Event-related potentials in pragmatic priming

Alice Rees[1, 2, 3]*, Lewis Bott[1], & Petra B. Schumacher[2]

[1]Cardiff University, Cardiff, UK

[2]University of Cologne, Cologne, Germany

[3]University of Derby, Derby, UK

Alice Rees

Online Learning Department,

University of Derby,

Enterprise Centre, Bridge Street,

Derby, DE1 3LD

UK

a.rees@derby.ac.uk

Lewis Bott

School of Psychology,

Cardiff University,

Tower Building, Park Place,

Cardiff, CF10 3AT

UK

bottla@cardiff.ac.uk

Petra B. Schumacher

University of Cologne

Department of German Language and Literature I

Albertus-Magnus-Platz

50923 Cologne

Germany

petra.schumacher@uni-koeln.de

Abstract

Priming of pragmatic enrichment has been found in behavioural studies. We extend this by examining the neural correlates of priming for two implicature categories, quantifiers and disjunctions. Participants engaged in a primed sentence-picture matching task where they were presented with a sentence (e.g., "some of the letters are Bs") followed by a picture. In prime trials the pictures were either consistent with an enriched interpretation (*some but not all*) or a basic interpretation (*some and possibly all*) of the sentence. The pictures in target trials were always consistent with the enriched interpretation. Using ERPs, we found a priming effect on the picture reflected in a reduced positivity for quantifiers when the preceding trial had an enriched interpretation, and no effect for disjunction. The pragmatic priming effect can be dissociated from expectation-based processes. It suggests that abstract derivation processes are primed during pragmatic alignment.

Keywords

Experimental pragmatics; Priming; Scalar implicature; Alignment; ERP; P600

Introduction

Speakers and listeners often repeat the same structures and expressions. For example, speakers are more likely to produce an active description of a picture, such as "lightning is striking the church" after hearing an active sentence "one of the fans punched the referee" than after a passive "the referee was punched by one of the fans" [1]. Such alignment between interlocutors confers advantages in terms of the predictability of the exchange and ultimately the ease with which people can communicate [2,3]. In the current research we investigate alignment of a different sort, pragmatic enrichment, using a phenomenon known as *scalar implicatures* [4,5], such as the enrichment that occurs from *some* to *some but not all*. Behavioural data on the processing of scalar implicatures shows evidence of priming [6,7] and in this study we use event-related potentials (ERPs) to better understand its underlying cause.

Scalar implicatures are paradigmatic examples of pragmatic enrichments [4,5] that arise by considering what the speaker could have said, but didn't. Consider the following examples:

(1) A: How did Mary do in her exams?
B: She passed some of them.
=> *Mary passed some but not all of the exams.*

(2) Dinner is spaghetti bolognaise or lasagne.

=> *Dinner is not both spaghetti bolognaise and lasagne.*

In (1), the listener could infer that Mary passed some but not all of the exams, and in (2), that she was allowed one but not both of the meals, even though this information was not explicitly present in the basic meaning of the utterance. According to Horn [5] and many subsequent authors, scalar implicatures arise because of linguistic scales that order lexical terms (e.g., <*some*, *all*>, <*or, and*>) with respect to the strength of the information they convey. Thus when a speaker uses a weak expression, such as *some*, the listener can infer that the stronger meaning of the sentence is not true. In (1), for example, the *all* proposition is negated, and in (2), the *and* proposition is negated. Scalar implicatures are a ubiquitous phenomenon that are sensitive to pragmatic factors, such as the knowledge of the speaker, but also semantic structure, such as downward entailment contexts. They are therefore ideal phenomena with which to investigate how semantics and pragmatics interact, and moreover, how Gricean pragmatics can be incorporated into processing theories [6-10].

