diagnosed to be causative in nature, involving a telic change of state and thus a salient end state. This allowed us to test whether verb causality can predict the coreference bias as suggested by Hartshorne and Snedeker (2013), Hartshorne et al. (2015), or whether biases does not follow from verb causality alone, as proposed in Bott and Solstad (2014, 2021).

2.1. Design

The sentence continuation experiment employed a $2 \times 2(\times 2)$ within-participants and within-items design manipulating the factors VERB TYPE (German *agent-evocator* vs. *agent-patient verbs*), CONNECTIVE (*weil* 'because' vs. *sodass* 'and so' prompts), and GENDER ORDER (NP1$_{fem.}$–NP2$_{masc.}$ vs. NP1$_{masc.}$–NP2$_{fem.}$). The latter factor was included in the design as a counterbalancing factor. The dependent variable was subject vs. object coreference of the first referring expression in the elicited sentence continuations.

2.2. Methods

2.2.1. Selection of verbs

We selected 20 German agent-evocator verbs which were either known to be associated with a strong I-Caus object bias from Bott and Solstad (2014, 2021) or close synonyms to those verbs. To us, as stated above, the defining criterion for agent-evocator verbs is whether they presuppose that there was an occasion that could constitute an external reason for the agents action (see also Au, 1986). As a diagnostic for the presence of such a presupposition, we used the classical negation test (see, e.g., Levinson, 1983), according to which we still infer that the presupposed content holds if a sentence is embedded under sentential negation. Thus, for *loben* 'praise', we would infer for both (3a) and it's negated counterpart (3b) that there was an occasion, upon which one could praise the evocator *Mary*:

---

predicate occurring in the *because* clause to be necessary for a causal relation to be established. Quite to the contrary: Although there are obviously typical and less typical ways of explaining a state-of-affairs, the point is that the Implicit Causality verb itself lexically triggers any subsequent sentence to be preferably interpreted as a cause/an explanation (see also the discussion in Asher and Lascarides, 2003, p. 251−252).

3 Solstad and Bott (2022) reported one more experiment (their Exp. 3) using a forced-reference paradigm for full stop continuations. This experiment is not paralleled in the current paper because I-Caus and I-Cons coreference

---

biases are not orthogonal for the verb types investigated here. This was, however, a central design feature in Solstad and Bott (2022).

(3)   a.   Peter praised Mary.
      b.   <u>It is not the case that</u> Peter praised Mary.

Furthermore, we selected 20 causative agent-patient verbs such as *poison*. The defining criterion for prototypical causative verbs is that the agent argument brings about a change of state in a patient. As our starting point, we included verbs from Levin (1993) classes involving a change of state like *vergiften* 'poison' and *töten* 'kill' (Class 42) or *heilen* 'heal' (Class 45). However, since many of the classical verbs of change of state did not seem suitable in non-metaphorical interpersonal relations (e.g., *break* or *destroy*), we included a number of verbs describing (i) caused change of position (e.g., *verjagen* 'chase away', *vertreiben* 'drive off', *wegschubsen* 'push away') or (ii) deprivation of possession (*berauben* 'rob', Levin Class 10.6). Importantly, these verbs should not carry a presupposition with regard to an occasion for the agent's action, which we again diagnosed using the negation test in (3): Whatever one may believe of there being an occasion for *Mary poisoned Peter*, the sentence *It is not the case that Mary poisoned Peter* does not seem to presuppose that there was such an occasion.

2.2.2. Participants

A total of 56 native German speakers (28 female, 28 male; mean age 24.6 years, range 18–35 years) reporting to be students were recruited via Prolific (www.prolific.co) and gave their informed consent to participate in the experiment for monetary compensation of £6. Participants were randomly assigned to eight lists with 7 participants in each list.

2.2.3. Materials

A total of 20 items were constructed according to a "*name verb-ed name, connective*" scheme following the above design, pairing one out of 20 German agent-evocator verbs with one of 20 agent-patient verbs (see the Open Science Framework archive at https://osf.io/gvbt3/) in combination with 20 unambiguously female and 20 unambiguously male German first names.

A Latin Square design was used to distribute the experimental items in eight prompt conditions on four lists. This was done in such a way that each item appeared twice in each list, once with an agent-evocator verb and one of the connectives and a second time with the respective agent-patient verb and the other connective, yielding a total of 40 experimental trials in each list. A sample item for the agent-evocator verb *congratulate* and the agent-patient verb *poison*, including the list distribution, is shown in (4):

(4)   a.   Margarethe congratulated Paul because … 🔊 (list 1)
      b.   Paul congratulated Margarethe because … 🔊 (list 2)
      c.   Margarethe poisoned Paul because … 🔊 (list 3)
      d.   Paul poisoned Margarethe because … 🔊 (list 4)
      e.   Margarethe congratulated Paul and so … 🔊 (list 4)
      f.   Paul congratulated Margarethe and so … 🔊 (list 3)
      g.   Margarethe poisoned Paul and so … 🔊 (list 2)
      h.   Paul poisoned Margarethe and so … 🔊 (list 1)

In addition, there were 80 filler trials, 40 of which were trials from Experiment 2 with full stop continuations ("Name₁

verb-ed Name₂.") and 40 of which employed stimulus-experiencer and experiencer-stimulus psych verbs in "connective plus pronoun" prompts ("Name₁ verb-ed Name₂ because/and so he/she …"), comparable to those in Experiment 3. Overall, participants received as many explanation prompts as they received consequence prompts.

2.2.4. Procedure

The experiment was conducted via the internet employing the free OnExp software (version 1.3.1, see http://onexp.textstrukturen.uni-goettingen.de/). After reading written instructions, participants proceeded to a short practice of three trials, upon which they received the experiment with 120 individually randomized trials in a single block. In each trial, a text field with the prompt appeared in the top of the browser with a sentence fragment ending in "…" and participants were asked to type the first continuation that came to their mind. There was no time limit for providing an answer. Only participants that completed the experiment were included in the analysis. On average, an experimental session took about 30 minutes.

2.2.5. Data annotation

The resulting data set of 2,240 continuations was annotated according to the following categories. First of all, it was coded whether the continuation was complete and sensible, excluding 68 cases (=3.0%) from the further analysis. It was then coded whether the continuation contained at least one anaphoric expression coreferent with NP1 (the linearly first name in the prompt) or NP2 (correspondingly, the second name), excluding another 125 cases (=5.6%). Since German allows both subject-verb-object (SVO) and object-verb-subject (OVS) interpretation of the prompts, it was subsequently coded whether the continuation corresponded to an SVO reading of the sentence prompt. Only SVO cases were included in the analysis, excluding 15 (=0.7%) OVS cases. Consequently, a total of 2,032 continuations were included in the annotation, in which the coreference of the first anaphoric expression with the subject or object in the prompt was recorded. The annotations were performed by two trained student assistants. Inter-annotator reliability for a subset of 200 continuations was found to be high enough (Cohen's κ for the biases was 0.86).

In the course of the annotation of the data from Experiment 3, it became clear that the connective *sodass*, which is ambiguous between a consequential interpretation (corresponding to "and so") and a purpose reading ("in order to"), was interpreted quite often as signaling purpose relations with the agentive verbs in this study. Since the purpose relation constitutes an explanation, rather than a consequence, the *sodass* 'and so' data from Experiment 1 were annotated post hoc by the first author and a student assistant for instances of purpose relations (a test replacing *sodass* by *damit* 'in order to' was used). All cases were resolved in agreement. As a consequence of this annotation, another 107 cases (=4.8%) were excluded from the the statistical analysis.

2.2.6. Statistical analysis

All remaining 1,925 continuations were statistically analyzed by fitting logistic mixed-effects regression models

with the afex and lme4 packages (Bates et al., 2015; Singmann et al., 2021) in R (version 4.2.2). The dependent variable was verb bias, that is, subject (coded as 1) vs. object reference (coded as 0). All predictors were centered. Due to failed convergence of more complex models computed including random slopes, the models reported throughout the paper only include random intercepts for participants and items. The significance of fixed effects was determined via model comparisons (model with vs. without the effect in question) by performing likelihood ratio tests.

