Competence by Default: Do listeners assume that speakers are knowledgeable when computing conversational inferences?

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Abstract

When engaged in conversation, do listeners make default assumptions about the epistemic states of speakers? According to some accounts, when listeners hear a sentence like "Sarah solved some of the math problems," they infer by default that speakers believe that the stronger statement involving "all" is false (i.e., that Sarah did not solve all of the problems). However, drawing on tests of reading time, eyetracking, and manipulations of cognitive load, multiple studies have argued that this form of inference (i.e., strong scalar implicature) is not computed by default. In this study, while acknowledging this claim, we explore whether important sub-processes of implicature might nevertheless involve default inferences. In particular, we tested whether listeners assume by default that speakers are knowledgeable about alternative utterances that are left unsaid—a critical precondition for computing strong scalar implicature. To do this, we tested 60 English speaking participants who heard utterances made by either knowledgeable speakers or ignorant speakers. In addition, half of these participants were placed under cognitive load using a dot-array memory task. We found that participants placed under load over-computed implicatures when speakers were ignorant, as though assuming that they were knowledgeable by default.

Keywords: Scalar Implicature, Ignorance Implicature, Default Reasoning, Cognitive Load, Epistemic reasoning, Contextual processing

1. Introduction

A defining property of natural language is that utterances commonly convey information about the truth of stronger propositions that could have been said but weren't. For example, a sentence like "Sarah solved some of the math problems," in (1), implies that a more informative proposition such as "Sarah solved all of the math problems," in (2), is false (sometimes called a Strong Scalar Implicature, or SSI).

(1) Sarah solved some of the math problems.

(2) Sarah solved all of the math problems.

Most accounts of SSI propose that listeners reason about alternative statements that a speaker could have said in order to compute implications that go beyond the literal meaning of a given utterance.[1] On such accounts, the computation of implicatures requires cognitive resources to generate alternative propositions, process contextual cues, and reason about a speaker's epistemic state (e.g., what information the speaker has access to). Considerable debate surrounds the nature of the computations involved in SSIs and how cognitive resources are deployed when executing them. Some have argued that SSIs like the one triggered by the utterance in (1), which Grice called *Generalized Conversational Implicatures*, occur by default unless additional contextual information inhibits or overrides their derivation (e.g., see Levinson, 2000, and references therein). In contrast, others have argued that SSIs are not computed by default, but that the computation of an SSI involves a form of rational choice made by the listener that depends on consulting contextual information, including the speaker's mental state. Versions of

[1] Technically, grammatical theories of SSIs, as discussed in Chierchia et al. 2012, incorporate the SSI into the literal meaning of an utterance. Still, the type of processing that is involved in computing a strengthened meaning is very similar to the processes hypothesized in most pragmatic accounts. For simplicity, we have framed our discussion through a Gricean perspective. In Appendix 2 we discuss considerations for a grammatical view.

this hypothesis appear in Relevance Theory (e.g., Sperber & Wilson, 1986/1995, 2012), Rational Speech Act (RSA) Models (e.g., Frank and Goodman, 2012; Goodman & Stuhlmüller, 2013; Degen 2023), constraint-based approaches (Breheny et al., 2006; Degen and Tanenhaus, 2015), as well as various Gricean and Neo-Gricean theories, whether implicitly or explicitly (e.g., see Grice, 1975; Soames, 1982; Leech, 1983; Horn, 1989; Matsumoto, 1995, among others).[2]

Previous studies have sought to adjudicate between these alternative views using a variety of experimental methods that probe online processing of SSIs via eye-tracking, reading time, and ERP. Many of these studies have concluded that SSIs are not computed by default because they take additional time relative to the computation of literal meanings (e.g., Noveck & Posada, 2003; Bott & Noveck 2004; Breheny et al., 2006; Huang & Snedeker, 2009; Tomlinson et al., 2013; Politzer-Ahles et al., 2013; Zhao et al. 2015, 2021).[3] Similar conclusions can be drawn from studies that place participants under cognitive load. For example, De Neys and Schaeken (2007) presented participants with sentences like "Some elephants have trunks" after being shown a dot pattern that was either easy to recall (e.g., a small number of dots arranged in a straight line) or difficult to recall (e.g., a greater number of dots arranged randomly). Participants then judged whether the sentences were true or false, followed by a probe to recall the dot pattern. Interestingly, when participants saw the more complex dot pattern before the test

[2] Grammatical theories of implicature (e.g., Chierchia 2004, 2006; Chierchia et al. 2012; Fox 2007; Meyer 2013; among others) are compatible with either strategy. Essentially the choice between interpreting an utterance with or without an SSI boils down to a semantic/syntactic ambiguity–an SSI parse vs. a non-SSI parse. Within such a framework, one could hypothesize that the SSI parse is adopted by default or, alternatively, that context feeds a choice between parses.

[3] Note that some exceptions exist. In certain experimental paradigms that emphasize contextual factors, pragmatically enriched meanings may be processed just as quickly as literal meanings (see Grodner et al., 2010; Politzer-Ahles & Fiorentino, 2013; Degen & Tanenhaus, 2016; Sun & Breheny, 2020). Here, we are ultimately not concerned with adjudicating between these accounts, and note simply that in most experimental paradigms that do not have contextual enrichment, the SSI-by-Default theory fails to make appropriate predictions.

sentence, they computed implicatures less often than when they saw the simpler pattern. Based on this result, De Neys and Schaeken (2007) concluded that SSIs are not computed by default, but instead require the use of additional cognitive resources that are inhibited when listeners are placed under cognitive load (see also Dieussaert et al., 2011; Marty & Chemla, 2013; Marty et al., 2013; Cho, 2020).

Although previous studies have repeatedly shown that SSIs often require cognitive effort and are not computed automatically, SSIs are not monolithic, and are generally thought to include multiple smaller inferences, each of which may involve default assumptions with important consequences. For example, a distinction can be made between the idea that SSIs are globally computed by default and the hypothesis that listeners make a more modest assumption that the speaker is knowledgeable about the truth or falsity of potential alternatives—what Guerts (2010) called the "Competence-by-Default" hypothesis. Whereas the SSI-by-Default hypothesis claims that listeners assume that stronger alternative statements are false when not uttered, the Competence-by-Default hypothesis posits that listeners assume a weaker proposition, in (3), that the speaker has enough information to judge whether or not those stronger alternatives are true or false.[4]

(3) **Competence**: For an alternative q to an utterance p, either the speaker knows that q is true or the speaker knows that q is false—i.e., $K(q) \vee K(\neg q)$, where K is Hintikka's (1962) "The speaker knows that" operator.[5]

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[4] Critically, this assumption is limited to scalar alternatives and not other forms of knowledge. For example, Competence-by-Default is not the weaker assumption that speakers only say things they think are true (e.g., Quality), nor is it the stronger assumption that speakers are knowledgeable about all unsaid propositions.