In our study we investigate how scalar implicatures can be primed. We build on work that demonstrated priming of quantifiers, numerals, and ad hoc scalar implicatures [5,6]. Bott and Chemla [6] used a sentence-to-picture matching task where participants matched a sentence to one of two pictures. The sentence-picture combination was such that in some prime trials participants were obliged to derive an enriched interpretation of the sentence in order to select the correct picture and in other primes no enrichment was required. In the target trials the sentence-picture combination could be interpreted sensibly with or without enrichment and thus provided participants with the choice of interpretation. Participants were more likely to derive the enrichment in the target trial if the prime trial required an enrichment. Bott and Chemla [6] suggested that the effect could have arisen from processes tied to the lexicon, similar to standard polysemy, or the priming of more abstract processes stored independently from the lexicon, much like the abstract syntactic representations argued for by Branigan and Pickering [11] and others to explain syntactic priming. In this study we use electrophysiology to test which account best explains their findings.

No ERP studies on pragmatic priming have been conducted but research has found neural correlates for structural priming. Research using ERPs in syntactic priming have found that two components are particularly important, the N400 and the P600. These effects are considered to reflect general cognitive mechanisms: the N400 (and negativities more generally) has been associated with predictive coding triggered by mismatches between top-down and bottom-up information and the P600 with shifts to an appropriate response and updating of mental representations [12-14]. In the following, however, we restrict the literature review to studies using priming. Reductions in the N400 amplitude are typically associated with processes that arise from meaning related expectations [15,16]. In the context of priming studies, the N400 is considered as a marker of prediction [17]. Reduced N400s are seen for predictable words and when a related word was present in the preceding context [18-20]. When an incongruent word was made predictable the N400 was eliminated [17]. Furthermore, Ledoux et al. [20] found a reduction in N400 amplitude in a structural priming task when a word was repeated. Thus, if structural priming involves priming of lexical meaning, then, a reduced N400 would be expected.

The other relevant ERP signature is the P600 [20,21]. If priming involves the alignment of procedures used to derive particular structures, differences across conditions in the P600 might be observed in priming studies. Two studies find support for this idea. In addition to N400 effects for verb repetition, Ledoux et al. [20] found that the repetition of sentence structure (reduced relative clause or main clause) led to a decrease in the amplitude of the P600, as did Tooley and colleagues [21] in a follow-up study. One way to interpret the P600 is that access to an abstract representation facilitates processing of a similar structure. That is, the mental model makes available certain representations or there are mechanisms that generate the implicature. This contrasts with a lexical explanation.

These ERP results are evidence for discrete neural correlates of the processing facilitation afforded by priming. In this paper we use the N400 and P600 as markers of the underlying process taking place in pragmatic priming.

The present study combines pragmatic priming with ERPs to investigate the priming effects found in behavioural data. Participants completed a picture-sentence matching task. They were presented with a sentence followed by a picture and had to decide whether the picture matched the sentence (see Fig.1.). There were prime trials and target trials. The prime trials were either strong or weak depending on the picture configuration (Fig.2). In strong trials the picture supported an enriched interpretation of the sentence (e.g., *some but not all*) whereas in weak trials the picture was consistent with an unenriched interpretation (e.g., *some and possibly all*). Target trials followed prime trials and were always strong trials (unlike Bott & Chemla [6], in which target trials always contained a weak picture). In all other respects target trials were identical in structure to prime trials.

