A visual world priming investigation of Gricean inferences

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Abstract Listeners often derive an enriched meaning of a sentence. For example replying "John is" to the question "Are John and Mary are coming to the party?" implies that *Mary is not coming*. Previous research, using interpretation judgements, has shown that it is possible to prime the comprehension of Gricean inferences. In Experiment 1 we aimed to investigate the effect priming has on the processing of Gricean inferences, in particular ad hoc inferences. In Experiment 2 we test between two explanations of how ad hoc implicatures are derived: (1) involving specific alternatives or (2) involving a more general *anything else* representation.

Key words Eye-tracking, Priming, Gricean inferences

1. Introduction

Utterances often communicate more than the literal meaning of the words used (Grice, 1975). Take the following for example:

A: "Are Mark and Sarah coming to the party?"

B: "Mark is."

Here speaker B says that Mark is coming to the party, but implies that Sarah is not. Instead of saying exactly what he means, speaker B is using Gricean implicatures and A has to make an inference in order to interpret B. The following shows A's reasoning process (based on Geurts, 2010) (i) What could B have said instead? What are the *alternatives*? One salient possibility is that the speaker could have used a stronger term and said "Mark and Sarah are coming to the party." Why didn't B say so? (ii) The most likely explanation is that B does not believe that "Mark and Sarah" is true. (iii) Presumably, B has an opinion about whether "Mark and Sarah are coming" is true. (iv) Combining (ii) and (iii) yields the implicature that the speaker believes *Mark is coming but not Sarah.*

Implicatures have been analysed in great detail since Grice's seminal work. For example, there are analyses from the perspective of theoretical semantics (e.g., Chierchia, 2004), acquisition (e.g., Noveck, 2001), clinical disorders (e.g. Chevallier, Wilson, Happé, & Noveck, 2010), and sentence processing (e.g., Bott & Noveck, 2004). More recent work has focused on the underlying representations and processes involved in inferences and implicatures by using structural priming (Bott & Chemla, 2016; Rees & Bott, 2017). The work presented here aims to extend the priming investigations of implicatures by exploring the effect priming has on the processing of implicatures.

1.1 Structural priming

People are inherently repetitive in their language use; they often repeat linguistic structures that they have recently encountered (Pickering & Ferreira, 2008). This is known as structural priming. One of the most well-known experimental demonstrations of priming is Bock (1986) in which participants had to describe a picture after having repeated a sentence. Participants' descriptions were more likely to use the same sentence structure as the sentence that they had repeated in the preceding trial than a different structure. Since Bock's initial study researchers have used priming to investigate a wide range of linguistic phenomenon. The results of priming experiments are informative about underlying linguistic representations and how they are processed (Branigan & Pickering, 2017; Pickering & Ferreira, 2008). If the processing of one stimulus affects the processing of a subsequent related stimulus then these two stimuli must share some dimension of representation within the language processor.

Priming effects are found throughout the language system: in written and spoken production (e.g. Hartsuiker & Westenberg, 2000; Pickering & Branigan, 1998), comprehension (e.g. Arai, van Gompel, & Scheepers, 2007; Myslin & Levy, 2016) and across languages (e.g. Lobell & Bock, 2003; Scheepers, 2003). Priming effects are often facilitatory; recent exposure to a structure facilitates the subsequent production and comprehension of similar structures by reducing the cost of processing and increasing the speed of processing. This is reflected in reduced reading times and faster response latencies (Noppeney & Price, 2004; Smith & Wheeldon, 2001, 2003). Whilst the majority of research has focused on syntactic priming there are also demonstrations of pragmatic priming.

Using a picture-sentence matching task Bott and Chemla (2016) and Rees and Bott (2015) found that the derivation of scalar implicatures can be primed within and between different categories of implicature (quantifiers, numerals, and ad hoc). Equivalent rates of priming were observed after making an implicature as after making the alternative salient without deriving an implicature.