[5] Soames (1982) specifies a logically equivalent variant of Competence whereby for any alternative q, $(q \rightarrow K(q)) \wedge (\neg q \rightarrow K(\neg q))$. Given the law of excluded middle (i.e., $q \vee \neg q$), $K(q) \vee K(\neg q)$ is equivalent to $(q \rightarrow K(q)) \wedge (\neg q \rightarrow K(\neg q))$.

Importantly, on many accounts a speaker's competence regarding alternatives is not directly implicated by an utterance, but must either be assumed or discovered from contextual information (Soames, 1982; Horn, 1989; Zimmermann 2000; Rooij & Schulz 2004; Sauerland, 2004; Geurts 2010).[6] Furthermore, without establishing competence, it is impossible to derive an SSI. For example, according to Soames (1982: 533), scalar reasoning with respect to a universal statement like, "Some of the boys were at the party" (hereon "p") involves roughly 5 steps (see also Horn 1989 and Sauerland 2004).

1. Infer via Quality that the speaker knows that the utterance is true: K(p).
2. Compute the alternative, "All of the boys were at the party" (hereon q).
3. Infer via Quantity that it is not the case that the speaker knows that, "All of the boys were at the party" (otherwise the speaker would have uttered q instead of p): $\neg K(q)$. [Weak Scalar Implicature][7]
4. Establish that the speaker either knows that "All of the boys were at the party" is true or that it is false: $K(q) \lor K(\neg q)$. [Competence][8]
5. Deduce via the results of Step 3 and Step 4 (in addition to Modus Tollendo Ponens)[9] that the speaker knows that not all of the boys are at the party: $\neg K(q)$, $K(q) \lor K(\neg q) \vDash K(\neg q)$. [Strong Scalar Implicature][10]

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[6] Note, under the grammatical account of SSIs, (3) is unnecessary since SSIs are incorporated into the literal meaning. Also, Gazdar (1979) and Levinson (2000) argued that SSIs follow directly from weak statements, without considering speaker competence.
[7] Also referred to as Primary Implicature (Sauerland, 2004) and Generalized Implicature (Soames, 1982).
[8] Also referred to as the Epistemic Step (Sauerland, 2004) and Contextual Background (Soames, 1982).
[9] Modus Tollendo Ponens: $A \lor B, \neg A \vDash B$
[10] Also referred to as Secondary Implicature (Sauerland, 2004) and Particularized Implicature (Soames, 1982).

Critically, Step 4 allows the listener to transition from the weak scalar implicature in Step 3 to the SSI in Step 5. However, what's involved in this step differs on different accounts. According to some, competence is assumed by default. For example, van Rooij and Schulz (2004) argue that the competence assumption "is made as long as it is consistent with what the interpreter already knows and the assumption that the speaker is obeying the maxims of Quality and Quantity" (p. 512). Under such an account, the listener must cancel this default assumption in order to preclude an SSI in contexts where such an inference is not warranted. Other approaches, in contrast, embrace what we will call a Contextual Licensing account, on which competence is not assumed, but requires contextual justification (see Leech, 1983:86; Horn, 1989:214; Soames, 1982:533-535; Zimmermann, 2000:286). On this view, when a weak scalar expression is uttered, the listener automatically computes a weak scalar implicature but makes no assumptions about the speaker's knowledge of stronger alternatives. Rather, the listener assesses broader contextual cues to the speaker's likely mental state. Although not explicitly stated, such a view is implicit in approaches that probe how contextual cues drive the listener's iterative reasoning about cooperative conversational partners (e.g., game-theoretic frameworks like Franke, 2011, constraint-based theories like Breheny, et al., 2013, and RSA models like Goodman & Stuhlmüller, 2013). Furthermore, a Contextual Licensing account is implicit in standard Gricean discussions of Quality vs. Quantity (see Grice, 1975:311; Matsumoto, 1995:24-25; and Russell, 2006:370-372).[11]

[11] According to Geurts (2010: 42), "The only way to settle this issue [of whether listeners assume speaker Competence by default] would be by collecting quantitative data, but unfortunately I don't see how this might be done." In this experiment, we attempt to gather such data.

Few studies have tested how listeners reason about the epistemic state of a speaker in a way that might distinguish Competence-by-Default from Contextual Licensing. In one relevant study, Bergen and Grodner (2012) tested how listeners computed SSIs under conditions in which the speaker's knowledge states varied. For example, in one condition the speaker began by making a statement that implied full knowledge such as, "At my client's request, I meticulously compiled the investment report." In a second condition, the speaker began by making a statement that implied partial knowledge such as, "At my client's request, I skimmed the investment report." Following this, in both conditions, the speaker then produced an under-informative statement featuring "some" (e.g., "Some of the real estate investments lost money") which was immediately followed by a third sentence that was compatible with only the "not all" implicature (e.g., "The rest were successful despite the recent economic downturn"). Bergen and Grodner found that reading times were longer for this third sentence under conditions of speaker ignorance (when an implicature was not expected), a result that they took as evidence that SSIs are not computed automatically (for similar studies that contextually manipulate speaker knowledge, see Breheny, Fergusson & Katsos, 2013; Goodman & Stuhlmüller, 2013). Importantly, while these results demonstrate the importance of speaker knowledge to SSIs, they do not address whether participants assume Competence-by-Default since they leave open whether SSIs will be computed when the speaker's knowledge state is unknown. Consequently, they do not assess whether listeners are more likely to assume ignorance or knowledge in absence of direct evidence about speaker states.

In a related study, Dieuleveut, Chemla and Spector (2019) presented participants with a set of ten playing cards, all of the same suit, and a character who could either see all of the cards or only half of them. Participants were then asked whether the character could have said the sentence, “Some of the cards are hearts” given what they could see. Dieuleveut et al. found that participants responded “no” significantly more in the knowledgeable speaker condition (~60%) than in the ignorant speaker condition (~30%), which they took as evidence that listeners were sensitive to speaker knowledge when judging the appropriateness of sentences. In particular, participants were aware that an utterance containing “some” is less appropriate if the speaker knows that a stronger statement containing “all” is possible, but not if the speaker is ignorant. Interestingly, Dieuleveut et al. noted that participants responded “no” in the ignorant speaker condition more often than expected, a result which might be taken as evidence that they are biased towards computing implicatures without considering speaker knowledge, as might be predicted if participants assumed Competence-By-Default. However, as they point out, other factors might also explain these judgments. For example, participants in the ignorant speaker condition might reject utterances containing “some” when “all” is true, not because they themselves compute SSIs, but because they are aware that the utterance might create such an implicature, and is therefore potentially misleading. In other words, rather than assuming speaker competence and computing an SSI, participants might merely think it is inappropriate for an ignorant speaker to utter a sentence that leaves room for a potential SSI misinterpretation.