A total of 95% confidence intervals of the condition means both for I-Caus as well as I-Cons biases of individual verbs were estimated applying non-parametric bootstrapping (Efron and Tibshirani, 1986) with the bootstrapping function from R's *bootstrap* package. All analyses and data are publicly available at the following Open Science Framework repository: https://osf.io/gvbt3/.
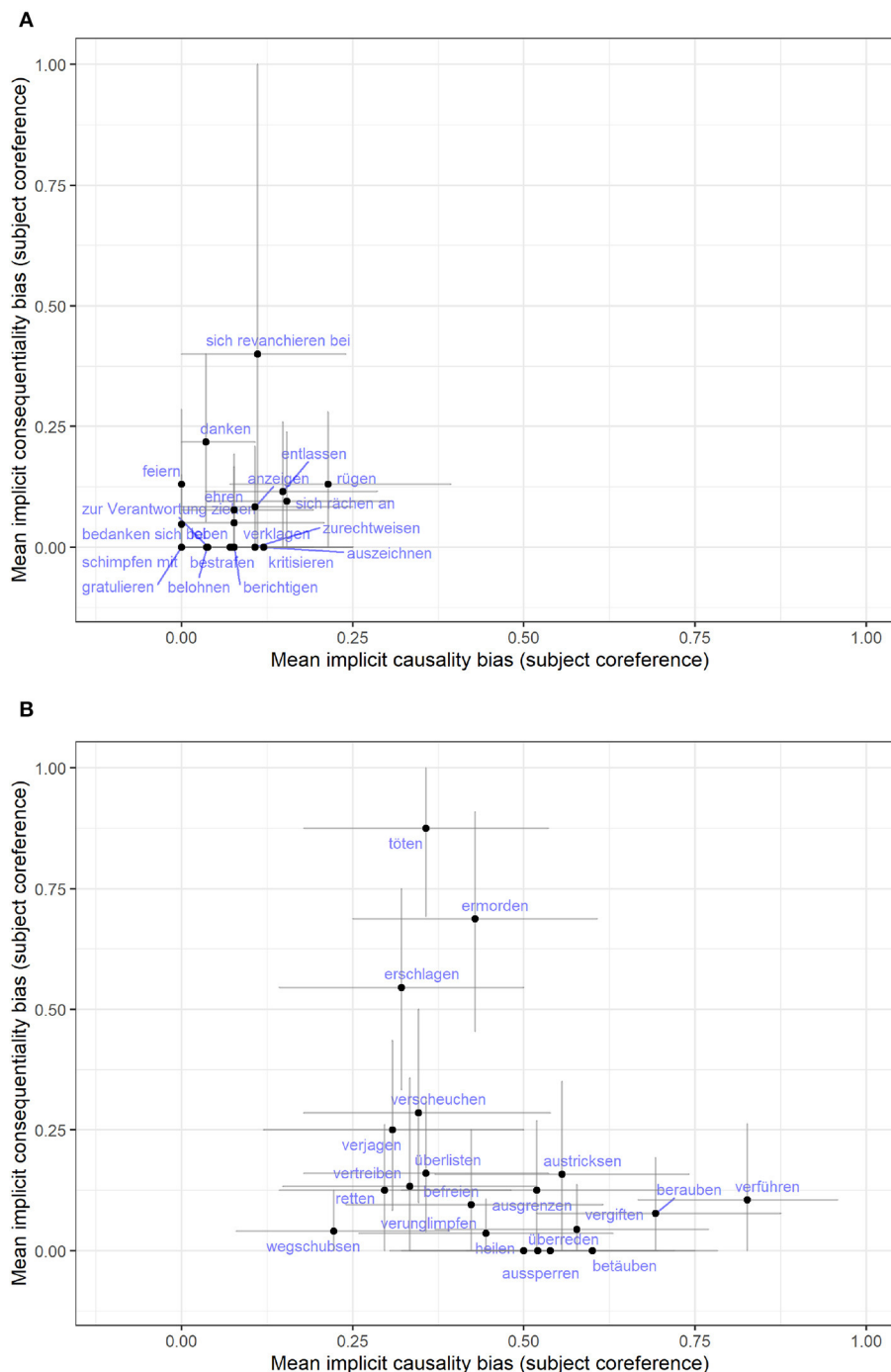

FIGURE 1
I-Caus and I-Cons biases of the verbs in the study plus bootstrapped 95% confidence intervals. I-Caus biases are plotted on the x-axis and I-Cons biases on the y-axis as the likelihood of coreference with the subject. The top panel **(A)** shows the biases of agent-evocator verbs and panel **(B)** at the bottom shows the biases of causative agent-patient verbs.

2.3. Results and discussion

The I-Caus and I-Cons biases for the agent-evocator and the causative agent-patient verbs are shown in Figure 1 with the descriptive statistics summarized in Table 1. Furthermore, a table of all verbs with their individual I-Caus and I-Cons biases can be found in the Supplementary material accompanying this article.

The verb classes clearly differed from each other in their respective I-Caus and I-Cons biases[4]: While agent-evocator verbs exhibited strong, uniform biases towards the object for both I-Caus and I-Cons, agent-patient verbs displayed a balanced I-Caus bias and an I-Cons bias towards the object argument with the three exceptions of *kill* type verbs in the sample, i.e., *töten* 'kill', *ermorden* 'murder', and *erschlagen* 'slay'.

The logit mixed model analysis corroborated the observed differences between the two verb classes. The GLMER analysis revealed a significant interaction between VERB TYPE and CONNECTIVE ($\hat{\beta} = 0.26, SE = 0.08, z = 3.33, p < 0.001$) as well as significant main effects of VERB TYPE ($\hat{\beta} = -0.92, SE = 0.08, z = -11.77, p < 0.001$) and CONNECTIVE ($\hat{\beta} = -0.45, SE = 0.08, z = -5.88, p < 0.001$). To break down the interaction, separate logit mixed-effects regression models were fit for the two verb classes.

The analysis of agent-evocator verbs revealed a strong overall object bias as indicated by a negative intercept estimate significantly below zero ($\hat{\beta} = -3.02, SE = 0.25, z = -11.88, p < 0.001$). What is more, there was no difference between the two connectives (fixed effect CONNECTIVE: $\hat{\beta} = -0.18, SE = 0.14, z = -1.32, p = 0.19$). Thus, the agent-evocator verbs showed equally strong I-Caus and I-Cons object biases.

The analysis of agent-patient verbs revealed a clear difference in bias strength as evidenced by a reliable effect of CONNECTIVE ($\hat{\beta} = -0.72, SE = 0.08, z = -8.89, p < 0.001$). In the *sodass* 'and so' conditions they displayed a clear object bias (82.9% coreference with the object argument). In order to investigate whether the agent-patient verbs were in fact unbiased with respect to I-Caus, the *because* agent-patient conditions were subjected to another GLMER analysis. This analysis revealed that the intercept indeed did not significantly differ from zero ($\hat{\beta} = -0.19, SE = 0.15, z = -1.27, p = 0.21$). Thus, the agent-patient verbs were completely unbiased with regard to I-Caus, even though they are clearly causative with a subject displaying causal efficacy.

Overall, the biases observed in this experiment closely resemble those reported in the literature (e.g., Ferstl et al., 2011; Garnham et al., 2020b): Agent-evocator verbs display a pronounced object bias for both I-Caus and I-Cons, while agent-patient verbs have a balanced I-Caus bias and an I-Cons object bias. The difference with regard to I-Caus coreference bias confirms our predictions derived from the Empty Slot Theory. Agent-evocator verbs involve an explanatory slot which is targeted uniformly in sentence continuations, while agent-patient verbs lack such

---

4 The Implicit Consequence bias of the verb *sich revanchieren* 'pay back' was almost unidentifiable because most consequence continuations only contained a plural anaphora (e.g., *so they were even again*).

TABLE 1 Relative and absolute (n) frequencies of subject vs. object coreference for Implicit Causality (*because*) and Implicit Consequentiality (*and so*) for agent-evocator and agent-patient verbs in Exp. 1.

	Subject		Object	
	%	n	%	n
because				
Agent-evocator	7.9	(42)	92.1	(490)
Agent-patient	45.4	(239)	54.6	(288)
and so				
Agent-evocator	5.5	(24)	94.5	(416)
Agent-patient	17.1	(73)	82.9	(353)

a slot, hence no I-Caus bias is expected. With regard to I-Cons, the results are also in line with our proposal concerning the Contiguity principle and I-Cons. The two verb classes, which carry no corresponding slot for consequences, behave rather similarly, with all verbs displaying I-Cons biases towards the object argument directly affected by the described action. The only exceptions to this general trend were the *kill* type verbs. This is not unexpected, however, as it seems highly unnatural to provide a consequence about the patient, since these verbs essentially imply the non-existence of the deceased object referent.