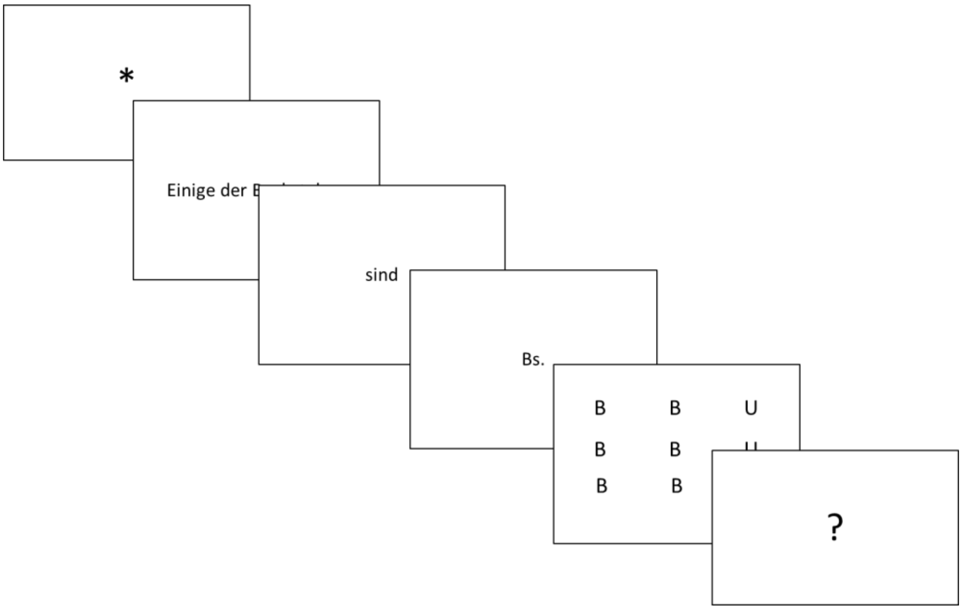

Figure 1. Example trial sequence. True colours were white letters on a grey background.

We expected facilitation on the (strong) target trials when they were preceded by a strong prime. If priming of enrichment is linked to meaning related expectations, we should observe a lower N400 amplitude in the strong prime relative to the weak prime condition, as in priming studies of polysemy and repeated word effects in structural priming [20,22]. If priming of enrichment is related to more abstract representations, we should observe a reduced P600 in the strong prime condition, either because less reanalysis of the mental representation occurs relative to the weak condition, as in previous abstract structural priming studies [20,21], or because the implicature derivation mechanisms themselves have been primed and so require less processing effort to execute.

Method

Participants

Thirty-two native German speakers were recruited from the University of Cologne. All reported normal or corrected-to-normal eyesight and gave written informed consent. Seven had to be excluded from the analysis because of extensive ocular artefacts. Consequently 25 participants (6 male, mean age 22.08 years) were included in the analysis, who had on average 30 trials remaining per condition after artefact rejection.

Materials

Each trial involved a sentence followed by a verification picture. Two categories of expression were used: quantifiers and disjunctions. Fig.2 shows examples of the pictures used. For quantifier trials the sentence frame was “Some of the letters are [letter]” (e.g., “Einige der Buchstaben sind Ts.”). The pictures contained 9 letters. In strong trials the nine letters consisted of six letters that matched the predicate (i.e., “T”) and three that did not (see Fig.2, top left). In weak trials all nine letters matched the predicate (see Fig.2, top right). For disjunction trials, the sentence frame was “There is a [letter] or a [letter]” (e.g., “Es gibt ein A oder ein H.”). In strong trials the picture contained one letter that had been mentioned in the predicate (Fig.2, bottom left). In weak trials the picture contained two letters that matched the predicate (Fig.2, bottom right). Prime trials included the strong or weak picture respectively, and target trials included the strong picture.

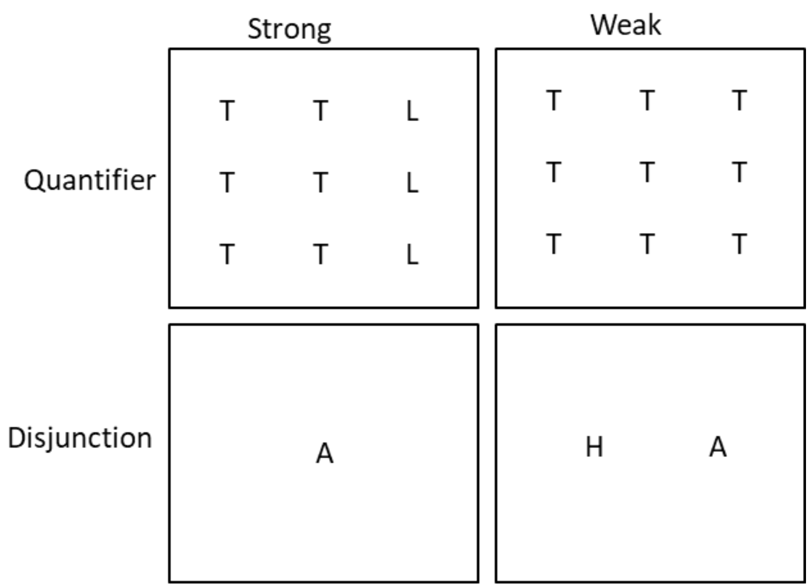

Figure 2. Example stimuli. Top left to right: Quantifier strong, weak for "Some of the letters are Ts." Bottom left to right: Disjunction strong, weak for "There is an A or a H." True colours were white letters on grey background.