In another relevant study, Hochstein et al. (2018) investigated the role of epistemic reasoning in scalar implicature by testing adolescents with autism spectrum disorders (ASDs). They reasoned that if scalar implicature depends upon epistemic reasoning, then adolescents with ASDs might struggle to use speaker knowledge as a condition for computing SSIs. In the study, participants witnessed a scene in which a speaker sat in front of three boxes, two of which were open, revealing identical contents (e.g., strawberries), the third of which was closed. The speaker then made a statement like, “Some of the boxes have strawberries” after either peeking into the third box (full knowledge condition), or not peeking inside it (partial knowledge condition). After the speaker made their statement, participants were asked whether the speaker knew what was in the third box in order to confirm that they were aware of the speaker's knowledge state. Next, they were asked whether the third box contained the same objects as the first two (e.g., whether it contained strawberries) in order to test whether they had computed an SSI. A "no" response was taken as evidence that participants computed an SSI, while an "I don't know" response indicated that they did not (note that "yes" responses were possible but not expected, since the listener never had direct evidence of what was contained in the third box).

As expected, neurotypical adult controls in the Hochstein et al. study generated SSIs in the knowledgeable speaker condition but not the ignorant speaker condition. In contrast, adolescents with ASDs exhibited a different pattern: they generated SSIs to the same degree in both cases. Of significance to the issue at hand, when they were explicitly asked at the beginning of each trial if the speaker knew what was inside the third box, all participants, including the adolescents with ASDs, answered correctly, indicating an ability to differentiate knowledge vs. ignorance. However, in cases where speakers were ignorant, participants with ASDs nevertheless computed SSIs even though the conclusion resulting from this inference—e.g., that the speaker knows that there are no strawberries in the third box—contradicted their explicitly attested belief that the speaker did not know the contents of the box. This is notable because it indicates a failure to integrate the two sources of information to derive the contradiction. In their discussion, Hochstein et al. argued that the data might be explained via a form of the SSI-by-Default hypothesis: adolescents with ASDs interpret "some" as "only some" by default,[12] but struggle to cancel this default parse using evidence of speaker ignorance.

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[12] In their paper, Hochstein et al. describe this proposal by adopting the grammatical view, though it is also possible to describe their proposal via a neo-Gricean default hypothesis.

While this is perhaps the best account of individuals with ASDs, a potential problem is that a different account seems necessary for neurotypical individuals, given the large literature challenging the SSI-by-Default view. Therefore, a compelling alternative is that adolescents with ASDs assume competence by default. Rather than struggling to use contextual information about the speaker's knowledge state to override an SSI, as proposed by Hochstein et al., they may instead struggle to override a competence assumption. According to this analysis, depicted in Figure 1, a listener might hear an utterance (e.g., "Some of the boxes have strawberries") and assume by default that it is spoken from a position of competence about alternatives. At this point, the listener might notice that this assumption is at odds with their prior observation and cancel the competence assumption.[13] However, this "repair" process might fail in individuals with ASDs if they are unable to use contextual information to override the competence assumption, resulting in an SSI. In particular, this process may be challenging for individuals with ASDs because it requires reasoning about two conflicting mental state attributions: one provided contextually ("The speaker does not know what is in the third box") and one implied by the assumption of competence ("The speaker either knows that all of the boxes contain strawberries or that not all of them do"). Previous studies have argued that problems of this form may be particularly challenging for individuals with ASDs (Frith & Happé, 1994; Happé & Frith, 2006). In fact, processing mental state representations is known to be resource intensive even for neurotypical adults, and often fails (Apperly et al. 2008; 2009; 2010; Bernstein et al., 2011; Keysar et al., 2003; Lin et al., 2010; Schneider et al., 2012; 2017). Given this, in the present

[13] Note, contextual evidence of a speaker's knowledge or ignorance is only considered after the speaker's utterance is completed. A listener cannot know which knowledge states are relevant with respect to alternatives before hearing the utterance from which alternatives are to be computed. For details, see the Discussion.

study we asked whether placing neurotypical individuals under cognitive load might impair their ability to integrate mental state information in the service of scalar implicature.

