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The cognitive cost of deriving implicature: A reaction-time study

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Abstract: If A asks B "Do you like berries?", and B replies "I like some berries," B would infer that A does not like all kinds of berries. Such inference derived by negating the stronger alternative (all) is known as the scalar implicature (SI). Earlier experimental studies showed that computation of SI requires additional processing time compared to literal interpretation, and hence they argued that derivation of implicature is cost-demanding. Some recent experiments, however, found that derivation of implicature does not require any additional processing cost. The present study re-examines the comprehension of implicature using a Truth Value Judgement task. The hypothesis of this study is that the computation of implicature is as immediate as the computation of literal meaning if the sentences are preceded by prior context and communicative intent as in real conversation. The study uses a two-between-subject design where 32 native English speakers were required to read a 'context', followed by a 'question' and an 'answer'. The context followed by the question either demanded the lower-bounded 'literal' meaning or the upper-bounded 'pragmatic' meaning of the under-informative answers which is the implicature. The result indicates that when a prior context and a clear communicative intent guide the hearer toward the intended meaning, both literal and pragmatic meaning comprehension is immediate. The result certainly indicates against the Default Inference accounts, but it also opposes the Literal-first hypothesis of the Contextualist school. The result strongly supports the Constraint-Based account of implicature derivation and brings additional support to the studies which argue for immediate implicature computation.

Keywords: Sentence Comprehension, Processing Cost, Scalar Implicature, Quantifier

1. Introduction

An inference is a conclusion that is derived by reasoning about certain evidence/information. When we talk about pragmatic inference, we exclusively focus on human verbal communication inference, which is associated with everyday language use. To make pragmatic inference, we use two types of information: first, the uttered sentence by the speaker, and second, our theory or hypothesis about the speaker's intention. The hypothesis that we make about the speaker's intentions, however, depends on what we know about the speaker's beliefs, which can be more clearly guessed by considering the events that had happened to the speaker earlier, and the environment that the speaker is in right now.

According to Grice (Grice, 1975), the inference made from an utterance by considering the speaker's intention is called conversational implicature. There are two types of implicatures as defined by Grice: the particularized or the relevance implicatures, and the generalized or the scalar implicatures. There is no dissent regarding what a relevance implicature is and how it is computed the general agreement is that relevance implicatures are derived by considering the contextual information. However, the definition of scalar implicature is debated; not regarding what the implicature is, but regarding how it is derived. The present study focuses on the computation of scalar implicature (SI).

A scalar implicature arises in a situation, where an under-informative sentence is uttered by the speaker to convey that its stronger alternative representation is not true. For example, if A asks B, "Do you like berries?", and B replies, "I like some berries", then A would infer that B does not like all kinds of berries. But logically, if B liked all kinds of berries, he would not be a liar to say that he likes some berries, because, if he likes all kinds of berries, he definitely likes some kinds of berries. However, when the speaker's intention is considered and the speaker is believed to be a rational being, then A would think that, if B liked all kinds of berries, he would have said so. What is the need to use a weaker statement, when the stronger alternative is available? Hence, B must have meant that he does not like all kinds of berries.

The logical meaning of any scalar term is lower-bounded (e.g., *at least some* and *possibly all*); but when the implicature is derived, the scalar term is understood in its upper-bounded meaning (*some, but not all*). The disagreement regarding the computation of scalar implicature is here. The *default inference account* (Chierchia, 2004; Levinson, 2000) advocates that scalar implicatures are computed by default because these implicatures do not require any contextual information; SIs are part of the lexicon (Levinson, 2000), or they are generated through the grammatical process (Chierchia, 2004). Therefore, whenever the hearer listens to an under-informative utterance, the upper-bounded meaning (implicature) is the first to be generated. Only if the computed upper-bounded meaning does not hold in the context, the lower-bounded meaning is taken as the intended meaning. Contrary to the default hypothesis of the Neo-Griceans, the *Literal-first hypothesis* believes that computation of implicature is cost-demanding, and all pragmatic meaning comprehension is preceded by the computation of the literal meaning of the sentence. Experimental results support the Literal-first account showing that derivation of SI requires extra processing time (hence extra processing cost) compared to the computation of logical meaning (Bott & Noveck, 2004; Huang & Snedeker, 2009; Noveck & Posada, 2003). Such results go contrary to what would be predicted by the Default inference account.