3. Experiment 2: coherence relations

Experiment 2 investigated the distribution of discourse relations and anaphoric dependencies after a full stop (for a similar approach, see, e.g., Kehler et al., 2008; Bott and Solstad, 2014, 2021; Solstad and Bott, 2022). In particular, we were interested in the distribution of explanation and consequence relations, corresponding to the two connectives *weil* 'because' and *sodass* 'and so'. If there is a slot in agent-evocator verbs that triggers (particular types of) explanations, this slot should exert its influence also in the absence of a causal connective. With no such slot in agent-patient verbs, the Empty Slot Theory predicts significantly fewer explanations for agent-patient verbs than agent-evocator verbs with full stop prompts. What is more, the Contiguity Principle predicts that there should be more consequence relations for causative agent-patient verbs than agent-evocator verbs since the causative, telic nature of the former offer a prominent endpoint that consequence relations can take as their "reference point".

The study by Bott and Solstad (2014) suggested that explanations are indeed strongly preferred for agent-evocator verbs, which were followed by explanations in approximately 60% of all cases. Furthermore, in the studies by Kehler et al. (2008) and Solstad and Bott (2022) explanations were three times more frequent than consequences overall for verbs with a strong I-Caus bias. For causative agent-patient verbs, Bott and Solstad (2021) reported significantly less explanations than for I-Caus bias verbs, without differentiating between other coherence relations. Based on these earlier findings, we expected the distribution of causal discourse relations for

agent-evocator relative to causative agent-patient verbs to pattern along these lines.

3.1. Design

The sentence continuation experiment employed a $2(\times2)$ within-participants and within-items design manipulating the factors VERB TYPE (*agent-evocator* vs. *agent-patient*), and GENDER ORDER (NP1$_{fem.}$–NP2$_{masc.}$ vs. NP1$_{masc.}$–NP2$_{fem.}$). The latter was included in the design as a counterbalancing factor. The continuations were annotated with respect to discourse relations and anaphoric dependencies.

3.2. Methods

3.2.1. Participants

The experiment was run together with Experiment 1, testing the same 56 participants allowing for cross-experiment statistical comparisons (see below).

3.2.2. Materials and procedure

The 20 agent-evocator and 20 agent-patient items from Experiment 1 were modified by taking out the connectives and inserting a full stop, as illustrated in (5):

(5) a. **agent-evocator**

Margarethe/Paul congratulated Paul/Margarethe. 🔊

b. **agent-patient**

Margarethe/Paul poisoned Paul/Margarethe. 🔊

A Latin Square design was used to distribute the resulting 20 items in four prompt conditions on two lists such that each item appeared twice in both lists but, crucially, each verb appeared only once. The 40 trials of Experiment 1 and 40 trials comparable to those in Experiment 3 served as fillers for the current experiment. This combination of experiments was exactly the same as in Solstad and Bott (2022). Overall, half of the filler trials with connectives contained *weil* 'because' and half contained *sodass* 'and so'. The procedure was identical to the one in Experiment 1.

3.2.3. Data annotation

The resulting data set of 2,240 continuations was annotated by the same two trained student research assistants as for Experiment 1 according to the following coding scheme. First, it was annotated whether the continuation was sensible *and* complete, excluding 444 cases (=19.8%) from the further analysis (the majority of these involved continuations that constituted a sensible completion of the prompt itself instead of a new, independent sentence, as in *Paula decorated Nico. . . . for his commitment*).

For the discourse relation analysis, the remaining 1,796 continuations were categorized into the following discourse relations: In a first step, we annotated relations of explanation (using a *weil* 'because' insertion test) and consequence (using a

sodass 'and so' insertion test) type. If these tests failed, annotators tested for occasion, elaboration and contrast/violated expectation relations, applying a *nachher* 'afterwards', an *und zwar* 'that is', and an *aber* 'but' test, respectively. These five categories accounted for 99.6% of the data. The remaining continuations including questions and ambiguous cases were merged into a category other.

For the coreference analysis, the same coding scheme was applied as in the previous experiment. It was coded whether the continuation contained at least one anaphoric expression coreferent with NP1 or NP2, excluding another 114 cases (=5.0%). Again, only subject-verb-object cases were included in the analysis, excluding 18 (=0.8%) object-verb-subject instances. In total, 1,664 continuations were included in the coreference analysis. The inter-annotator agreement for all categories—discourse relations as well as coreference—was checked on a randomly drawn subset of 200 continuations and found to be good for these combined categories (Cohen's $\kappa = 0.77$).

3.2.4. Statistical analysis

For the analysis of discourse relations, two logit mixed-effects regression models were fitted to the data. The first analyzed causal (vs. other) relations, that is, explanation and consequence relations together in one category vs. other relations, while the second analysis was conducted within causal relations and modeled the likelihood to produce an explanation relation (vs. a consequence relation). Models included the fixed effects of VERB TYPE, GENDER ORDER, and their interaction as well as random intercepts of participants and items.

The analysis of coreference was performed in the same way as in the previous experiment. The only difference was that coreference was conditioned on the discourse relation realized by the participants. A total of 1,295 continuations were causally related (771 explanation and 524 consequence relations), and only these were included in the GLMER models analyzing coreference. An additional analysis of coreference biases was conducted on the merged data from Experiments 1 and 2 including EXPERIMENT as predictor. All analyses are publicly available in the accompanying OSF archive.

3.3. Results and discussion

The distribution of discourse relations is shown in Figure 2. As predicted from the Empty Slot Theory, explanation relations were the most frequent relation for agent-evocator verbs with 58.3% (vs. 31.9% for agent-patient verbs). For agent-patient verbs, however, the most frequent category were consequence relations with 41.9%, which only constituted the second-most frequent category for agent-evocator verbs at 21.1%. The other categories were similarly distributed for both verb classes, with relations of contrast/violated expectation as the third-most frequent category at 10.2% (agent-evocator: 9.5%; agent-patient: 10.9%). Elaboration relations were somewhat rarer at 8.8% (agent-evocator: 8.5%; agent-patient: 9.1%) and occasion relations hardly occurred with less than 3.1% continuations altogether. The distribution of the

FIGURE 2
Distribution of discourse relations in Exp. 2 for agent-evocator (AG-EVO) and agent-patient (AG-PAT) verbs.
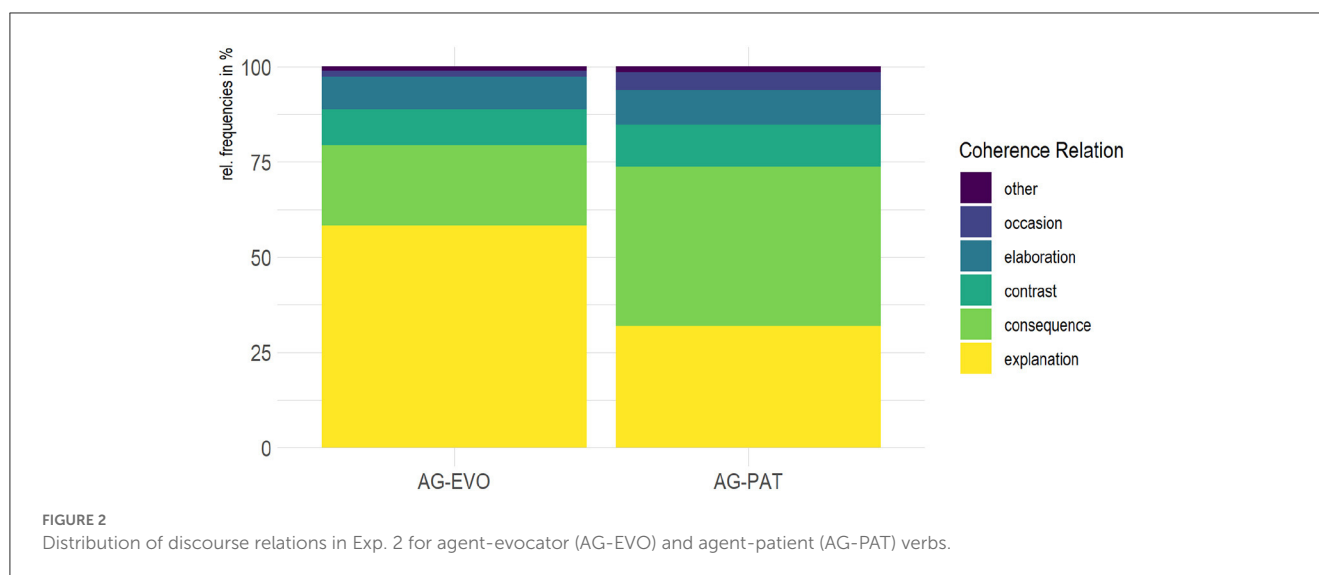
discourse relations for all verbs investigated in Experiment 2 can be found in the Supplementary material.