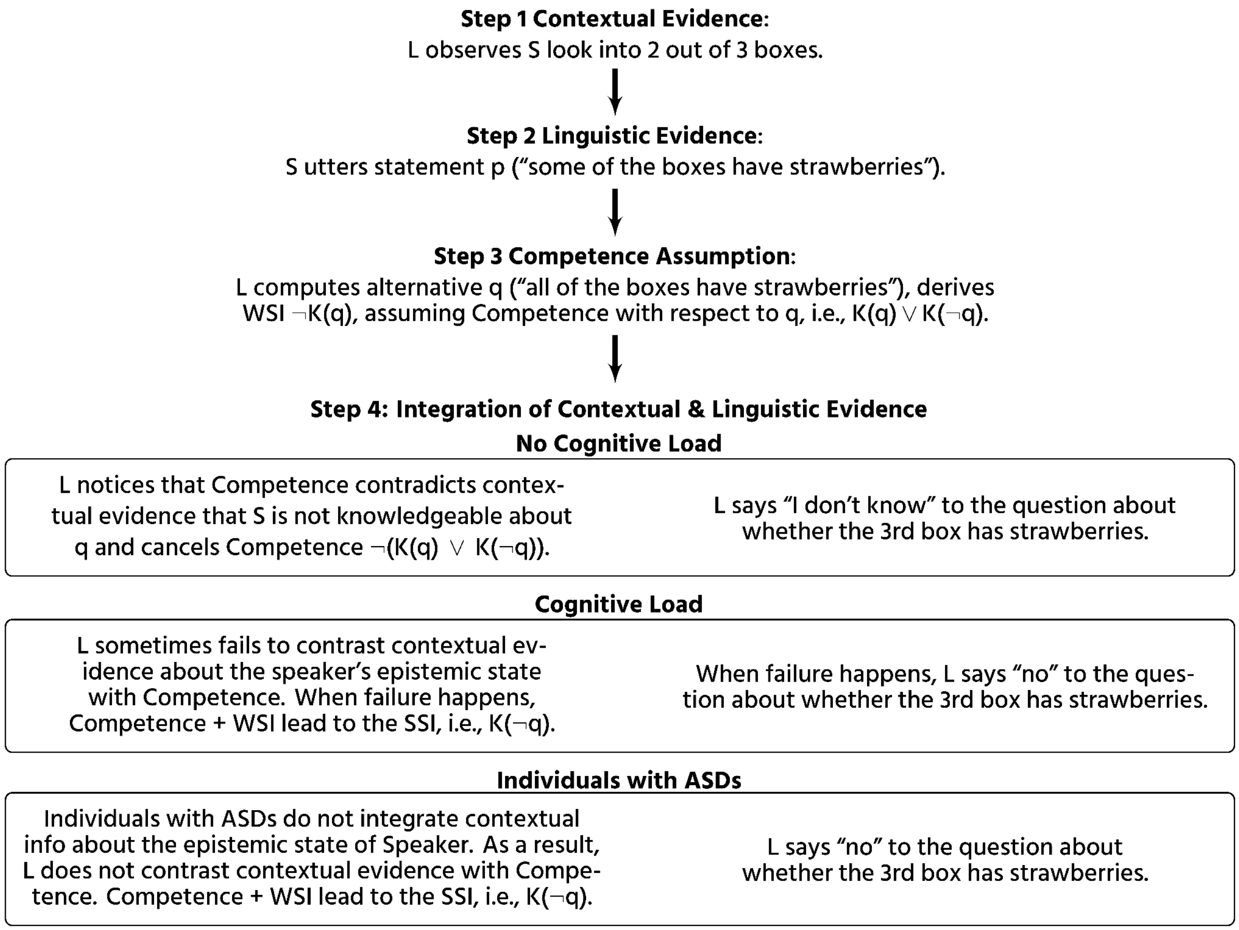

Figure 1. Possible impacts of cognitive load and ASDs on the integration of contextual & linguistic evidence about the epistemic state of the speaker. L = Listener, S = Speaker, WSI = Weak Scalar Implicature, K = Hintikka's "Speaker knows that" operator.

As already noted, previous studies have investigated the SSI-by-Default hypothesis by placing participants under cognitive load, on the assumption that such tasks will interfere with processes involved in implicature. However, no previous study has tested whether it is possible to interfere with a participant's ability to draw on contextually available information about the mental state of the speaker when computing implicatures to test the Competence-by-Default hypothesis. One possibility, for example, is that the integration problem seen in adolescents with ASDs can also be elicited in neurotypical adults when they are placed under load, allowing for a test of whether neurotypical listeners assume competence by default. Previous studies suggest that although neurotypical adults easily infer the mental states of others, they often struggle to use this contextually gained knowledge to make subsequent judgments (Apperly et al., 2008), to predict the actions of others (Keysar, Lin, & Barr, 2003), or to interpret the instructions of an ignorant speaker (Apperly et al., 2010). What's more, mental state reasoning declines with age (Bernstein et al., 2011), is degraded in individuals with lower working memory abilities (Lin et al., 2010), and is severely disrupted when participants are placed under cognitive load (Lin et al., 2010; Schneider et al., 2012). Given these facts, we reasoned that cognitive load may also impair the ability of neurotypical participants to integrate contextually gained information about a speaker's mental states when computing implicatures. If so, then, on the Competence-by-Default hypothesis, we might expect them to compute SSIs more often than expected under conditions of speaker ignorance.

In order to address this question, and to contrast the Competence-by-Default and Contextual Licensing hypotheses, we conducted a study in which we placed neurotypical adults under cognitive load, and tested them using methods similar to those of Hochstein et al. (2018). In addition, we included a condition analogous to previous tests of the SSI-by-Default hypothesis to confirm that our methods are comparable to those used in past studies. To address the SSI-by-Default hypothesis, we placed participants under load in conditions where speakers were knowledgeable. Based on past results, we expected that, contrary to the SSI-by-Default hypothesis, cognitive load should result in fewer SSIs, since it should inhibit processes involved in the strengthening of literal statements. More importantly, to contrast the Contextual Licensing and Competence-by-Default hypotheses, we asked how cognitive load impacted participants in conditions where speakers were ignorant and no SSI was expected. Here, matters are more complex, since past studies predict that load should make it harder to compute SSIs, but the Competence-by-Default hypothesis, unlike Contextual Licensing, predicts higher levels of SSI than expected under conditions of speaker ignorance. Specifically, if a listener assumes that a speaker is knowledgeable about alternatives, then they should believe that an SSI is warranted unless this assumption is overturned by contextual information indicating that the speaker is ignorant. Therefore, under conditions of speaker ignorance, even if cognitive load makes it harder to compute SSIs, we may expect implicatures to occur more frequently than expected if load also impairs the listener's ability to integrate contextual information concerning speaker ignorance.

2 Methods

2.1 Participants

We tested 60 English-speaking participants, ranging in age from 18 to 45 years old (mean 23.48; 20 male) at Concordia University, Canada. Participants were recruited using advertisements on campus and were compensated with course credit. All participants were native English speakers (English dominant). Because in Montreal it is common to be bilingual, we asked participants what percentage of their daily interactions were in English. Of the 60 participants, 17 reported 100% of their daily communication to be in English, 14 reported 80% to be in English, and 6 reported 50% or less to be in English. An additional 23 participants did not provide this information, as it was initially an optional question.

2.2. Design

Methods were adapted from Hochstein et al. (2018), which included younger participants. Given that the current study tested only adults, participants were warned that the experimental tasks were designed for "little kids" and would be "very straightforward." Participants were asked to go with their "natural instinct and try not to overthink anything".

Each participant performed a warm-up task and then completed a scalar-implicature task. Whereas the warm-up task was the same for all participants, participants were divided into two groups for the scalar implicature task resulting in a between subjects design. The Cognitive Load group completed the scalar implicature task while also performing an interference task that aimed to place participants under cognitive load. The Control group completed the same scalar implicature task but without any additional cognitive load.

2.2.1 Warm-up Task

The warm-up task was designed to focus participants on the knowledge states of speakers. Details and results of this task are given in the Appendix 1.