Design

There were two sorts of expressions, quantifier or disjunction, which could be combined with a strong picture or a weak picture to form primes, or a strong picture to form targets. Thus there were four categories of prime-target trial pairs (quantifiers: strong-> strong, weak->strong; disjunctions: strong->strong, weak->strong). For each category, there were 40 prime-target pairs, resulting in 160 experimental pairs overall (= 320 trials). There were also filler trials to obscure the experimental structure and cause participants to vary their response. There were 160 weak filler trials (80 quantifier, 80 disjunction) that required a positive response (sentence-picture match) and 200 filler trials (50 weak quantifier, 50 strong quantifier, 50 weak disjunction, 50 strong disjunction) that required a negative response (sentence-picture non-match). For negative filler trials, the visually presented letters did not match the predicate. In total there were 680 trials.

One filler trial occurred before each experimental prime-target pair. The remaining filler trials occurred at random positions. Experimental pairs were presented in a different random order for each participant.

Procedure

Prior to the experimental session participants took part in a practice session, which comprised of eight trials. This allowed participants to become familiar with the task.

A trial began with the presentation of a fixation point for 500ms. Then the sentence was presented either in three chunks for quantifiers "Einige der Buchstaben | sind | [letter]" or two chunks for disjunctions "Es gibt | ein [letter] oder ein [letter]." Chunks were presented for 450ms with an interchunk interval of 150ms; the sentence-final chunk for disjunction was presented for 550ms. After 500ms the picture was presented for 1000ms followed by the presentation of a question mark. Participants were asked to indicate whether each picture matched the previous sentence and they were told to hold their response until the question mark appeared. The question mark remained until participants responded or 2000ms had passed (see Fig.1).

EEG recording & data processing

The electroencephalogram (EEG) was recorded from 32 scalp electrodes mounted on the scalp by an elastic cap (*Easycap*), which conformed to the standard 10-20 system for electrode positioning. The EEG was digitised at a rate of 500Hz and amplified by a *Brain Vision Brain-Amp* amplifier (impedances <4kΩ). The EEG was referenced online to the left mastoid and re-referenced offline to linked mastoids (ground: AFz). To control for eye-movement artefacts, we placed three electrodes around the participant's right eye and one electrode at the outer cantus of the left eye.

To avoid slow signal drifts, the data were processed offline with a 0.3-20Hz bandpass filter. Automatic (±40μV at ocular electrodes) and manual rejections were performed to exclude trials that contained ocular or other artifacts prior to averaging (23.8%). ERPs were time-locked to the onset of the picture and average ERPs were calculated per condition and participant before grand averages were computed over all participants. The critical time windows were determined by first running analyses over 50ms windows from picture onset until 900ms thereafter in order to determine intervals spanning at least 100ms. ANOVAs for mean amplitude values were computed with prime type and ROI (topographical region of interest) as factors and for lateral and midline channels separately. The lateral electrodes were grouped by location as follows: left anterior (F7/F3/FC5/FC1/C3), right anterior (F4/F8/FC2/FC6/C4), left posterior (T7/CP5/CP1/P7/P3), and right posterior (T8/CP2/CP6/P4/P8). The six electrodes from the midline were grouped anterior (Fz/FCz/Cz) and posterior (CPz/Pz/POz). This data is available at https://osf.io/qfwrg/.

Results

Behavioural data

Participants responded with a button press indicating whether the sentence matched the picture. For experimental trials, participants responded overwhelmingly with "match" (99.8% responses to primes and 99.7% responses to targets). For the filler items that were designed such that the sentence and picture did not match, participants responded 100% of the time with "non-match". Thus, participants were not sticking with one response throughout the experiment. Consequently, we interpret the responses to target trials as reflecting implicature interpretations.