The GLMER analysis on causal relations—that is, explanation and consequence relations—vs. other discourse relations revealed a significant fixed intercept ($\hat{\beta} = 1.34, SE = 0.14, z = 9.89, p < 0.001$) and a significant fixed effect of VERB TYPE ($\hat{\beta} = 0.17, SE = 0.06, z = 2.88, p < 0.01$). Thus, causal relations were more frequent overall than other relations, with 73.8% causal relations after agent-patient prompts and 79.4% causal relations after agent-evocator prompts. The VERB TYPE effect furthermore corroborates that agent-evocator verbs in fact led to more causal relations than the causative agent-patient verbs.

The second GLMER analysis modeling the distribution of explanation vs. consequence relations within the causal relations showed that the distributions varied strongly between the two verb classes. While agent-evocator verbs generally gave rise to explanation relations, agent-patient verbs instead gave rise to consequence relations. This difference was reflected in a significant fixed effect of VERB TYPE ($\hat{\beta} = 0.79, SE = 0.07, z = 11.77, p < 0.001$). The results of the present experiment are consistent with and extend those reported in Bott and Solstad (2021), where the same verb classes were investigated with respect to the likelihood of producing an explanation relation. In the present experiment, a larger set of discourse relations was annotated. Still, agent-evocator verbs triggered explanations in a majority of cases to approximately the same degree as in the previous studies investigating continuations after a full stop (Kehler et al., 2008; Bott and Solstad, 2014, 2021). As in Bott and Solstad (2021), causative agent-patient verbs showed no comparable coherence bias towards explanations even though they involve a causing agent in their argument structure. This is fully in line with the Empty-Slot Theory of Bott and Solstad (2014, 2021), who proposed that the presupposition of agent-evocator verbs can be cataphorically satisfied in subsequent discourse (see also Bott and Solstad, 2022; Solstad and Bott, 2023), whereas the direct causes of causative agent-patient verbs cannot be specified in a *weil* "because" clause. This suggests that the coherence bias of Implicit Causality verbs

is in fact determined by the presence of a (suitable) presupposed occasion rather than verb causality.

In addition, we analyzed the coreference of the first anaphoric expression contingent on the discourse relation realized in the continuation. Table 2 presents the respective coreference biases for the three most frequent coherence relations explanation, consequence, and contrast, in sum accounting for 86.7% of all continuations in the sample. The descriptive statistics show that the two verb classes had rather similar biases for the discourse relations consequence and contrast, respectively. Both were clearly biased towards the object. explanations, however, show different coreference patterns for the two verb classes. While explanations after agent-evocator prompts were very strongly biased towards the object argument, explanations after agent-patient prompts were unbiased. The coreference biases of explanation and consequence relations were analyzed in a GLMER analysis including the predictors VERB TYPE and CAUSAL RELATION (*explanation* vs. *consequence*) as well as their interaction. The analysis revealed qualitatively similar effects as the GLMER analysis of Experiment 1 with a significant interaction between VERB TYPE and CAUSAL RELATION ($\hat{\beta} = 0.33, SE = 0.10, z = 3.36, p < 0.001$) besides significant main effects of both VERB TYPE ($\hat{\beta} = -0.74, SE = 0.10, z = -7.64, p < 0.01$) and CAUSAL RELATION ($\hat{\beta} = -0.39, SE = 0.10, z = -3.93, p < 0.001$). These findings are fully consistent with the coreference biases reported in the previous experiment and in line with evidence on the relation between coherence biases after *because* and in full stop explanations in earlier research (Kehler et al., 2008; Bott and Solstad, 2014; Solstad and Bott, 2022). The additional GLMER analysis on the merged data from Experiments 1 and 2 including the fixed effect of EXPERIMENT furthermore showed that coreference biases conditioned on discourse relations were indistinguishable. A model comparison between the saturated model including all three factors EXPERIMENT, VERB TYPE, and COHERENCE RELATION as well as their interactions and a model without EXPERIMENT only including the fixed effects of VERB TYPE and COHERENCE RELATION in addition to their two-way interaction revealed that the latter model

TABLE 2 Relative and absolute (n) frequencies of subject vs. object coreference for agent-evocator (AG-EVO) and agent-patient (AG-PAT) verbs in Exp. 2 for the three most common discourse relations Explanation, Consequence, and Contrast.

	Subject		Object	
	%	n	%	n
Explanation				
AG-EVO	8.1	(40)	91.9	(455)
AG-PAT	40.6	(112)	59.4	(164)
Consequence				
AG-EVO	7.9	(14)	92.1	(164)
AG-PAT	14.7	(51)	85.3	(295)
Contrast				
AG-EVO	9.8	(8)	90.2	(74)
AG-PAT	26.1	(23)	73.9	(65)

explained coreference equally well as the saturated model ($\chi^2(4) = 2.88$; $p = 0.58$). Thus, coreference was highly similar in explicitly triggered (Exp. 1) and in the freely produced (Exp. 2) explanations and consequences after a full stop.

4. Experiment 3: types of explanations and consequences

The Two-Mechanism Account does not only make predictions about how coreference biases pattern for I-Caus and I-Cons. It also claims that these patterns come about due to two different strategies: First, explanatory slots lead to a strong I-Caus bias towards the argument associated with the slot. Second, consequences target the argument associated with the end point of the event introduced by the verb. This should be reflected in different types of continuations beyond mere coreference properties. As shown by Solstad and Bott (2022); see also Bott and Solstad (2014) and Bott and Solstad (2021), the causal relations can be subdivided into more fine-grained types and these types differ for bias-congruent and bias-incongruent continuations. Experiment 3 investigated these detailed properties of explanations and consequences for prompts involving agent-evocator and agent-patient predicates. More precisely, it was investigated what characterizes those subject- and object-oriented explanations and consequences for these verb classes.

For consequences, the Contiguity Principle predicts that continuations should not specify an entity in the semantic structure of the two predicates and also that the two verb classes should display a similar pattern of consequences types since in both cases, an eventuality subsequent to the one denoted by the verb in the prompt must be introduced.

For explanations, on the other hand, the Empty Slot Theory predicts that the two verb classes should differ, since only agent-evocator verbs are semantically determined for a particular kind of explanation. What is more, agent-evocator predicates should show a different pattern for subject- vs. object coreference than

agent-patient predicates, since subject-continuations are clearly incongruent with the object bias in the first case, but not in the latter. More specifically, continuations about the object should be associated with a more uniform distribution of explanation relations for agent-evocator than for agent-patient verbs.

4.1. Design

Experiment 3 added a further factor to the design of Experiment 1. The coreference of causal relations was manipulated by including a personal pronoun following the connective that was either coreferent with the subject or the object of the prompt sentence:

(6)   Paul congratulated/poisoned Margrethe because/and so he/she… ✎

Consequently, the sentence continuation experiment employed a 2×2×2(×2) design manipulating within-participants and within-items the factors VERB TYPE (*agent-evocator* vs. *agent-patient*), CONNECTIVE (*weil* 'because' vs. *sodass* 'and so'), COREFERENCE (pronoun prompt *coreference with the subject* vs. *coreference with the object*) and GENDER ORDER (NP1$_{fem.}$–NP2$_{masc.}$ vs. NP1$_{masc.}$–NP2$_{fem.}$), the latter of which was again included in the design as a counterbalancing factor.

4.2. Methods

4.2.1. Participants

A total of 32 native German speakers (14 female, 17 male; 1 non-binary; mean age 23.5 years, range 18–32 years) were recruited via the platform Prolific (www.prolific.co) and participated in the experiment for monetary compensation of £3. Participants were randomly assigned to eight lists with 4 participants in each list. All participants gave their informed consent to the study.

4.2.2. Materials

The 20 items (20 agent-evocator and 20 agent-patient verbs) from the previous experiments were tested with prompts as in (6). A Latin Square design was used to distribute the resulting 20 items in 16 prompt conditions to eight lists such that each item appeared twice in each list and each verb appeared only once. It was furthermore ensured that each list contained five trials in each of the eight experimental conditions (i.e., two plus three trials in the two gender orders). The lists were individually randomized for each participant.

4.2.3. Procedure

The procedure was identical to the one in Experiments 1 and 2, apart from the fact that the experiment was implemented using the freely available PCIbex software (version 0.3.9, see https://doc.pcibex.net). On average, the experiment took about 10 minutes to complete.