Huang & Snedeker (2009), in their visual paradigm study, gave their participants a picture. The picture had four quadrants: first quadrant (top-right corner) - a girl has two socks; second quadrant (top-left) - there is a boy who has two socks; third quadrant (bottom-left) - a boy has nothing; and fourth quadrant (bottom-right) - a girl has three soccer balls. Participants heard sentences like "Point to the girl who has some of the sock|s" and "Point to the girl who has all of the soc|cer balls" The vertical bar is the point of disambiguation. Their study showed that participants take longer to increase their looking time on the target when they hear the 'some' sentence than when they hear the 'all' sentence (for the some-sentence, the target is the first quadrant, and for the all-sentence, the target is the fourth quadrant). Therefore, they concluded that the computation of implicature requires additional processing time. However, Grodner et al. (2010) found evidence of immediate implicature derivation. Each trial in their study began with a pre-recorded sentence describing the total number and type of objects in the display, to draw participants' attention to the total cardinality of each type of item. And they also included the quantifier none. In this setup, convergence on the target in the some- and all- conditions were equally fast.

Support for additional processing time for SI derivation also came from a self-paced reading time study (Breheny et al., 2006). BKW gave their participants two types of contexts with the under-informative utterances embedded in them, and they measured their self-paced reading times:

a. Upper-bound (context1): Mary asked John whether he intended to host all of his relatives in his tiny apartment. John replied that he intended to host *some of his relatives*. *The rest* would stay in a nearby hotel.

b. Lower-bound (context2): Mary was surprised to see John cleaning his apartment and she asked the reason why. John told her that he intended to host *some of his relatives*. *The rest* would stay in a nearby hotel.

Their study saw that the phrase, "some of his relatives," had a longer processing time in the upper bounded context as compared to the lower bounded context. Therefore, it was concluded that implicature derivation is cost-demanding. However, a new study (Politzer-Ahles & Fiorentino, 2013) argued that the delay in computing implicature in BKW was due to the asymmetry in the context. The phrase 'his relatives' is repeated in the upper-bounded scenario, which makes it infelicitous, as the pronoun is an unnecessary repetition. P&A gave their participants more similar contexts:

a. Upper-bounded: Mary was preparing to throw a party for John's relatives. She asked John whether all of them were staying in his apartment. John said that *some of them* were. He added that the rest would be staying in a hotel.
b. Lower-bounded: Mary was preparing to throw a party for John's relatives. She asked John whether any of them were staying in his apartment. John said that *some of them* were. He added that the rest would be staying in a hotel.

The participants in their study show no difference in the time taken to understand the phrase "some of them" in the two conditions.

Bott and Noveck (2004) conducted a Truth Value Judgement task where they gave their participants sentences like "some elephants are mammals" and asked them to decide whether the sentence is true or false. The study divided its participants into two groups. They instructed one group to think "some" as "some and possibly all" and instructed the other group to think "some" as "some, but not all". The study showed that the second group took longer to respond to the sentence than the first group. Hence, they concluded that the computation of implicature requires additional processing effort. Support for additional processing effort for deriving implicature comes from another Truth Value Judgement task (Chevallier et al., 2008). Chevallier et al tested whether participants were more likely to reject an under-informative 'or sentence' as false if they were allowed more processing time. Participants in their study saw a letter string (e.g., TABLE) which was followed by a descriptive sentence like "there is an A or a B". In one experimental condition, the participants' processing time was cut short by removing the letter string before the descriptive sentence occurred. In another experimental condition, participants were allowed deeper processing by extending the amount of time the letter string remained on the screen. Their study found that participants were more likely to derive implicature when they received more processing time, compared to when they received less processing time. Further, De Neys and Schaeken (2007) in their TVJT study showed that participants are less likely to derive implicature if they are given an extra cognitive load of remembering a dot pattern. Thus, they concluded that SI derivation is cost demanding.