EEG data

We analysed data from target trials. Based on successive 50ms window analyses, we determined effect windows of at least 100ms length and examined the grand average ERPs in the windows 400-600ms and 600-700ms for the quantifier contrast. Fig.3 indicates facilitation through priming for quantifiers: after strong prime trials there is a reduced positivity in the 400-600ms window, which extends to the 600-700ms over right posterior electrodes. No other differences between the quantifier conditions emerge. No effect of prime type is observable for disjunction.

We ran separate ANOVAs for each expression type (corrected for sphericity violations using the Huynh-Feldt procedure [23]). In quantifiers between 400-600ms we observed an interaction of prime and ROI [$F(3,72)=6.07$, $p<.003$] and a main effect of prime [$F(1,24)=30.70$, $p<.001$]. The effect of prime was significant for all ROIs [$F's(1,24)>6.21$, $p's<.02$]. For the midline electrodes, quantifiers revealed a main effect of prime [$F(1,24)=23.07$, $p<.001$]. The analysis between 600-700ms registered an interaction of prime and ROI [$F(3,72)=5.87$, $p<.002$]. Resolution of this interaction by ROI showed an effect of prime over right posterior sites [$F(1,24)=10.34$, $p<.004$]. No effect emerged over midline electrodes.

Surprisingly, there was no effect for disjunctions over lateral and midline regions [all $F's<3.8$, $p's>.05$]. We used Bayes factors to interpret the non-significant findings [24]. Bayes factors using the JZS prior were <.33 (0.19 and 0.21 respectively) which indicates "substantial" evidence in favour of the null hypothesis [25].

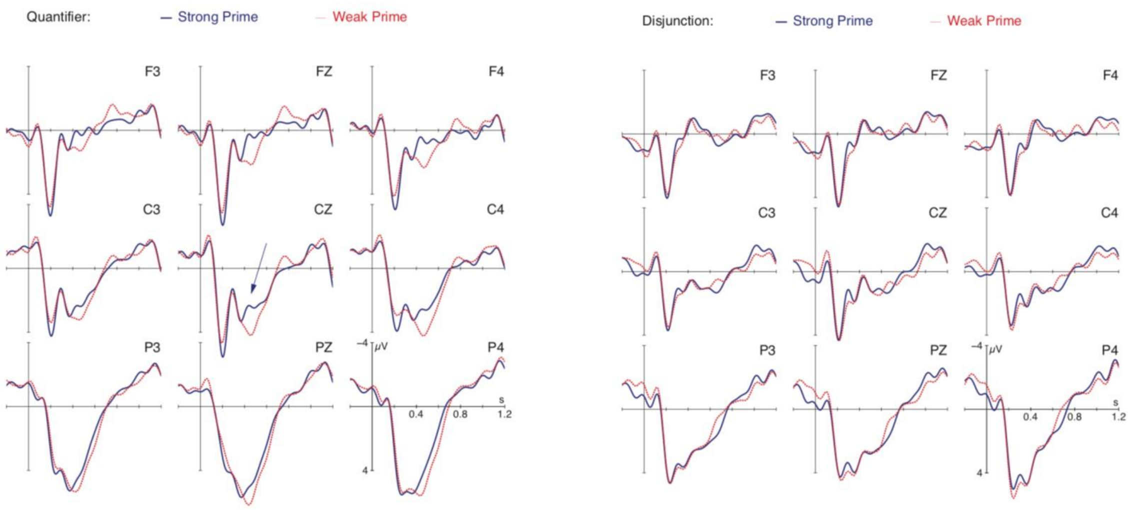

Figure 3. Grand mean averages time locked to picture onset. Left panel shows waveforms for quantifiers and right panel shows disjunctions. Negative polarity is plotted upwards. Arrow marks difference between weak and strong prime condition. An 8Hz low pass filter was applied for plots only.