4.2.4. Data annotation

The elicited data set of 1,280 continuations was annotated for subtypes of explanation and consequence relations. The annotation included some further, general categories that were applied also in the previous experiments (see above). Following the annotation according to those general categories, 52 continuations that were incomplete or nonsensical were excluded from the analysis (=4.1% of the data). Another 23 continuations (=1.8% of the data) were excluded in which participants had interpreted the prompt with object-verb-subject order. The remaining 1,205 continuations were annotated as follows.

The categories of the explanation relations were based on the ones applied in Bott and Solstad (2014, 2021) and Solstad and Bott (2022), but adjusted somewhat for the characteristics of the verb classes in the present investigation. Below, we merely list examples along with the categories. More elaborate remarks on the particular examples as well as on the categories and their relation to categories used in previous work can be found in the Supplementary material accompanying this paper.

Explanations, that is, continuations as prompted by *weil* 'because', were annotated according to the following categories:

- *Reasons:* Does the explanation provide a rationale for the intentional action of an agent (Solstad, 2010)? A differentiation was made between reasons anchored externally to the agent's mind (7) and reasons that were internally anchored, that is, mental states or attitudes of the agent (8):

    (7) **External reasons:**
         Lisa honoured Marco because he had won the first prize.

    (8) **Internal reason:**
         Annika pushed Manuel away because she hated him.

- *Backgrounds:* Is the explanation necessary, but insufficient for the event? Backgrounds were additionally annotated for whether they involved a *mental state*

    (9) **(Non-mental) background**
         Phillip healed Valerie because he is a doctor.

    (10) **Mental background**
          Nicole outsmarted Fabian because she is very intelligent.

- *Explanatory specifications:* Does the explanation provide the direct, simple cause (Bott and Solstad, 2014, 2021) as given by the predicate?

    (11) **Explanatory specification:**
          Fabian outsmarted Nicole because he took a shortcut.

The main categories to be expected for explanatory continuations of agentive interpersonal verbs of both agent-evocator and agent-patient type are *external and internal reasons*, see (7) and (8) (Bott and Solstad, 2014, 2021).

Consequences, that is *sodass* 'and so' continuations, were annotated as follows:

- *Subsequent consequences:* Is the reference time of the consequence disjoint (and subsequent) to the end state in the predicate? Consequences were additionally annotated for whether they included a mental state of the agent or patient.

    (12) **Subsequent (non-mental) consequence:**
          Clemens robbed Vera, and so he had to go to prison.

    (13) **Subsequent mental consequence (patient):**
          Isabella criticized Sebastian, and so he felt bad.

    (14) **Subsequent mental consequence (agent):**
          Vera scolded Clemens, and so she got a bad conscience.

- *Consequence specifications:* Does the consequence specify, or restate the caused state as given in the verb?

    (15) **Consequence specification:**
          Phillip healed Valerie, and so she was healthy again.

- *Finality:* Does the *sodass* continuation constitute the intended goal of the agent? The conjunction *sodass* allows for an 'in order to' reading. These cases had to be sorted out as they provide reasons, that is, a kind of explanation.

Since neither agent-evocator nor agent-patient verbs involve an empty slot for consequences, the most important consequence category is that of subsequent consequences (12), that is, the category predicted by the Contiguity Principle. Consequence specifications (15), which elaborate on the verb's end state (e.g., being dead is the end state of killing), were included for comparability with the results in Solstad and Bott (2022).

The annotation was done by the first author. A random sample of 100 continuations was independently annotated by the second author. Inter-annotator agreement proved to be good given the subtlety of semantic decisions required for this task (Cohen's κ = 0.79). Prior to analysis, the complete set of annotations was checked for consistency by the first author.

4.2.5. Statistical analysis

After excluding 101 (7.9% of all data) consequence continuations of finality type (see above), the remaining 1,104 continuations were statistically analyzed. For the 616 *explanations* in the sample, a GLMER analysis was conducted including the centered predictors VERB TYPE, COREFERENCE as well as their interaction. The logit mixed-effects regression analysis modeled the production of external reasons vs. other explanation types, which are the most important categories for action verbs. For the 488 *consequences* in the sample, only descriptive statistics, and no inferential statistics, was computed because consequences showed an almost uniform distribution. All analyses are publicly available (see the OSF archive).

4.3. Results and discussion

The distribution of explanation and consequence relations is shown in Tables 3, 4. Among the explanations, most were of reason type, with internal and external reasons modulated by the coreference of the prompt. As expected, subject coreference gave rise to internal reasons whereas object coreference gave rise to external reasons. For agent-evocator verbs, bias-congruent continuations were almost exclusively external reasons (98.1%). For agent-patient verbs, the internal and external reasons for subject and object continuations, respectively, weren't as dominant (e.g., 78.6% external reasons for object continuations). Of particular note, the proportion of external reasons for subject continuations was higher for agent-evocator (16.2%) than for agent-patient verbs (2.6%). This can be taken to reflect the strategy of filling Empty Slots for agent-evocator verbs, despite the subject argument not being the one biased for this type of explanations. Put differently: Although an explanation referring to the subject goes against the bias, participants surprisingly often manage to find a way to include the preferred type of explanation. Counter-intuitive as this strategy may seem for external reasons, a closer look at these cases revealed that these continuations did indeed follow the expected patterns: Participants provided incongruent continuations in which the subject in the prompt wasn't assigned the agent role in the continuation, such as passive constructions (16a) or benefactives involving *get* or *become* (16b):

(16) a. Elena reported Matthias to the police because she had been robbed.
      b. Bianca thanked Florian because she had received some flowers.

While both continuations in (16) constitute incongruent continuations, the particular constructions that are used allow the preferred type of explanation, which has been underlined in (16) to be included. It is implicitly understood that the object argument, which is not overtly realized in the *because* clauses in (16) is taken to be responsible for the robbery (16a) or for gifting the flowers (16b), respectively.

As for consequences, they were almost entirely of the subsequent consequence type for both verb classes, specifying non-mental events, or, somewhat rarer, subsequent mental states of the agent or the patient argument, respectively. The latter result further corroborates the analysis reported in Solstad and Bott (2022) where basically all consequences were in line with the Contiguity Principle, with no specifying consequences observed. Different from the suggestion in Hartshorne et al. (2015), I-Cons is not due to the consequences explicit in verbs, but relates to eventualities well beyond the event denoted by the verb (i.e., consequent events or states outside a verb's event nucleus in the sense of Moens and Steedman, 1988). Given the lack of variance in the distribution of types of consequence relations, no inferential statistics was computed for consequences.

Turning to the inferential statistics for I-Caus, the GLMER analysis of external reasons, which are mainly associated with the object argument, revealed two significant main effects in the absence of an interaction. First, the significant main effect of COREFERENCE ($\hat{\beta} = -2.64, SE = 0.21, z = -12.32, p < 0.001$) was due to the fact that external reasons were much more frequent in the object coreference conditions than in the subject coreference conditions. Second, the main effect of VERB TYPE ($\hat{\beta} = 1.15, SE = 0.21, z = 5.57, p < 0.001$) was due to the fact that across both coreference conditions, continuations after agent-evocator prompts were more likely to be external reasons than after agent-patient conditions. Taken together, these findings are fully in line with the predictions derived from the Two-Mechanism Account. There are clearly preferred types of

TABLE 3 Relative and absolute (n) frequencies of Explanation subtypes for agent-evocator and agent-patient verbs in subject and object coreferent conditions in Experiment 3.

	Specifying		Ext. reason		Int. reason		Backgr.	
	%	n	%	n	%	n	%	n
AG-EVO, subject	0.0%	(0)	16.2%	(25)	55.2%	(85)	28.6%	(44)
AG-EVO, object	0.0%	(0)	98.1%	(153)	1.9%	(3)	0.0%	(0)
AG-PAT, subject	3.3%	(5)	2.6%	(4)	69.7%	(106)	24.3%	(37)
AG-PAT, object	0.0%	(0)	78.6%	(121)	9.1%	(14)	12.3%	(19)

AG-EVO, agent-evocator; AG-PAT, agent-patient; ext. reason, external reason; int.-reason, internal reason; backgr., background.

TABLE 4 Relative and absolute (n) frequencies of Consequence subtypes for agent-evocator and agent-patient verbs in subject and object coreferent conditions in Experiment 3.