Under the default and literal-first hypotheses, semantics and pragmatics are separated in the semantic and pragmatic processing. However, *constraint-based frameworks*, like that of Degen & Tanenhaus (2015), do not draw such a sharp boundary; they do not assign a default status to either literal or pragmatic comprehension. Instead, the framework assumes that the speed of SI computation is in primarily determined by context. As per this framework, listeners gather multiple probabilistic contextual cues to speaker meaning during sentence processing, and it is not the integration of pragmatic information that is costly, but rather it is the processing of the inference in contexts where support for the pragmatic processing is weak. The speed and ease of processing depend on the strength of the contextual cues available. QUDs (Question Under Discussion) in conversation are also taken to be such a contextual cue, and have thus been predicted to influence implicature computation and processing (Degen & Tanenhaus 2015; Ronai and Xiang, 2020).

Degen and Tanenhaus (2015) used a gumball paradigm, where participants saw a display of a gumball machine with an upper chamber filled with 13 gumballs and an empty lower chamber. Participants heard a "ka-ching" sound before the gumballs moved from the upper to the lower chamber. Then they heard a sentence like *You got some of the gumballs* as a description of a set of facts that made the stronger alternative *You got all of the gumballs* true. Participants were asked whether they agree with the statement. If participants interpreted the utterance literally, they responded "agree". If, instead, they interpreted the utterance pragmatically, they responded, "disagree". The argument is that the more the context supports the inference (as measured in proportions of pragmatic responses), the faster participants should be to provide a pragmatic response and the slower they should be to provide a literal response. Conversely, the weaker the contextual support for the inference, the slower the pragmatic response should be, and the faster the literal one. For "agree" responses, both response times for participants who on average interpreted *some* semantically and response times for participants who interpreted *some* pragmatically increased when *some* was used to refer to the unpartitioned set and to small sets. And pragmatic responses to *some* were marginally slower than semantic responses on the subset of the data that included only consistent responders. Their result was incompatible with both of the most influential approaches to the processing of scalar implicatures: default hypothesis and literal first hypothesis. The result is most compatible with a Constraint-Based account where the speed of the implicature is determined by the probabilistic support it receives from multiple cues available in the linguistic and discourse context, including the task/goal relevant information.

Ronai and Xiang (2020), in their study further bring evidence for constraint-based account by showing the importance of QUD in implicature computation. They show that the effect of QUDs on calculation rates extends beyond the case of scalar inference to other types of quantity implicatures, specifically it-cleft exhaustivity. Further, they show that QUDs modulate both the calculation rates of implicatures and the reaction time cost of that calculation.

Using a Truth Value Judgment task, the present study re-examines adults' comprehension of scalar implicature which involves the quantifier, *some*. Unlike Degen and Tanenhaus (2015), whose paradigm used visual and auditory cues, the present study uses a reading paradigm where the cues for calculating the intended meaning in given in the [written] discourse between two interlocutors. The participants read a paragraph to understand the context, and then read the conversation between the interlocutors.

1.1 Present study

The study here tests whether the derivation of scalar implicature requires additional processing effort. The usage of a Truth-Value Judgment Task helps us compare the study with other TVJ studies (e.g., Bott & Noveck, 2004; Chevallier et al., 2008; De Neys & Schaeken, 2007; Degen and Tanenhaus, 2015), and the usage of a reading paradigm will help us extend on the study by Degen and Tanenhaus (2015)'s gumball paradigm.