2.2.2 Scalar Implicature Task

The Scalar Implicature task was identical for participants in both the Control group and the Cognitive Load group. In this task, the experimenter placed three brown circular boxes with lids onto the table and re-introduced participants to Farmer Brown (the non-blindfolded character from the previous warm-up task). The experimenter then told the participants the following.

> *Farmer Brown doesn't know what is inside the boxes, but he is going to look, sometimes in all of them, and sometimes only in two of them. Then he is going to tell you what he knows. He's trying to help you. He's not trying to trick you or anything. Then, I'm going to ask you some Yes/No questions about the boxes, and you can use what you saw and what Farmer Brown knows to make an educated guess. Then you can answer either "Yes" or "No". But sometimes if you have no idea, or you can't possibly know what's inside the box, then you should just say, "I don't know". So your options are "Yes," "No," and "I don't know."*

In each trial, Farmer Brown opened and looked in either two or three of the boxes and then made a statement about what was inside them. Farmer Brown always opened Box 1 and Box 2 in such a way that the contents of these boxes were fully visible to the participant. Box 1 and Box 2 always had two foam cubes inside, all of them the same color. Critically, the participants were unable to see what was in the third box. On some trials, Farmer Brown looked into the third box (hereon, *full-knowledge* trials), on others he did not (hereon, *partial-knowledge* trials).

Once Farmer Brown had finished looking inside the appropriate boxes for a given trial, the experimenter then pointed to the third box and asked the participant, "Does Farmer Brown know what's in this box?" Participants were expected to answer *yes* in the full-knowledge trials and *no* in the partial-knowledge trials. If the participants gave the wrong response (N=3 out of 540 trials), the experimenter repeated the question at which point all participants were able to provide correct responses. Once participants had responded correctly, the experimenter then said: "Now Farmer Brown is going to tell you what he knows."

The statement made by Farmer Brown varied between trials. In Full-Knowledge+All trials (FK+All), Farmer Brown peeked into the third box and made a statement using the quantifier *all* (e.g., "All of the boxes have red cubes"). In such trials, participants were expected to infer that, like the two open boxes, the third box contained, e.g., red cubes. In Full-Knowledge+Some trials (FK+Some), Farmer Brown peeked inside the third box and made a statement using the quantifier *some* (e.g., "Some of the boxes have red cubes"). In such trials, participants were expected to infer that the third box did not contain any, e.g., red cubes. In the Partial Knowledge+Some trials (PK+Some), Farmer Brown looked into the first two boxes but not the third, and made a statement using the quantifier *some* (e.g., "Some of the boxes have red cubes"). In such trials, participants were not expected to infer anything about the content of the third box (since Farmer Brown did not know what it contained). For all three trial types, after Farmer Brown made his statement the experimenter pointed to the third box and asked, e.g., "Do you think there are red cubes in this box?". We expected that participants would respond "yes" in the *FK+all* trials, "no" in the *FK+some* trials, and "I don't know" in the *PK+some* trials.

Each participant completed 9 trials, three of each type. Within each trial, the same color of cubes was displayed within the open boxes. However, the color of cubes (and the color word used) varied between trials. Each participant was given one of two counter-balanced orders. Order 1 was as follows: 1) FK-All trial, 2) FK+Some trial, 3) PK-Some trial, 4) FK+Some trial, 5) FK+All trial, 6) PK+Some trial, 7) FK+Some trial, 8) PK+Some trial, 9) FK-All trial. Order 2 was the reverse of Order 1.

The Control group completed this Scalar Implicature task without any additional cognitive load. The Cognitive Load group, however, performed an additional task prior to each Scalar Implicature trial. Specifically, prior to each implicature trial, participants were asked to look at a computer screen and to memorize a display that was presented for three seconds. They were told that they would be tested on their ability to recall the display later in the task. The display presented three boxes, each divided into four equal quadrants that varied randomly with respect to whether they contained a dot (see Figure 2).

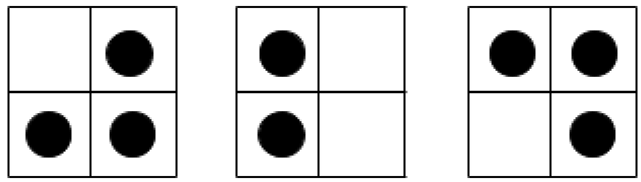

Figure 2. An example of a dot display used in the memorization task.

After viewing the display, participants then completed the Scalar Implicature trial as described above. After the implicature trial, they were then asked to report their memory of the display on a sheet of paper containing three empty boxes.

3. Results

Our first analysis asked whether participants engaged in the cognitive load task, in order to ensure that there was a true difference between the two conditions (which would not be the case if participants in the Cognitive Load condition failed to engage with the task). Participants in the Cognitive Load condition were assigned a score out of 12 on the dot-recall task, where a point was given for each of the 12 quadrants that was correctly replicated. Overall, participants responded correctly on 71.9% of trials (minimum 8.3%, maximum 100%, SD=21.0), which is significantly greater than expected by chance according to a one-sample t-test ($t = 17.1$, $df = 269$, $p < 0.001$).