	Specifying		Subsequent					
			Non-mental		Agent-mental		Patient-mental	
	%	n	%	n	%	n	%	n
AG-EVO, subject	0.0%	(0)	65.3%	(62)	23.2%	(22)	11.6%	(11)
AG-EVO, object	0.7%	(1)	61.4%	(86)	0.0%	(0)	37.9%	(53)
AG-PAT, subject	0.0%	(0)	86.7%	(91)	10.5%	(11)	2.9%	(3)
AG-PAT, object	8.1%	(12)	74.3%	(110)	0.7%	(1)	16.9%	(25)

AG-EVO, agent-evocator; AG-PAT, agent-patient.

explanations associated with the subject and the object argument. However, for agent-evocator verbs, the bias towards object-oriented external reasons is sufficiently strong to trigger explanations of external reason type even if the continuation is incongruent in terms of coreference, see the examples in (16). While being bias-incongruent, such continuations can be said to be explanatorily congruent with the Empty Slot.

5. General discussion

In this paper, we presented a study investigating the Implicit Causality and Consequentiality coreference and coherence biases of agent-evocator and agent-patient verbs. We were particularly interested in three aspects: (i) To what extent can the biases be considered to be driven by semantic properties of the verb, (ii) what is the inter-relation between coreference and coherence biases, and (iii) how are I-Caus and I-Cons biases related to each other (if at all)? Previous research has provided much evidence on the coreference biases of agent-evocator and agent-patient verbs, but had little to say on the coherence biases, and even less so for more well-defined verb classes. Furthermore, this paper is the first to present a fine-grained analysis of the causal relations that are found with I-Caus and I-Cons for these verb classes. As a whole, the results in this paper complement the findings from Solstad and Bott (2022) on stimulus-experiencer and experiencer-stimulus verbs.

Previous research has hypothesized that I-Caus and I-Cons are driven by a common mechanism drawing upon verb argument structure (Crinean and Garnham, 2006; Hartshorne et al., 2015). In contrast, we investigated the Two-Mechanism Account, from which we derived the prediction that the two verb-classes should behave differently with regard to coreference, coherence and finer-grained types of causal relations: Agent-evocator verbs involve a semantically underspecified presuppositional entity which allows for a slot-filling strategy to be pursued when providing explanations. No such corresponding slot exists for agent-patient verbs, however. Therefore, we predicted the verb classes to differ with regard to (i) (I-Caus) coreference bias, (ii) coherence relations after a full stop and (iii) the subtypes of explanations relations used. For I-Cons, we predicted the two verb classes to be more similar with respect to both coreference biases and consequence subtypes. Both verb classes lacking a corresponding consequence relation slot, the strategy for providing consequences follows the more general, verb-class independent Contiguity Principle, which states that continuations follow the end point of previous discourse.

Experiment 1 established coreference biases for the agent-evocator and agent-patient verbs, showing that they differ with regard to I-Caus, but are similar regarding I-Cons. For I-Caus, agent-evocator verbs displayed a strong object bias, whereas agent-patient verbs showed an overall balanced bias. As for I-Cons, the two verb classes displayed a comparable, strong object bias. We take this to constitute evidence in favor of the Two-Mechanism Account. According to the Empty Slot Theory, the explanatory slot associated with the evocator argument is responsible for the strong I-Caus object bias that agent-evocator verbs display.

Correspondingly, the lack of such a slot in causative agent-patient verbs explains why their I-Caus bias is balanced. This finding is even more compelling when one considers that we took care to include only causative agent-patient verbs since previous research has speculated that verb causality is a determinant of the coreference bias (Hartshorne et al., 2015). With regard to I-Cons biases, the Contiguity Principle correctly predicts both classes to display a strong object bias, since the object argument is associated with the endpoint of the event denoted by action verbs. These results furthermore corroborate empirical findings by Au (1986), Crinean and Garnham (2006), Ferstl et al. (2011), Hartshorne and Snedeker (2013), Hartshorne et al. (2015), and Garnham et al. (2020b).

In Experiment 2, we investigated the coherence bias of agent-evocator and agent-patient verbs. According to the Two-Mechanism Account, the slot associated with the object argument of agent-evocator verbs should lead to the production of explanations, as participants follow a slot-filling strategy (Empty Slot Theory). Lacking such a slot, agent-patient verbs should trigger much fewer explanations and evoke consequences following the endpoint of the event denoted by the verb instead (Contiguity Principle). The results clearly provided support for this account, confirming the hypothesized effects: For agent-evocator verbs, explanation relations were by far the most frequent category, almost three times as frequent as consequence relations, which constituted the second-most frequent category. Agent-patient verbs, however, evoked more consequences than explanations. Other discourse relations (such as, for instance, contrast relations) were equally distributed for the two verb classes. This is, to our knowledge, the first study providing such evidence for these more well-defined verb classes. Whereas Kehler et al. (2008) did not control for semantic verb class, Bott and Solstad (2014) only reported the proportion of explanations.

Finally, Experiment 3 provided a more in-depth look at the particular causal relations provided after *because* and *and so* prompts where continuations had to make reference to either the subject or the object. Turning first to explanations, what we characterized as reasons are expected to follow subject and object continuations closely, external reasons being associated with the object, and internal reasons with the subject. However, the results again supported the Empty Slot Theory to the extent that there were significantly more references to the reason evoked by the slot associated with the object even when participants had to provide a continuation about the bias-incongruent subject. As expected from the Contiguity Principle, the two verb classes displayed no significant differences with regard to the types of consequences provided. Experiment 3 complements the causal typology for I-Caus and I-Cons presented in Solstad and Bott (2022).

We contend that all data reported for Experiments 1 through 3 should be taken as evidence in favor of the Two-Mechanism Account. The principles behind it, the Empty Slot Theory and the Contiguity Principle, allow us to capture the lexical properties involved in Implicit Causality. Verb semantics is a significant force behind I-Caus bias, whereas I-Cons bias is driven by more general discourse principles.

Whereas Solstad and Bott (2022) showed for two verb classes with strong, but mirror-like I-Caus and I-Cons biases that the two

biases follow from those two different mechanisms, the present study has shown in more detail for the Empty Slot Theory how slots impact coreference and coherence biases. Participants will seize on suitable slots to provide a particular explanation, as with agent-evocator verbs. If such a slot is lacking, as for (causative) agent-patient verbs, explanations will be less uniformly distributed both in terms of coreference, coherence and types of causal relations. For consequences, where no comparable slot is available for the verbs included in this study, a more general strategy is pursued: Based on the Contiguity Principle, participants provide consequences that are subsequent to the eventuality introduced in the prompt.

The Two-Mechanism Account crucially differs from previous accounts, which have suggested that a single mechanism should be made responsible for I-Caus and I-Cons coreference biases (e.g., Crinean and Garnham, 2006; Hartshorne et al., 2015). These accounts share what one may characterize as a causal duality view on I-Caus and I-Cons: "[I]mplicit causality and consequentiality biases are a systematic function of Levin verb class," as Hartshorne et al. (2015, p. 726) put it (see Levin, 1993). Very broadly, the reasoning would be that since causes and effects are tied together counterfactually—no effect without a corresponding cause—they should relate in parallel ways to I-Caus and I-Cons, respectively. While this may work well for the coreference biases of stimulus-experiencer and experiencer-stimulus verbs, which do display mirror-like biases for I-Caus and I-Cons, it seems less well-suited to account for the coreference biases of agent-evocator and agent-patient verbs. Also, as argued by Solstad and Bott (2022), the dual view does not seem well suited to explain coherence biases, which favor explanations over consequences not only for agent-evocator verbs, but also for stimulus-experiencer and experiencer-stimulus predicates (Solstad and Bott, 2022). Of note, consequences are only the dominant category for agent-patient verbs, which display a balanced coreference bias.

What is more, making reference to verb causality alone would make the wrong predictions for coreference and coherence biases. If causality were the defining property, causative agent-patient verbs should pattern with stimulus-experiencer verbs, which are also causative (Solstad and Bott, 2022). However, while stimulus-experiencer verbs have a strong subject bias, causative agent-patient verbs display a balanced bias. And while stimulus-experiencer verbs trigger an overwhelming amount of explanations (around 60%), consequences constitute the dominant category for causative agent-patient verbs.

It should be emphasized that the Two-Mechanism Account can be applied to verb classes beyond the action verbs investigated in this paper. Obviously, the Contiguity Principle can apply to all predicates introducing a state, which could be taken as the starting point for subsequent discourse. A more interesting question is, perhaps, which other predicates provide slots for discourse expectations and which types of slots there are. At this point, we have no comprehensive answer to offer, but one could speculate whether verbs of change of state, such as *fall*, or intransitive *break*, are associated with a coherence bias triggering explanations, as long as the end state can be externally caused (as opposed to, e.g., *bloom*, see Levin, 1993). In these cases, the coreference bias would be of less interest, since these verbs only have one argument.