Discussion

This experiment investigated the neural response to priming scalar implicatures. We tested two types of scalar implicatures, quantifiers and disjunction. For quantifiers, we observed facilitatory effects on a positive deflection around 400-600ms, which was less pronounced following priming. We take this effect to be part of the P300/P600 family. This suggests that the underlying cause of the priming observed in previous behavioural research [6] involved priming of the initial structure building mechanisms or the reanalysis procedures. It further extends the findings on syntactic priming [11,20,21], suggesting that the underlying process is not specific to syntactic structures. Interestingly, we did not observe the same effects for disjunctions.

One potential concern with our findings is that participants responded with “match” to strong target trials regardless of whether the prime was strong or weak, unlike Bott & Chemla [6] and others in which behavioural responses altered as a function of the prime. Does this mean that there were no priming effects? We argue that the ERP data is evidence of a priming effect. Indeed, the absence of differential behavioural responses across prime conditions is consistent with our aims. We wished to create a paradigm in which the prime would alter the ease with which the interpretation was derived but not the final interpretation itself. Differential responding across prime conditions (e.g. 90% “match” responses in one condition, 50% in the other) would render the ERP differences difficult to interpret, as would the different verification strategies that would be required for different interpretations (e.g. a quick and simple existential search for *some-and-possibly-all* interpretations, a slow and complex, two stage search for *some-but-not-all* interpretations). Consistent with this aim, we chose the strong image to be the target, which created an unambiguous sentence-picture pairing ([6] observed that participants overwhelmingly selected the implicature interpretation when given the choice between an implicature and a literal meaning), and so would be difficult for the prime to influence.

The quantifier conditions demonstrate an early positivity that is less pronounced following a strong-strong priming sequence than following a weak-strong sequence. This reduced positivity following strong primes reflects facilitation; a larger positivity is indicative of an increase in processing effort. This is consistent with studies investigating syntactic priming that showed a reduced P600 in target trials when preceded by the same type of trial in a prime [20,21]. The observed effect differs partially from the P600 seen in previous studies on structural priming because it shows an earlier onset latency (see also [20] for early effects). This is likely due to differences in the tasks. Previous priming studies reported ERPs time-locked to a particular word. In the present study, however, the ERPs were time-locked to the picture. At this point the sentence has already been processed and expectations have been generated for the upcoming picture, which may result in a latency advantage. Note that previous research that used pictures as stimuli in sentence-picture verification and comprehension tasks yielded the same processing patterns as observed with linguistic stimuli [26-28]. For instance, Lüdtke and colleagues [26] studied negation in a sentence picture matching paradigm (“a ghost” vs. “no ghost”) and found N400 and late positivity effects on the picture, where the former reflected the matching of noun and picture (e.g., presence of ghost) and the latter the derivation of the negation. Moreover, the P600 is considered part of the P300 family [29-30], which is elicited by unexpected stimuli, reflects context updating, and critically shows varying latency. The observed effect is thus taken to reflect the mechanisms underlying priming during implicature processing.

We have argued that the P600 effect that we observed correspond to either priming of the procedures used to derive the implicature or to a reanalysis of the initial interpretation. Which of these turn out to be correct depends partly on when participants are assumed to derive the implicature. If they commit to a fully-fledged implicature interpretation while reading the sentence, i.e. prior to the onset of the image, the P600 effect likely relates to structural reanalysis. Conversely, if implicature commitment is delayed until the onset of the image, the P600 could reflect the derivation process itself. There is no immediate way of distinguishing these accounts with our data but previous studies using paradigms similar to our own suggest that participants delay responding. Behavioural sentence verification tasks [31,32] find response time effects at the end of the sentence, long after reading the scalar expression (for an overview see [10]). This is also supported by additional analyses in the regions that contain the scalar expression in the current study (see https://osf.io/qfwrg/). While some reading time studies have found effects on the quantifier [10], these effects are small and have been difficult to replicate, and effects are larger in subsequent sentences even for studies that find effects on the quantifier. Moreover, in a sentence verification paradigm in which both strong and weak interpretations are used and few contextual cues are available, it is more cost-effective to delay commitment to the implicature until the verification predicate (the image), as in “good enough” processing [33], because of the reanalysis costs of choosing the incorrect image (the same is not true in contexts where the context heavily constrains the interpretation, such as the visual world studies of [34] and [35]).