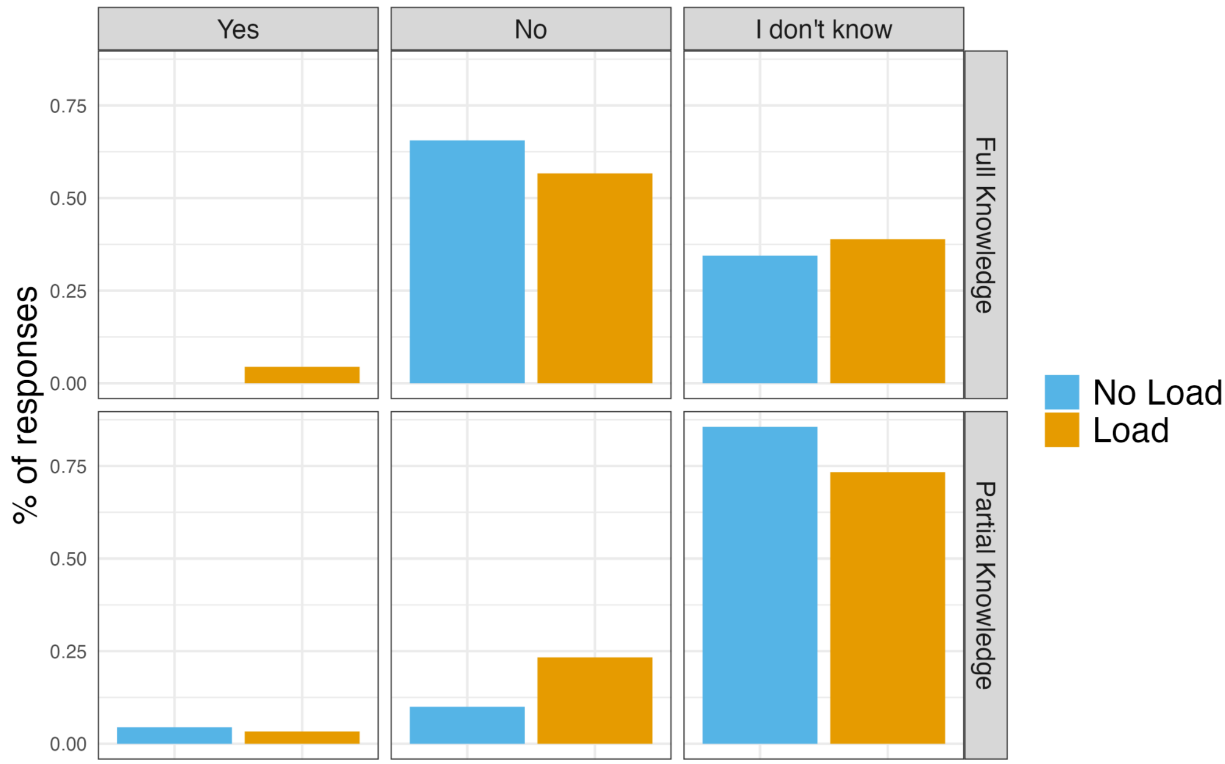

Figure 3. Proportion of "Yes", "No", and "I don't know" responses in trials with *some* for the No Load and Load conditions where either the speaker was knowledgeable (Full Knowledge+Some trials) or ignorant (Partial Knowledge+Some trials) about the content of the third box.

Participants performed at ceiling (i.e., they responded "Yes" 100% of the time in the Load condition and 97% of the time in the No Load condition[14]) in trials where *all* was used, as expected. To assess whether cognitive load impacted how participants computed scalar implicatures when speakers were either ignorant or knowledgeable, we constructed two generalized linear mixed-effects models with the *glmer* package (Bates et al., 2015) in R (R Core Team, 2022). Our first model predicted the proportion of "no" responses as a binary outcome in *some* trials from Cognitive Load, Knowledge State, and their interaction. With the number of

[14] The other 3% were "I don't know" responses.

participants and items in this experiment, models resulted in a singular fit when random intercepts of both participant and item were included, and failed to converge when we added random slopes of any sort. Thus only the random intercepts for participants are included. This model revealed a significant effect of Knowledge State (β =-5.06, SE = 0.8, $p < .001$), and more importantly, a significant interaction between Cognitive Load and Knowledge State in comparison to a model with no interaction (β = 2.62, SE = 0.86, $\chi^2(1) = 11.3$, $p < .001$). To understand this interaction, we conducted *post hoc* t-tests comparing responses in Load vs. No Load conditions in the Partial-Knoweledge and Full-Knowledge trials. We found a significant difference between responses in the Partial-Knowledge+Some trials with participants providing more "no" responses in the Load condition (10% to 23.3%; t = -2.43, df = 178, $p = 0.02$), compatible with making more scalar implicatures. In contrast, there was no increase in "no" responses due to cognitive load on Full Knowledge+Some trials. Instead, there was a modest, non-significant, reduction in scalar implicatures (65.6% to 56.7%; t = 1.22, df = 178, $p = 0.22$) when participants were under load, a difference (8.9%) that was similar in size to reductions seen in some previous studies, which range from approximately 5% to 15% (De Neys & Schaeken, 2007; Dieussaert et al., 2011; Marty & Chemla, 2013; Marty et al., 2013; Cho, 2020; van Tiel et al., 2019).[15] Furthermore, the reduction in scalar implicatures did not coincide with a significant increase in "I don't know" responses (34.4% to 38.9%; t = -0.62, df = 178, $p = 0.54$), indicating that the effect of load was not simply to induce confusion and uncertainty.

These analyses indicate that participants performed differently when under load than when not under load. However, they do not test whether accuracy on the load task was related to the likelihood of computing implicatures across different conditions. To probe this, a final,

[15] One unpublished report, noted by an anonymous reviewer, finds a difference of approximately 25% between no-load vs. load conditions (Marty et al., 2020).

exploratory, analysis asked whether performance on the Cognitive Load (dot memorization) task was related to judgments on the Scalar Implicature task. A glmer model predicting "correct" responses on the Scalar Implicature task (i.e., computing SSIs in the Full Knowledge condition, and not computing them in the Partial Knowledge condition) from score on the Cognitive Load task found that when participants correctly recalled dot arrays, they were more likely to provide correct responses on the Scalar Implicature Task ($\beta = 1.4$, SE = 0.71, $p = 0.05$).

4. Discussion

We investigated whether listeners make the default assumption that speakers are competent with respect to alternatives when computing scalar implicatures. To do this, we tested the ability of participants to draw on contextually available information about the epistemic state of the speaker during a test of scalar implicature while they were placed under cognitive load. We found that, when participants interpreted the utterances of an ignorant speaker, they computed significantly more implicatures under cognitive load.

These results are analogous to those reported by Hochstein et al. (2018) who found that adolescents with ASDs over-computed SSIs in contexts where the speaker was ignorant. In their study, Hochstein et al. raised the possibility that adolescents on the autism spectrum compute SSIs by assigning a default exhaustive parse. However, as noted in the introduction, their results could also be explained if such individuals assumed competence by default. On this view, individuals with ASDs may overcompute SSIs because they are unable to use contextual information about the epistemic state of the speaker to override this default assumption (see Appendix 2 and Figure 1, Introduction). Similarly, neurotypical participants placed under load might also overcompute SSIs under conditions of speaker ignorance, again because resolving the contradiction between competing representations of mental states is resource intensive. Specifically, cognitive load may interfere with the listener's ability to cancel a default assumption of competence when they are presented with contextual information that a speaker is ignorant, resulting in an SSI.

To make this concrete, consider the case in our experiment where a speaker utters the statement in (4) when they are ignorant about the contents of the third box.

(4) Some of the boxes have red cubes.