We must, however, defer further discussion of this question to future research.

In the introduction, we discussed general findings on the online processing of I-Caus and I-Cons. We believe that the Two-Mechanism Account can offer a slightly new perspective of potential relevance for future research. For coherence biases, our results with regard to the primacy of explanations fits well with the results in Hoek et al. (2021b), according to which causal connectives are less expected if an explanation is provided before the *because* clause in the form of a relative clause (see also Solstad and Bott, 2013; Bott and Solstad, 2021). However, the significant differences between agent-evocator and agent-patient verbs suggests that this effect should be reduced for agent-patient verbs, since an explanation is not as expected in the first place. Concerning the coreference bias, we believe that comparing the online processing of I-Caus and I-Cons for agent-evocator and agent-patient predicates with the methods applied in Garnham et al. (2020a) makes interesting predictions. While Garnham et al. (2020a who investigated stimulus-experiencer and experiencer-stimulus verbs) found what they characterized as early effects for both biases for stimulus-experiencer and experiencer-stimulus verbs, we would expect only agent-evocator verbs to display an early effect for I-Caus, whereas both verb classes should display early effects for I-Cons. Given that I-Caus bias is verb-based, while I-Cons bias is more strongly dependent on the presence of a connective, this would mean that the I-Cons connective is integrated immediately (Crain and Steedman, 1985; Altmann and Steedman, 1988; Millis and Just, 1994, among others) since only the I-Caus bias can be derived from verb semantics alone. The Two-Mechanism Account still predicts a processing advantage for I-Caus with agent-evocator verbs, since both the connective and the pronoun serve the coherence bias, whereas a consequence connective like *and so* violates the expectation for an explanation evoked by the slot. In the terminology of Garnham et al. (2020a), for agent-evocator verbs we would predict "early effects" for I-Cons, and "very early effects" for I-Caus. It is an open question whether "very early" effects of I-Cons should be expected for agent-patient verbs, since they display a coherence bias towards consequences, although not as pronounced as the explanation bias of agent-evocator verbs.

In conclusion, the present investigation has provided evidence for the importance of empty slots in verb semantics in determining I-Caus and I-Cons coreference biases in addition to coherence biases. Based on the presence of an explanatory slot in agent-evocator verbs as opposed to agent-patient verbs and the lack of a parallel "consequence slot" in the two verb classes, we have argued that Implicit Causality and Consequentiality constitute two different phenomena with regard to coreference and coherence biases. Our study complements the findings in Solstad and Bott (2022), showing for controlled semantic verb classes how I-Caus and I-Cons biases play out, what the relation between coreference and coherence biases is and how this can be traced back to the level of fine-grained types of causal relations. In our view, this makes I-Caus and I-Cons even more interesting for future investigations, for both online and offline processing. In comparing I-Caus and I-Cons, we are not merely comparing coreference after a connective following an interpersonal verb, we are also comparing how verb

semantic (I-Caus) and more general discourse-structural principles (I-Cons) influence incremental discourse processing.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/gvbt3/.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Bielefeld University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

TS and OB contributed in equal parts to the conception and design of the study, the statistical analysis of the data, and the writing and revision of the paper. Both authors approved the submitted version.

Funding

Acknowledgments

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author OB declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/flang.2023.1143214/full#supplementary-material

References

Altmann, G., and Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition* 30, 191–238. doi: 10.1016/0010-0277(88)90020-0

Asher, N., and Lascarides, A. (2003). *Logics of Conversation*. Cambridge: Cambridge University Press.

Au, T. K. (1986). A verb is worth a thousand words: The causes and consequences of interpersonal events implicit in language. *J. Memory Lang.* 25, 104–122. doi: 10.1016/0749-596X(86)90024-0

Bates, D., Mchler, M., Bolker, B., and Walker, S. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 67, 1–48. doi: 10.18637/jss.v067.i01

Bott, O., and Solstad, T. (2014). "From verbs to discourse-a novel account of implicit causality," in *Psycholinguistic Approaches to Meaning and Understanding Across Languages*, eds. B. Hemforth, B. Mertins, and C. Fabricius-Hansen (New York: Springer) 213–251. doi: 10.1007/978-3-319-05675-3_9

Bott, O., and Solstad, T. (2021). Discourse expectations: explaining the implicit causality biases of verbs. *Linguistics* 59, 361–416. doi: 10.1515/ling-2021-0007

Bott, O., and Solstad, T. (2022). "Cataphoric presupposition verification and symmetric filtering: The case of occasion verbs," in *Proceedings of the 23rd Amsterdam Colloquium*, eds M. Degano, T. Roberts, G. Sbardolini, and M. Schouwstra. (Amsterdam: ILLC) 397–404.

Brown, R., and Fish, D. (1983). The psychological causality implicit in language. *Cognition* 14, 237–273. doi: 10.1016/0010-0277(83)90006-9

Commandeur, E. (2010). *Implicit causality and implicit consequentiality in language comprehension*. Doctoral dissertation, Tilburg University, Tilburg.

Corrigan, R. (2001). Implicit causality in language: Event participants and their interactions. *J. Lang. Soc. Psychol.* 20, 285–320. doi: 10.1177/0261927X01020003002

Cozijn, R., Commandeur, E., Vonk, W., and Noordman, L. G. (2011). The time course of the use of implicit causality information in the processing of pronouns: A visual world paradigm study. *J. Memory Lang.* 64, 381–403. doi: 10.1016/j.jml.2011.01.001

Crain, S., and Steedman, M. (1985). "On not being let up the garden path: the use of context information by the psychological syntax processor," in *Natural language parsing: psychological, computational, and theoretical perspectives*, eds. D. Dowty, L. Karttunen, and A. Zwicky (Cambridge, UK: Cambridge University Press), 320–358. doi: 10.1017/CBO9780511597855.011

Crinean, M., and Garnham, A. (2006). Implicit causality, implicit consequentiality and semantic roles. *Lang. Cogn. Proc.* 21, 636–648. doi: 10.1080/01690960500199763

Das, D., and Taboada, M. (2018). Signalling of coherence relations in discourse, beyond discourse markers. *Disc. Proce.* 55, 743–770. doi: 10.1080/0163853X.2017.1379327

Efron, B., and Tibshirani, R. (1986). The bootstrap method for standard errors, confidence intervals, and other measures of statistical accuracy. *Stat. Sci.* 1, 1–35. doi: 10.1214/ss/1177013815

Ehrlich, K. (1980). Comprehension of pronouns. *Quart. J. Exper. Psychol.* 32, 247–255. doi: 10.1080/14640748008401161

Featherstone, C. R., and Sturt, P. (2010). Because there was a cause for concern: An investigation into a word-specific prediction account of the implicit-causality effect. *Quart. J. Exper. Psychol.* 63, 3–15. doi: 10.1080/17470210903134344

Ferstl, E. C., Garnham, A., and Manouilidou, C. (2011). Implicit causality bias in English: a corpus of 300 verbs. *Behav. Res. Methods* 43, 124–135. doi: 10.3758/s13428-010-0023-2

Garnham, A., Child, S., and Hutton, S. (2020a). Anticipating causes and consequences. *J. Memory Lang.* 114, 104130. doi: 10.1016/j.jml.2020.104130

Garnham, A., Traxler, M., Oakhill, J., and Gernsbacher, M. A. (1996). The locus of implicit causality effects in comprehension. *J. Memory Lang.* 35, 517–543. doi: 10.1006/jmla.1996.0028

Garnham, A., Vorthmann, S., and Kaplanova, K. (2020b). Implicit consequentiality bias in English: A corpus of 300+ verbs. *Behav. Res. Method.* 53, 1530–1550. doi: 10.3758/s13428-020-01507-z

Garvey, C., and Caramazza, A. (1974). Implicit causality in verbs. *Lingu. Inquiry* 5, 459–464.