The tasks used by Bott and Chemla (2016) and Rees and Bott (2015) relied on metalinguistic interpretation judgements. Since these judgements occur once processing is completed they cannot tell us about online linguistic processing and thus may not reflect standard linguistic processing. Furthermore it is unclear how priming affects implicature processing and whether the priming effects relate to initial sentence analysis or later reanalysis (Branigan, Pickering, Liversedge, Stewart & Urbach, 1995). We present two experiments to further investigate pragmatic priming and the representations that underpin scalar implicatures. We used a visual world paradigm (Eberhard et al, 1995) to provide an online measure of processing since eye movements are closely time-locked to comprehension and thus provide a naturalistic measure of how comprehension unfolds over time.

2. Experiment 1

The aim of Experiment 1 was to establish whether the priming effect found in interpretation judgements is also reflected in processing. There were two types of prime trial (1) implicature and (2) no implicature trials. The target trials always required an implicature to be derived. Since implicature interpretations can be primed it is likely that implicature processing can also be primed. This is likely to be reflected by faster implicature derivation after making an implicature.

Participants were presented with a set of four cards and heard a sentence. The task was for the participant to identify the card being described. In all trials the cards followed the structure shown in Figure 1 and all descriptions took the form “The card with the [object]”.

Experimental items involved prime->target pairs. Prime trials could refer to either the A card or the AB card. In these cards the A object was duplicated (the pencil in Fig. 1) and consequently descriptions of the A card (“The card with the [A]”) were ambiguous between the A and AB card. In order for participants to correctly identify the card being described they were required to make an inference, thus the A card trials were implicature trials. Descriptions of the AB card were not ambiguous because they referred to the unique item (“The card with the [B]”). AB card trials were no-implicature trials. The target trials always referred to the A card.

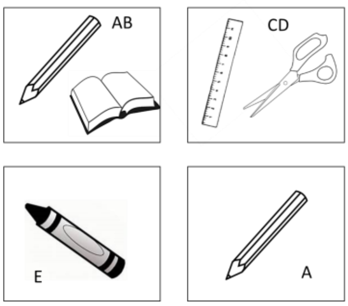

Figure 1. Example item with labels

In order to identify the correct card in target trials participants were required to make an inference. It was predicted that participants would be faster to identify the correct card following trials where they had derived an implicature (A primes) than following trials where no implicature was derived (AB primes). Thus we expect more looks to the target card at an earlier time point following implicature primes than no implicature primes.

2.1 Method

2.1.1 Participants

42 participants were recruited from the Cardiff University population. Five participants were excluded for having fewer than 75% valid trials.

2.1.2 Design and materials

Experimental items referred to the A and AB cards. Prime trials referred to either the A or the AB card and target trials always referred to the A card. These were organised into 32 prime->target pairs (16 AB primes and 16 A primes). The position of the correct card was rotated across the four positions in both prime and target trials so that the correct card appeared in each position an equal number of times. The correct card was in the same position in both prime and target for 25% of trials. Experimental items were counterbalanced so that each pair had an A and an AB prime. Participants saw either the A or the AB version and across all participants each item was seen with both prime types.

In the experimental items the A card was selected 48 times whereas the AB card was only selected 16 times. Consequently filler trials were included to prevent biasing participants to the A card. Filler trials referred to the AB, C, and DE cards. To ensure that each card type was selected an equal number of times there were 32 AB, 48 C, and 48 DE cards. The correct card was rotated in each of the four positions to prevent participants becoming biased towards a particular position.

At the start of the experiment there were 16 practice items (4 of each card type) to allow participants to get used to the experiment. These items were indistinguishable from the main experiment. Consequently there were 32 (prime x target pairs) + 128 fillers + 16 practice items = 208 trials. Experimental pairs and filler items were presented randomly.

Audio descriptions were recorded by a female native British English speaker. She was given a script to read from and did not see the items.

2.1.3 Procedure

Participants were seated in front of a 23 inch colour monitor with an independent eye tracking system (Tobii TX300) running at 120 Hz sampling rate. Viewing was binocular and eye movements were recorded from both eyes simultaneously. Participants completed a 9 point calibration at the start of the experiment.