Prior to hearing the utterance in (4), the listener sees the speaker look into 2 out of 3 boxes, which supports the inference that they don't know what's in the third box. Next, on Gricean-inspired analyses of SSI, when the listener hears the utterance in (4) they generate the alternative containing "all", in (5). They then compute the weak scalar implicature in (6) via standard pragmatic reasoning (e.g., Maxim of Quantity), which is compatible both with an SSI and also with speaker ignorance. This inference reflects the belief that if the speaker had known that all of the boxes had red cubes, then they should have said so. Next, because they have assumed that the speaker is competent with respect to unsaid alternatives, the proposition in (7) follows—i.e., that the speaker knows what is contained in all of the boxes.

(5) All of the boxes have red cubes. [Hereon, q]

(6) It is not the case that the speaker knows that all of the boxes have red cubes. [$\neg K(q)$]

(7) The speaker knows whether or not all of the boxes have red cubes. [$K(q) \vee K(\neg q)$]

(8) The speaker knows that not all of the boxes have red cubes. [$K(\neg q)$]

Critically, only after reaching the inference in (7) is the listener in a position to notice a contradiction between the linguistic inference just reached and their prior knowledge gained from the non-linguistic context (i.e., that the speaker did not look in the third box, and therefore must be ignorant of its contents). Thus, at this point a participant who is *not* under load should draw upon their contextual knowledge to reject the inference in (7). However, if they cannot integrate contextual knowledge in this way, then the SSI in (8) arises—i.e., the speaker knows that not all of the boxes have red cubes. This integration of linguistic and non-linguistic knowledge, we suggest, may be the process that is impaired when participants are placed under cognitive load, and may also be impaired in participants with ASDs. Notably, if listeners do not assume Competence-by-Default, then they should not generate the inference in (7), precluding the possibility of generating the SSI in (8).[16]

An important consequence of adopting this view is that it posits two distinct ways in which cognitive load might impact the computation of implicatures. In keeping with past studies, the hypothesis assumes that cognitive load affects scalar implicature by having a generalized impact on inferential processes, which might include the ability to generate and/or negate alternatives, or more general processes such as ambiguity resolution and/or contextual integration (for discussion, see Marty et al., 2020; Marty & Chemla, 2013). Thus, when a speaker is knowledgeable, we should expect a generalized impairment of the inferences involved in implicature, leading to fewer SSIs under load. However, the Competence-By-Default hypothesis also posits that this generalized impact should impair the integration of epistemic information, such that listeners who assume competence should be more likely than expected to compute inferences when a speaker is ignorant. Furthermore, to account for the data, cognitive

[16] For simplicity, we have described this hypothesis via stepwise Gricean reasoning. However, this hypothesis can also be modeled by alternative architectures including game theoretic models (Franke, 2011), RSA (Goodman & Shuhlmüller 2013), Constraint-based frameworks (Breheny et al., 2013), and Relevance Theory (Sperber & Wilson, 1986/1995). Also, given certain assumptions, grammatical theories can also likely model our findings (see Appendix 2). Each of these approaches maintains that listeners integrate information about a speaker's epistemic state, as well as other contextual information, when computing inferences. Critically, the proposed architectures are not necessarily committed to when contextual information is deployed, and thus are potentially compatible with either Competence-by-Default or Contextual Licensing.

load must have a larger effect on reasoning about speaker knowledge than on other processes involved in implicature (since, if the magnitude of these two effects were equal, we would expect them to cancel out in the ignorant speaker condition, resulting in no difference between the load vs. no-load conditions). An important question is whether this assumption of diverse effects of load is warranted, and also whether load should impact mental state reasoning more than, e.g., ambiguity resolution, generation of alternatives, etc. On the one hand, the assumptions seem reasonable, since previous studies report that belief processing is severely impaired—or completely absent—when neurotypical adults are placed under load, suggesting a very large effect (Lin et al., 2010; Schneider et al., 2012), whereas studies of SSI that don't involve manipulation of speaker knowledge generally find modest impacts of load, that never fully erase implicatures (De Neys & Schaeken, 2007; Dieussaert et al., 2011; Marty & Chemla, 2013; Marty et al., 2013; Cho, 2020; van Tiel et al., 2019). On the other hand, effect sizes vary from one study to the next depending on methodology, and so it is an empirical question whether mental state reasoning is more impaired than other inferential processes in paradigms like the one we present here.

Naturally, alternative explanations of these data are also possible. In particular, one broad class of hypotheses that should be addressed in future work is the possibility that paradigms that place participants under load don't actually reveal how utterances are interpreted by default — either in our study of Competence-by-Default, or in past studies that have probed the SSI-by-Default hypothesis — but instead reflect a retreat to priors, or a generalized state of confusion. One version of this idea posits that when participants are placed under load, they experience increased uncertainty, leading their "No" judgments to regress toward 50% Yes/No (chance) levels or to more judgments of "I don't know". Against this idea, however, participants who were placed under load in the ignorant speaker condition of our study showed a selective reduction of “I don’t know” responses (from 85.6% to 73.3%) and an increase in “No” responses (from 10% to 23.3%), with no corresponding increase in “Yes” responses. Meanwhile, participants placed under load in the knowledgeable speaker condition showed equally large increases in “I don’t know” and “Yes” responses, a pattern more compatible with confusion.

On another version of this hypothesis, suggested by a reviewer (and consistent with the account given in Marty & Chemla, 2013), interference due to cognitive load might not cause listeners to guess randomly, but instead to revert to priors. According to such an account, listeners may represent the prior probability of a strengthened meaning and use contextual factors to compute the likelihood of an implicature, given evidence of speaker ignorance or knowledge. Thus, for example, if they represented the prior probability of a strengthened meaning as 0.5, they would represent the likelihood of implicature given evidence that the speaker is knowledgeable as greater than this value (e.g., 0.8), and the likelihood of implicature given evidence that the speaker is ignorant as lower (e.g., 0.2). Given this, placing participants under load in the knowledgeable speaker condition might reduce implicatures, while placing them under load in the ignorant condition might cause an increase. Thus, a single factor, interference with the integration of contextual cues, might explain both the increase and decrease in the computation of SSIs.