The hypothesis of this study is that the computation of implicature is as immediate as the computation of literal meaning. The hypothesis is motivated by two factors. First, the incorporation of contextual information does not necessarily require additional processing effort. According to the Relevance theory (Sperber and Wilson, 1995), when a hearer encounters an utterance, he first processes the utterance with his latest activated assumptions in the memory (assumptions that are active in the short-term memory). If he does not find the relevance of the new utterance there, he then extends his context by looking for assumptions in his long-term memory. When he extends his context and actively searches for relevant assumptions, he gives processing effort, which requires additional processing time. Thus, the degree of processing effort is decided by the amount of context extension done. But if the relevant assumptions are available in the hearer's latest activated memory, which the theory calls the deductive device, then there remains no question of extra processing effort; hence, no extra processing time.

Second, the communicative intent in the conversation raises the expectation of informativeness. The intent decides whether the degree of informativeness is relevant or not. It is to be noted that, the utterance of an under-informative sentence does not necessarily require the computation of implicature. The same sentence, in some contexts, may require implicature derivation, but in other contexts, it might not (we will shortly observe this phenomenon in our experiment design below). This can also argue for the importance of QUD in deriving implicature.

In the earlier TVJ studies (Bott and Noveck, 2004; Chevalier et al., 2008; De Neys and Schaken, 2007), the utterances had no communicative goal. Thus, negating the upper-bounded meaning had no reason behind it. Further, hearers were expected to use encyclopedic information from their memory, which required them to search for information in the long-term memory leading to greater processing effort. Hence, the present study tests adults' comprehension of scalar implicature by providing the participants in each trial with a written scenario, which helps them form a hypothesis about the speaker's mental state. Further, a communicative goal in the conversation is introduced through a question that raises the expectation about which meaning (lower bounded/upper bounded) is intended by the speaker. The study tests the scale <*some, all*>.

2. Methods

2.1 Participants

32 native English speakers participated in this study. The participants were recruited through the recruiting website named Prolific, and they took the test online on the platform called Pavlovia. The participants had been divided into two equal groups: one group was labeled as the *pragmatic group* (16 participants), and the other as the *literal group* (16 participants).

2.2. Stimuli and procedure

The task was to judge whether a sentence is the "truth" or a "lie". For each trial, both the groups receive the same scalar utterance, but with different contexts (see Table 1).

The scenario helps the participant to guess what Molly and her mother already know or do not know. The question asked by the mother indicates what the goal of the communication is. In the pragmatic group, the mother knows that Molly knows that she has to fill six jars. Again, Molly knows that her mother knows that Molly knows that there are six jars, and all the jars were supposed to be filled by Molly, no less is accepted. Hence, here the degree of informativeness is relevant. Thus, when Molly says some jars are empty, it means not all the jars are empty. Again, it is also important to notice that there was a reason for Molly to lie, as she did not complete the task assigned to her. Hence, there was no anomaly in the conversation.

Table 1. Test trial example

	Scenario	question	answer	Expected response
Pragmatic group (Some pragmatic)	Molly's mother asked Molly to fill the six jars with lemonade, because many guests were coming to their party tonight. Molly totally forgot about the task. Later a guest tried to help herself with the lemonade, but the jar was empty.	Mother: Are the jars still empty?	Molly: Some jars are empty.	Lie (Press 'D')
Literal group (Some literal)	There was news that the city will not get water for the next three days. Hearing this, Molly's mother stored water in all the vessels in the house, but she could not see the six empty jars under the bed. Later she asked Molly whether any more containers were left.	Mother: Is there anything still empty?	Molly: Some jars are empty.	Truth (Press 'J')

On the other hand, for the literal group, Molly's mother wanted to know whether any vessel is empty, it does not matter how many. Again, Molly also knows that her mother does not know the total number of jars. Hence, her utterance of some does not intend to make an upper boundary.

The hypothesis is that both the groups should take similar processing time to understand Molly's implicated meaning, as the required information is made well-accessible to the participant. Hence, their response times would be similar (Processing $\text{time}_{\text{pragmatic}}$ = Processing $\text{time}_{\text{literal}}$). However, if the contextualist account is correct (that pragmatic processing takes additional processing time), then the pragmatic group should take longer processing time to comprehend the scalar utterances (Processing $\text{time}_{\text{pragmatic}}$ > Processing $\text{time}_{\text{literal}}$). Again, if the defaultist account is correct (that pragmatic meaning is the default meaning and only gets canceled when the context does not permit so), then the literal group should take the longer processing time (Processing $\text{time}_{\text{pragmatic}}$ < Processing $\text{time}_{\text{literal}}$).