The experiment was controlled using MATLAB 2014a. Each trial began with a centrally located fixation cross presented for 2000msec before the trial was automatically initiated. At this point the fixation cross was replace by a set of four cards and after 25ms the description was played. The picture stayed on screen, and eyes were tracked until participants made a selection.

2.1.4 Data processing

For analysis, any samples that were deemed invalid (e.g. due to blinks or head movement) were removed from the data. The spatial coordinates of the remaining samples were used to calculate the location of the eye-gaze. These samples were aggregated into packets of 25ms.

For each packet the proportion of looks to the target card was calculated by first scoring each sample (8ms) as looking to target or not, then totalling the samples looking to target and dividing by the total number of samples in the packet.

2.2 Results

The data were split into two sections: before referent and after referent. We analysed 250ms prior to referent onset, and each time bin from referent onset to 1 second after. Average referent offset was 475ms after onset. Figure 2 shows proportion of time looking to target in each 25ms bin from 250ms before referent onset to 1 second after referent onset.

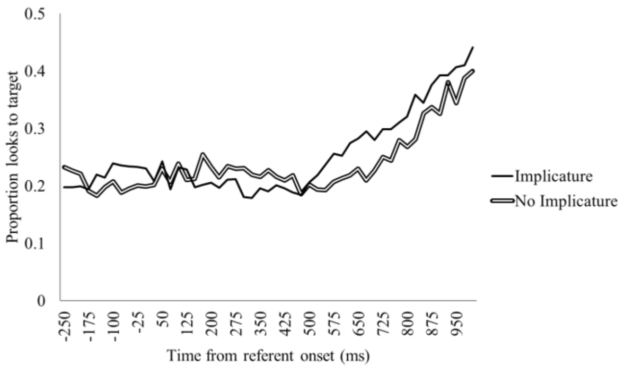

Figure 2. Proportion of looks to target card from 250ms before referent onset to 1000s after onset

2.2.1 Before referent onset

A repeated measures ANOVA was run from 250ms before referent onset to 25ms before onset. Time and condition were included as between-participants factors. There was no effect of time or prime for participants (F1 (9, 324) = .69, p = .716; F1 (1, 36) = .001, p = .970) or items (F2 (9, 279) = 1.13, p = .342; F2 (1, 31) = .39, p = .535). There was a significant interaction between time and condition for both participants and items (F1 (9, 324) = 2.328, p < .015; F2 (9, 279) = 2.50, p = .009).

2.2.2 After referent onset

A repeated measures ANOVA was run from referent onset to 1 second after. Time and prime were included as between-participants factors. There was no main effect of prime for participants or items (F1 (1, 36) = .13, p = .726; F2 (1, 31) = .96, p = .336). There was a main effect of time for participants and items (F1 (40, 1440) = 15.11, p < .001; F2 (40, 1240) = 13.62, p < .001). There was a significant interaction between time and prime for participants (F1 (40, 1440) = 1.51, p = .022) and items (F2 (40, 1240) = 1.62, p = .009).

3. Discussion

Experiment 1 demonstrated facilitatory priming for implicature processing. Participants looked to the target card more often and quicker following prime trials that required an implicature. Thus people are faster to derive an implicature if they have recently derived one. Priming effects demonstrate that two stimuli are related on some dimension within the language system (Branigan & Pickering, 2016). Consequently the results of Experiment 1 could be due to priming implicature specific representations or priming implicature specific processes, such as searching for the alternative.

Deriving an implicature involves the negation of alternatives. However, ad hoc implicatures do not have a clearly defined set of alternatives in the same way that, for example, quantifiers do (quantifier scale ordered in terms of informativity <some, many, all>). How are ad hoc implicatures derived? One possibility is that temporary contextual scales are formed and the alternatives in this scale are negated (Rooth, 1985). Recall the A-card from Figure 1. The description "The card with the pencil" is ambiguous because there is a pencil in two cards. Consequently participants are required to derive an implicature. Under this account, the *specific model*, participants would negate the contextually based alternative ("The card with the book and the pencil") to derive the implicature "The card with the pencil and not the card with the book and the pencil". Bott and Chemla (2016) and Rees and Bott (2015) present data consistent with this account.