Goikoetxea, E., Pascual, G., and Acha, J. (2008). Normative study of the implicit causality of 100 interpersonal verbs in Spanish. *Behav. Res. Method.* 40, 760–772. doi: 10.3758/BRM.40.3.760

Greene, S. B., and McKoon, G. (1995). Telling something we can't know: Experimental approaches to verbs exhibiting implicit causality. *Psychol. Sci.* 5, 262–270. doi: 10.1111/j.1467-9280.1995.tb00509.x

Hartshorne, J. K., O'Donnell, T. J., and Tenenbaum, J. B. (2015). The causes and consequences explicit in verbs. *Lang. Cogn. Neurosci.* 30, 716–734. doi: 10.1080/23273798.2015.1008524

Hartshorne, J. K., and Snedeker, J. (2013). Verb argument structure predicts implicit causality: The advantages of finer-grained semantics. *Lang. Cogn. Proc.* 28, 1474–1508. doi: 10.1080/01690965.2012.689305

Hartshorne, J. K., Sudo, Y., and Uruwashi, M. (2013). Are implicit causality pronoun resolution biases consistent across languages and cultures? *Exper. Psychol.* 60, 179–196. doi: 10.1027/1618-3169/a000187

Hobbs, J. R. (1979). Coherence and coreference. *Cogn. Sci.* 3, 67–90. doi: 10.1207/s15516709cog0301_4

Hoek, J., Rohde, H., Evers-Vermeul, J., and Sanders, T. J. M. (2021a). Expectations from relative clauses: Real-time coherence updates in discourse processing. *Cognition* 210, 104581. doi: 10.1016/j.cognition.2020.104581

Hoek, J., Rohde, H., Evers-Vermeul, J., and Sanders, T. J. M. (2021b). Scolding the child who threw the scissors: Shaping discourse expectations by restricting referents. *Lang. Cogn. Neurosci.* 36, 382–399. doi: 10.1080/23273798.2020.1852292

Kehler, A. (2002). *Coherence, Reference, and the Theory of Grammar*. Stanford: CSLI Publications.

Kehler, A., Kertz, L., Rohde, H., and Elman, J. L. (2008). Coherence and coreference revisited. *J. Semant.* 25, 1–44. doi: 10.1093/jos/ffm018

Kehler, A., and Rohde, H. (2019). Prominence and coherence in a Bayesian theory of pronoun interpretation. *J. Pragmatics* 154, 63–78. doi: 10.1016/j.pragma.2018.04.006

Kim, H., and Chun, E. (2022). Effects of topicality in the interpretation of implicit consequentiality: evidence from offline and online referential processing in Korean. *Linguistics*. Ahead-of-print version. doi: 10.1515/ling-2020-0197

Klein, W., and von Stutterheim, C. (1987). Quaestio und referentielle Bewegung in Erzhlungen. *Linguistische Berichte* 109, 163–183.

Koornneef, A. W., Dotlačil, J., van den Broek, P., and Sanders, T. J. M. (2016). The influence of linguistic and cognitive factors on the time course of verb-based implicit causality. *Quart. J. Exper. Psychol.* 69, 455–481. doi: 10.1080/17470218.2015.1055282

Koornneef, A. W., and van Berkum, J. J. A. (2006). On the use of verb-based implicit causality in sentence comprehension: Evidence from self-paced reading and eye tracking. *J. Memory Lang.* 54, 445–465. doi: 10.1016/j.jml.2005.12.003

Kuehnast, M., and Meier, E. (2019). Implicit causality of action verbs at the interface between conceptual structure and discourse coherence relations. *Questions Answers Linguist.* 5, 11–36. doi: 10.2478/qal-2019-0002

Kuperberg, G. R., Paczynski, M., and Ditman, T. (2011). Establishing causal coherence across sentences: An ERP study. *J. Cogn. Neurosci.* 23, 1230–1246. doi: 10.1162/jocn.2010.21452

Levin, B. (1993). *English Verb Classes and Alternations: A Preliminary Investigation*. Chicago: University of Chicago Press.

Levinson, S. C. (1983). *Pragmatics. Cambridge Textbooks in Linguistics*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511813313

McDonald, J. L., and MacWhinney, B. (1995). The time-course of anaphor resolution: Effects of implicit verb causality and gender. *J. Memory Lang.* 34, 543–566. doi: 10.1006/jmla.1995.1025

Millis, K. M., and Just, M. A. (1994). The influence of connectives on sentence comprehension. *J. Memory Lang.* 33, 128–147. doi: 10.1006/jmla.1994.1007

Moens, M., and Steedman, M. (1988). Temporal ontology and temporal reference. *Comput. Linguist.* 14, 15–28.

Murphy, E. (2021). Predicate order and coherence in copredication. *Inquiry* 2021, 1–37. doi: 10.1080/0020174X.2021.1958054

Onea, E. (2016). *Potential Questions at the Semantics-Pragmatics Interface*. Leiden/Boston: Brill. doi: 10.1163/9789004217935

Pickering, M. J., and Gambi, C. (2018). Predicting while comprehending language: A theory and review. *Psychol. Bull.* 144, 1002–1044. doi: 10.1037/bul0000158

Pickering, M. J., and Majid, A. (2007). What are implicit causality and consequentiality? *Lang. Cogn. Proc.* 22, 780–788. doi: 10.1080/01690960601119876

Pykkönen, P., and Järvikivi, J. (2010). Activation and persistence of implicit causality information in spoken language comprehension. *Exper. Psychol.* 57, 5–16. doi: 10.1027/1618-3169/a000002

Roberts, C. (1996/2012). Information structure in discourse: Towards an integrated formal theory of pragmatics. *Semant. Pragmat.* 5, 1–69. doi: 10.3765/sp.5.6

Rohde, H., and Horton, W. S. (2014). Anticipatory looks reveal expectations about discourse relations. *Cognition* 133, 667–691. doi: 10.1016/j.cognition.2014.08.012

Rudolph, U., and Försterling, F. (1997). The psychological causality implicit in verbs: A review. *Psychol. Bull.* 121, 192–218. doi: 10.1037/0033-2909.121.2.192

Sanders, T. J. M. (2005). "Coherence, causality and cognitive complexity in discourse," in *Proceedings/Actes SEM-05, First International Symposium on the Exploration and Modelling of Meaning* 105–114.

Semin, G. R., and Fiedler, K. (1988). On the causal information conveyed by different interpersonal verbs: The role of implicit sentence context. *Soc. Cogn.* 6, 21–39. doi: 10.1521/soco.1988.6.1.21

Singmann, H., Bolker, B., Westfall, J., Aust, F., and Ben-Shachar, M. S. (2021). *afex: Analysis of Factorial Experiments*. R package version 0.28–21.

Solstad, T. (2010). "Some new observations on "because (of)"," in *Amsterdam Colloquium 2009*, eds. M. Aloni, H. Bastiaanse, T. de Jager, K. Schulz (Berlin/Heidelberg: Springer) 436–445.

Solstad, T., and Bott, O. (2013). "Towards a formal theory of explanatory biases in discourse," in *Proceedings of the 19th Amsterdam Colloquium*, eds. M. Aloni, M. Franke, F. Roelofsen (Amsterdam: ILLC, University of Amsterdam), 203–210.

Solstad, T., and Bott, O. (2022). On the nature of implicit causality and consequentiality: the case of psychological verbs. *Lang. Cogn. Neurosci.* 37, 1311–1340. doi: 10.1080/23273798.2022.2069277

Solstad, T. and Bott, O. (2023). Cataphoric presuppositions: The case of occasion verbs. *Semant. Pragmat.* Submitted. doi: 10.4119/unibi/2978989

Stewart, A. J., Pickering, M. J., and Sanford, A. J. (1998). "Implicit consequentiality," in *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society* (Mahwah, NJ: Lawrence Erlbaum Associates, Inc.) 1031–1036. doi: 10.4324/9781315782416-186

Stewart, A. J., Pickering, M. J., and Sanford, A. J. (2000). The time course of the influence of implicit causality information: Focusing versus integration accounts. *J. Memory Lang.* 42, 423–443. doi: 10.1006/jmla.1999.2691

Trabasso, T., and van den Broek, P. (1985). Causal thinking and the representation of narrative events. *J. Memory Lang.* 24, 612–630. doi: 10.1016/0749-596X(85)90049-X

van Berkum, J. J. A., Koornneef, A. W., Otten, M., and Nieuwland, M. S. (2007). Establishing reference in language comprehension: An electrophysiological perspective. *Brain Res.* 1146, 158–171. doi: 10.1016/j.brainres.2006.06.091

van den Hoven, E., and Ferstl, E. C. (2018a). Discourse context modulates the effect of implicit causality on rementions. *Lang. Cogn.* 10, 561–594. doi: 10.1017/langcog.2018.17

van den Hoven, E., and Ferstl, E. C. (2018b). The roles of implicit causality and discourse context in pronoun resolution. *Front. Commun.* 3, 53. doi: 10.3389/fcomm.2018.00053

Zwaan, R. A., and Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychol. Bull.* 123, 162–185. doi: 10.1037/0033-2909.123.2.162