The control trials were similar to the test trials, except that instead of *some*, the quantifier *all* and the cardinals two and three had been used (Appendix section has all the items). Both the groups get the same control trials. Thus, there were 7 test trials for each group, 4 all true trials, 4 all lie trials, 4 number true trials, and 4 number lie trails (see the Table 2).

Table 2. Test and Control Trials Distribution

Trial Type	Scenario and question	Answer	Pragmatic group	Literal group	Number of items
Test trial	Different	Same	Some_pragmatic	Some_literal	7
Control trial	Same	Same	All_truth	All_truth	4
	Same	Same	All_lie	All_lie	4
	Same	Same	Number_truth	Number_truth	4
	Same	Same	Number_lie	Number_lie	4

The participants sat in front of their Desktop monitor, where for each trial they saw 7 slides. On the first slide, the participants saw the scenario described in words. They took their own time to read it. After that, on the "right" click, they read the "question". Then again on "right" click, they read the name of the person, who is about to answer (e.g., Molly:). Then again on the "right" click, the participants saw the first word of the answer. The word displayed on the screen for 250 ms, and then after a 50 ms gap the second word appeared for 250 ms, and so on he read the entire answer which consisted of four words in total. The last slide contained the last/fourth word of the answer, which unlike the previous words did not stay on the screen for 250 ms, but it waited until the participant responded. The participant entered "J" if he thought the answer was the "truth", or he entered "D" if he thought it was a "lie". The response time was calculated from the onset of the display of the last answer word till the participant entered his/her response (see the diagrammatic representation below).

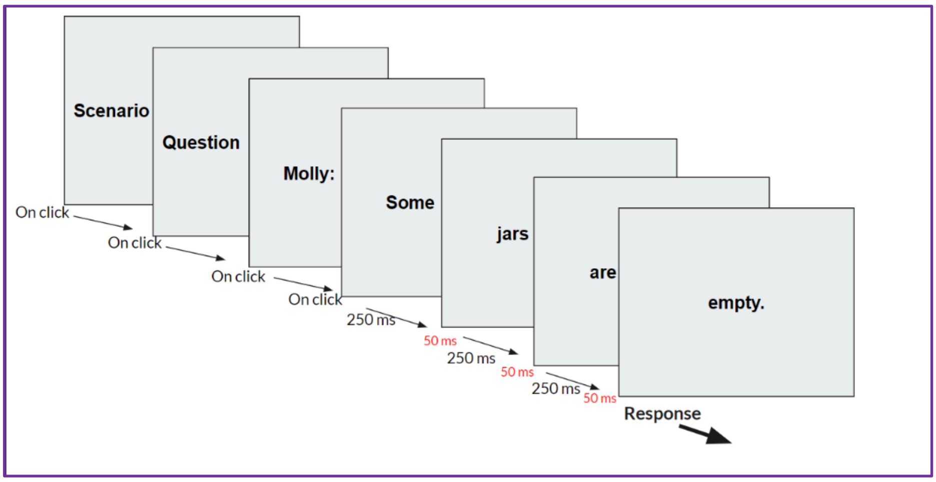

Figure 1. Demo of the presentation of each trial items to the participants

3. Results

The result shows that the success rate of the pragmatic group in the test trial is significantly lower than the literal group, and there is a marginally significant difference in the case of number_truth control trials.