An alternative approach is that participants do not negate specific alternatives, but instead, they negate a general alternative, *anything else*, as in "The card with the pencil and nothing else." According to this account, participants make an exhaustivity inference by assuming that if a speaker meant to say anything more then they would have. Take the following example (from Geurts, 2010):

A: What did you have for lunch?

B: I had some strawberries.

B's reply is likely to imply that she only ate strawberries. According to the contextual model of implicature derivation, A would likely have to negate an indefinite set of alternatives, e.g. "I had some strawberries and a biscuit", "I had some strawberries, a biscuit, and a sandwich". The computational effort this counterfactual reasoning would require seems counterproductive for efficient communication. A more efficient approach would be to assume that if B had eaten anything else then she would have said so. There is some experimental evidence that exhaustivity inferences (similar to those required here) are derived without recourse to specific alternatives (van Tiel & Schaeken, 2016).

4. Experiment 2

Experiment 2 tested between two possible explanations for ad hoc implicature derivation. One involves reasoning about the specific alternatives and the other about general alternatives. To test between these explanations we had two types of prime (1) no implicature and (2) alternative. No implicature primes were the same as in Experiment 1; they referred to the AB card using a simple noun phrase. Alternative prime trials also referred to the AB cards but they used the alternative structure; instead of using a simple noun phrase a conjunction was used e.g. "The card with the book and the pencil." Target trials referred to the A cards and thus required participants to derive an implicature.

If deriving ad hoc implicatures involves specific alternatives, the alternative prime trials should prime the derivation of implicatures. Therefore there should be more looks to the target card earlier following the alternative than the no alternative primes. However, if only general alternatives are involved, there should be no difference in looks to the target between alternative and no implicature primes.

We also included a lexical overlap manipulation where for half the trials the referent was repeated across prime and target trials. Priming effects are often boosted when there is lexical overlap (Branigan & Pickering, 1998). Thus if alternatives are required for deriving ad hoc implicatures then the overlap between alternative prime and target trials should increase the priming effect. Therefore participants should look to the target more often and earlier when there is overlap.

4.1 Method

4.1.1 Participants

30 participants were recruited from the Cardiff University population.

4.1.2 Design & Materials

Experimental items referred to the A and AB cards. A cards were always target trials and AB cards were always prime trials. The no-implicature primes were the same as the AB primes from Experiment 1. The alternative prime trials also described the AB card however the descriptions used a conjunction ("the card with the [A] and the [B]").

Items were organised into 64 prime->target pairs. Pairs could be overlap or no-overlap. In overlap pairs the referent was repeated across the prime and target trials (a different picture was used). This meant that for no-implicature primes participants heard the same sentence in prime and target trials, consequently these trials were not analysed. For alternative primes the [B] referent was repeated in the prime and target trials.

This resulted in 4 conditions: alt overlap, alt no overlap, no implicature overlap, and no implicature no overlap. Experimental pairs were counterbalanced so that each pair appeared in each condition, this resulted in 4 separate lists. The position of the correct card was rotated across the four positions in both prime and target trials so that the correct card appeared in each position an equal number of times. The correct card was in the same position in both prime and target for 25% of trials. Filler trials referred to the C and DE cards. There were 64 DE fillers and 64 C fillers, 32 DE fillers had a referent overlap with the C fillers.

At the start of the experiment there were 16 practice items (4 of each card type), 8 of which had overlapping referents. These items were indistinguishable from the main experiment. Consequently there were 64 (prime x target pairs) + 128 fillers + 16 practice items = 240 trials. Experimental pairs and filler items were presented randomly.

The procedure was the same as in Experiment 1 however the eye-tracker sampling rate was 300hz.

4.2 Results

Figure 3 shows the proportion of looks to the target card from 250 ms before referent onset to 1000ms after referent onset. Average referent offset was 534 ms after referent onset.