Currently available data can’t decide between the hypothesis we aimed to test—which posits competence by default—and an account that appeals to confusion, or regression to priors. However, in keeping with the motivation of our study, any successful account should explain why adolescents with ASDs often overcompute implicatures in ignorant speaker conditions, and also why the same behavior is found in neurotypical adults placed under load. The

Competence-by-Default hypothesis provides a synthesis of both data points. In contrast, it may be challenging to explain both findings via a model that posits generalized confusion or regression to priors. First, we don't currently know how individuals represent the prior probability of an SSI, or what this value might be (though corpus studies estimate that SSIs for *some/all* are overall quite infrequent; Eiteljoerge et al., 2018). Second, it is unclear whether such an estimate, once obtained, could explain the behaviors of individuals with ASDs, while also explaining data for neurotypical adults under load. In particular, any such estimate should account for the fact that individuals with ASDs compute SSIs 85-90% of the time for both ignorant and knowledgeable speakers, while neurotypical adults under load do so much less frequently. While this may be possible, we believe that an equally natural explanation of the data is that individuals with ASDs compute SSIs like neurotypical adults: both groups assume speakers are competent and have difficult updating this assumption using contextual information about a speaker's mental states, though to differing degrees.[17]

In summary, by placing participants under cognitive load, we tested the hypothesis that listeners adopt the competence assumption about alternatives by default. In support of this hypothesis, we found that, under load, participants computed more strong scalar implicatures than expected when the speaker was ignorant. This finding is compatible with the idea that, when under load, listeners struggle to integrate the epistemic entailments of an utterance with contextually available information about speaker knowledge. Future studies should explore alternative theoretical explanations of these data, and should probe other forms of implicature, to test whether similar results can be found in a more diverse range of phenomena.

[17] Note that several studies have found that individuals with ASDs compute SSIs to the same degree as neurotypical individuals (see Pijnacker et al. 2009; De Marchena et al. 2011; Hochstein et al. 2018; among others).

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All data are available at https://osf.io/xe65y/?view_only=740ab55c261941fa9efb210985e33559

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Appendix 1: Warm-up task

A warm-up task was used to focus the attention of participants on the knowledge state of speakers. Participants were asked whether certain statements (about an event that had just happened) were uttered by a blindfolded character or a non-blindfolded character. Participants were expected to attribute accurate statements to the non-blindfolded character and inaccurate statements to the blindfolded character.

In this task, there were 5 trials presented in a fixed order. Before the trials, the participants were introduced to two characters in the form of small action figures, Farmer Brown and Cowboy Black. The experimenter explained to the participants that, "Cowboy Black has a blindfold on, so he cannot see what's happening… [he] might say something funny or not true because he cannot see. He can still hear, but he cannot see anything." Farmer Brown on the other hand, was not blindfolded, and the experimenter explained to participants that, "Farmer Brown will say the correct things because he can see and he can hear."

In each of the 5 trials, the experimenter placed one or two small foam cubes on the table (one in the first two trials and two in the remaining three). The experimenter then brought out a stuffed tiger who announced its intention to take something without naming what it wanted to take. The tiger then proceeded to take a cube (either the only cube present, or one of the two). The experimenter then told the participant, who was watching the scene, that someone said a certain statement. The participants were asked which character, the blindfolded Cowboy Black or the non-blindfolded Farmer Brown, said the statement. They were also asked to justify their response.

In the first two trials, the experimenter presented the participants with a sentence explicitly mentioning sight. In trial 1, the experimenter told the participant that someone said, "The tiger took something. I didn't see what he took." In trial 2, the experimenter told the participant that someone said, "I saw the tiger take the yellow cube." It was expected that the participants would attribute the first statement to the blindfolded character (Cowboy Black) and the second statement to the non-blindfolded character (Farmer Brown).

For each of the remaining three trials (trials 3 to 5), the experimenter placed two small cubes on the table. In these trials, the stuffed tiger first named the colors of the two cubes on the table before announcing its intention to take something. For example, on one trial the tiger said, "It's me, Tiger. Look, a green cube and an orange cube. Look what I'm taking." The stuffed tiger then took one of the cubes. On each of the three trials, the experimenter told the participants that someone said that the tiger took a specific cube (e.g., "Someone said 'The tiger took the orange cube'."). In trials 3 and 5, the color mentioned by the experimenter matched the actual color of the cube that was taken. Thus, the statement presented to the participants was an accurate description of what happened. In trial 4, the color mentioned by the experimenter was a mismatch and, thus, the statement mentioned by the experimenter did not accurately describe what happened. It was expected that participants would attribute the accurate statements to the non-blindfolded character (Farmer Brown) and the inaccurate statement to the blindfolded character (Cowboy Black).

As expected, participants performed almost perfectly and responded correctly 99% of the time, with 3 unexpected responses out of 300, each given by different participants (1 in the control group, 2 in the group who were subsequently assigned to the cognitive load group).

Appendix 2: Grammatical Strengthening and Competence

Although we framed Competence through a Gricean perspective, it is critical to note that similar assumptions need to be made even when inferences commonly labeled as "implicatures" arise through grammatical strengthening (Chierchia, 2004, 2006; Fox, 2007; Chierchia et al., 2012; Meyer, 2013; among others). According to such accounts, SSIs are derived via a phonologically null exhaustivity operator (*Exh*), which has a meaning similar to the focus particle *only*. When this operator is inserted into an utterance like, "Some of the boxes have red cubes," the resulting meaning is similar to uttering "only some". As a result, a "some but not all" meaning (i.e., the SSI) is encoded entirely within the grammatical representation, with no need for a listener to consider speaker competence. However, within the grammatical perspective, sentences with "some" permit at least two grammatical parses: one that includes an *Exh* operator with relevant alternatives that lead to the derivation of a strengthened meaning, and another that yields a weaker meaning, either by omitting the *Exh* operator altogether, or by pruning the relevant set of alternatives so that such an operator applies vacuously (see the discussions in Crnic et al. 2015 and Singh et al. 2016). Thus, a listener, upon hearing a sentence like "Some of the boxes have red cubes" must choose between two possible parses: one that entails "not all" and another that permits the possibility of "all". The issue of speaker competence reappears, not as a step in the derivation of the strengthened meaning, but rather as a step in the choice between two parses.

Within this type of theory, context must be able to influence the choice of parse. For example, within our experimental condition without cognitive load, listeners must choose the strengthened parse when it is clear that speakers have looked into the third box, but yet choose the weak parse when it is clear that speakers haven't looked. Since perceived speaker competence influences the choice of parse, the questions discussed in this paper might be reframed when considering the grammatical view. Relevant questions might be (1) do listeners assess contextual cues relevant in determining a speaker's mental state before choosing between parses (i.e., the Contextual Licensing strategy), and (2) do listeners have a default assumption that speakers are competent with respect to alternatives, and thus a default tendency towards the strong parse, only overriding this assumption when contextual cues intervene (i.e., Competence by Default)? The grammatical theory, thus, could account for the patterns we see in this paper by adopting a Competence-by-Default strategy which, in turn, would lead to an exhaustive parse if the listener was unable to integrate contextual information about the speaker's epistemic state.