Table 3. Partcipants' success rate in each trial type and their significance

Pragmatic group		Literal group		Comparison
Sentence type	success _rate (%)	Sentence type	success _rate (%)	Chi-square test of independence
Some_pragmatic	74.10	Some_literal	93.75	p = 0.0001
all_truth	89.06	all_truth	95.31	p = 0.323
all_lie	89.06	all_lie	93.75	p = 0.528
number_truth	87.5	number_truth	98.43	p = 0.038
number_lie	82.8	number_lie	85.93	p = 0.807

Table 4. Anova analysis of the response times

Pragmatic group	Literal group	ANOVA Analysis
Some_pragmatic	Some_literal	F(1, 186) = 1.64, p = 0.202
all_truth	all_truth	F(1, 116) = 0.35, p = 0.55
all_lie	all_lie	F(1, 115) = 0.71, p = 0.4
number_truth	number_truth	F(1, 117) = 1.83, p = 0.179
number_lie	number_lie	F(1, 106) = 0.11, p = 0.737

Nevertheless, the focus of this study was the response times. For the analysis of the response times, only the correct responses were taken into consideration and the response time values were log-transformed for normalization. An ANOVA analysis shows no significant difference between the processing times taken by the two groups in the test-trials, nor in the control trials (Table 4). However, it is observed that, for both the groups, the responses to all_lie trials took significantly longer time than all_truth trials (p=0.002 for pragmatic group; p=0.0003 for literal group) (Fig 2). On a revision of the items, two incongruous items were observed in the all_lie trials (highlighted in the appendix section). Once they were removed, there remained no difference across trails and also between the groups (Fig 3). Further, an analysis of the response times in the participants' failed trials showed that the responses to the failed trials took significantly longer time than the passed trials in the case for both groups (Fig 4).

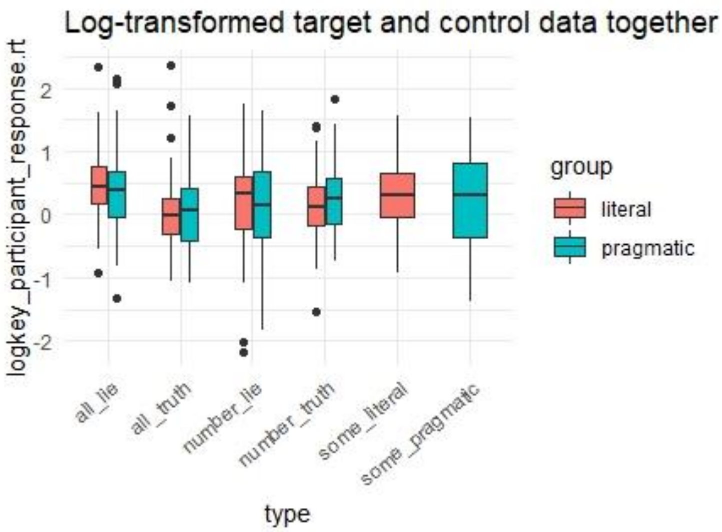

Figure 2. Box-plot of the log-transformed response times.