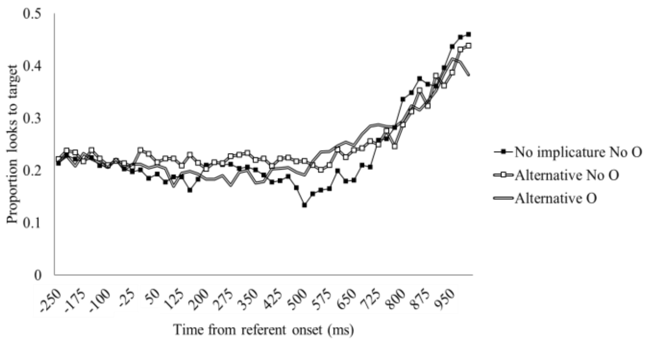

Figure 3. Proportion of looks to target card from 250ms before referent onset to 1000s after onset

If a specific alternative structure is represented then participants should be more to look to targets following the alternative prime than following the no implicature prime. Consequently we conducted pairwise comparisons between the two conditions from referent onset to 1 second after referent onset. There was no significant difference in proportions of looks to the target following no implicature or alternative primes for participants or items (t_1 (29) = -1.31, *p* = .200, BF = 0.4; t_2 (63) = -1.28, *p* = .207, BF = 0.3). This is consistent with the representations not including a specific alternative structure. Further support for this conclusions comes from the comparison between overlap and no overlap trials; no difference was found (t_1 (29) = .29, *p* = .771, BF = 0.2; t_2 (63) = -.26, p = .797, BF = 0.1).

4.3 Discussion

There was no difference in looks to target following alternative and no implicature primes, nor was there an effect of lexical overlap. These results are inconsistent with ad hoc implicatures being derived without specific alternatives. Instead the results are consistent with an exhaustivity operator that involves only a general alternative. This is supported by the Bayesian analysis carried out; Bayes Factors < 0.3 indicate substantial support for the null hypothesis. In this case, the Bayes Factors indicate there was no difference between no implicature and alternative primes (although the by-participants BF suggests a lack of power, the by-items BF supports our conclusion). This is further strengthened by the failure to find an effect of lexical overlap.

5. General Discussion

We present two visual world priming experiments to investigate the processing of pragmatic enrichments. Experiment one tested whether the priming effects that had previously been found using sentence interpretation judgements are reflected in processing. The results confirmed this prediction; participants were more likely to look at the target earlier following an implicature prime trial than a no implicature trial. Experiment 2 tested how ad hoc implicatures are derived. We compared a specific and general alternatives account. The results of Experiment two were consistent with the second latter.

The results of Experiment 2 are an important demonstration that while metalinguistic tasks are useful it is necessary to complement them with an online measure of processing. Previous work on implicature priming included ad hoc scales and found a similar pattern of responses for ad hoc, quantifier, and numeral scales. Furthermore there were equivalent rates of priming after deriving an implicature and after raising the saliency of the alternative (Rees & Bott, 2015). Whilst this finding is inconsistent with the results of Experiment 2 it is important to note that rates of implicature derivation for ad hoc scales were significantly lower than for quantifiers and numerals (Rees & Bott, 2015). This is likely to be due to the differences between the scale types.

Priming effects are typically accounted for by the priming of representations (Branigan & Pickering, 2017). Thus we suggest that these results provide further evidence for an implicature specific representation. Based on the experiments presented here the representation would not include the alternatives. This would be problematic for other types of implicatures which do require the alternatives. However, as shown by van Tiel et al (2014) there is considerable variation across different scales. Consequently it may be that there are several related representations responsible for implicatures.

6. Conclusions

Our study makes two important contributions. First, we have shown that implicature priming effects seen using offline methodologies are also found in online processing. This suggests that priming in implicatures is not metalinguistic and arises incrementally, during normal language processing. Second, we show that ad hoc implicatures are not derived through standard Gricean reasoning involving specific alternatives, but through a more general, *anything else* alternative.

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