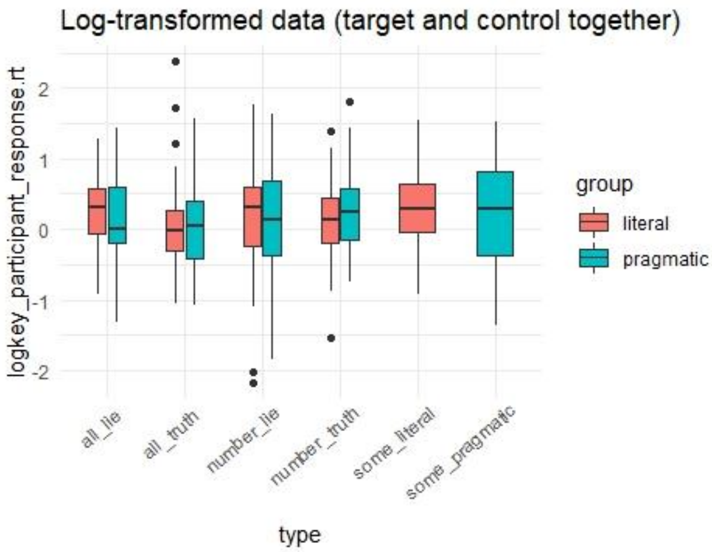

Figure 3. Box-plot of the log-transformed response times of revised data

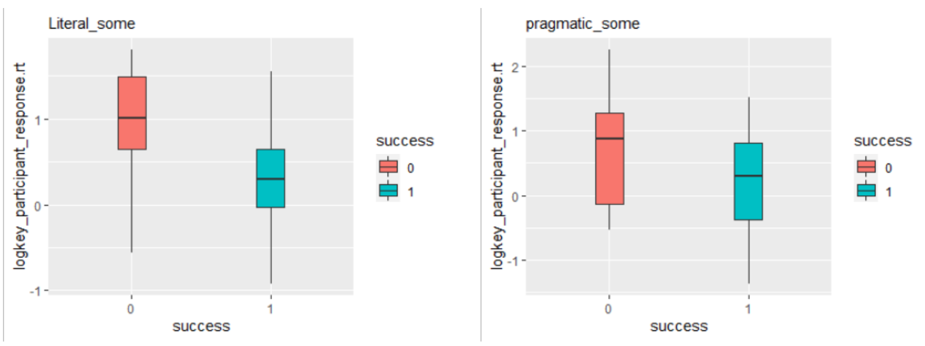

Figure 4. Box-plot of the log-transformed response times of passed and failed trials

4. Discussion

The present study tested adults' comprehension of scalar implicature involving the quantifier, *some*. The study tested the hypothesis of whether pragmatic meaning derivation is as immediate as literal interpretation.

The result indicates that both literal and pragmatic meaning comprehension is immediate when a prior context and a clear communicative intent guide the hearer toward the intended meaning. The study tests pragmatic processing with a TVJ task, which helps us do a direct comparison of this study with the other TVJ studies most of which have so far shown that implicature derivation requires additional effort. Importantly, the study brings additional support to the earlier studies, which showed no delayed processing time for pragmatic meaning derivation (Grodner et al., 2010; Politzer-Ahles & Fiorentino, 2013; Degen and Tanenhaus, 2015, Ronai and Xiang, 2020).

The result here indicates against the Default inference account (Levinson, 2000; Chierchia, 2004) as it does not show any longer processing time for the literal meaning. However, the result also indicates against the Literal-first hypothesis which says that pragmatic processing takes longer processing time. The present result brings evidence in support of the Constraint-Based account (Degen and Tanenhaus, 2015). The constraint-based account aligns strongly with the Relevance-theoretic (contextualist) account which advocates that not only the upper-bounded meaning of scalar sentences, but in fact, the lower-bounded meaning too is context-dependent, when understood in real-time. The Literal-first school is usually believed to be following the contextualist school. However, perhaps the concept of the relevance-theoretic (contextualist) account is not quite clear to the earlier studies. As per the contextualists (e.g., Sperber and Wilson, 1995; Carston, 1998) no utterance is understood without a context. Hence, both the computation of lower-bounded and upper-bounded meaning should take similar processing time as both the interpretation requires contextual information.

Another important aspect of the present study is that it analyses the response times of the wrong responses. The data shows that the response times for the wrong responses are significantly longer than that of correct responses for each group. This is a novel observation. It indicates that when the communicative intent indicates toward the lower-bounded meaning, then derivation of upper-bounded meaning is cost demanding, and when the communicative intent indicates toward the upper-bounded meaning, then the logical interpretation is cost demanding.

Future studies have the scope of studying implicature processing using better experiment designs, which can argue for against the popular theories more robustly.

5. Conclusion

The present study has tested whether the derivation of scalar implicature is cost demanding. It studies English-speaking adults' comprehension of the quantifier, some. The conclusion derived from the obtained result is that implicature derivation is as immediate as literal interpretation when supported by a prior context and communicative intent as in real conversation. The present result strongly supports the Constraint-Based account of implicature computation.

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Does this article screened for similarity?

Yes

Conflict of interest

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