A reanalysis explanation comes in several forms. One version is that the P600 reflects abstract linguistic processes involved in the rejection of the weak interpretation and the subsequent derivation of the strong interpretation. Another is that the P600 reflects different verification strategies. The weak prime condition requires participants to first verify that a weak interpretation holds, reject that interpretation, and then verify whether a strong interpretation holds, whereas the strong prime condition requires only that the strong interpretation be derived and verified. The difference between these reanalysis accounts is that the former assumes a linguistic basis for the effects whereas the latter assumes a strategic, or verification, basis. However, it is extremely difficult to distinguish between the two because all language involves verification of some kind, whether it is against a visual image, as in our study, or a cognitive representation, as in more abstract discourse. An added complication in this case is that the strong interpretation formally requires that the weak interpretation be verified (the strong interpretation entails the weak), hence the verification strategies for weak and strong interpretations require many of the same processes.

Priming of the initial procedures and the reanalysis account are both functional explanations that can be accounted for within a domain-general approach [12-14]. This views the P600 as a cortical response to incoming information that yields reorienting or updating of mental representations. Our data are thus not specific to scalar inferencing. Crucially, they indicate that the observed facilitation reflects ease of updating and (re)orienting rather than predictive coding.

The data revealed a distinction between quantifiers and disjunctions. For quantifiers we observed a robust effect of priming but for disjunctions we did not (note that the Bayes Factors for the disjunction analysis shows that the absence of an effect was not due to general insensitivity of the experiment). While the data does not provide an unambiguous explanation for the absence of an effect, we can make several suggestions. Most interestingly, it is possible that the exclusive disjunction interpretation is not derived via a scalar implicature from the inclusive interpretation, contrary to the accepted norm [36]. Indeed, some authors have argued, on theoretical grounds, against exclusive disjunction being a conversational implicature [37,38]. This mirrors other work suggesting that so called *free-choice* inferences associated with disjunctions are also not computed with (second-order) scalar implicatures [39-41]. Another possibility is that the exclusive interpretation is extremely simple to derive given the visual context. If so, the strong prime would have no facilitatory effect on the target interpretation (priming effects are generally weak when structures are common and hence easy to retrieve; see [2]).

Overall the current study indicates that the neural mechanisms underlying pragmatic priming with quantifiers can be dissociated from lexically-based alignment. The observed positivity effect suggests that abstract derivation processes are primed, either through facilitation of initial processes or reanalysis. This mirrors alignment effects of sentence structures that have also given rise to positive deflections. It thus points towards a common neural basis underlying pragmatic and syntactic alignment.

Acknowledgements

This research was funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) [grant no. SCHU 2517/6-2] within the Priority Program SPP1727 “XPrag.de: New Pragmatic Theories based on Experimental Evidence”. We would like to thank Hanna Weiland-Breckle for her programming skills and Brita Rietdorf for her assistance with data collection.

References

[1] Bock, K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18,* 355-387

[2] Pickering, M., & Ferreira, V. (2008). Structural priming: a critical review. *Psychological Bulletin, 134*, 427-459

[3] Garrod, S., & Pickering, M. (2004). Why is conversation so easy? *Trends in Cognitive Science, 8*, 8-11.

[4] Grice, H. (1989. *Studies in the way of words*. Harvard University Press, Boston.

[5] Horn, L. (1972). On the semantic properties of logical operators in English. Ph.D. thesis, University of California, Los Angeles.

[6] Bott, L., & Chemla, E. (2016). Shared and distinct mechanisms in deriving linguistic enrichment. *Journal of Memory and Language, 91*, 117-140.

[7] Rees, A. & Bott, L. (2018). The role of alternative salience in the derivation of scalar implicatures. *Cognition, 176*, 1-14.

[8] Hunt, L., Politzer-Ahles, S., Gibson, L., Minai, U., & Fiorentino, R. (2013). Pragmatic inferences modulate N400 during sentence comprehension: Evidence from picture–sentence verification. *Neuroscience Letters, 534*, 246-251.

[9] Spychalska, M., Kontinen, J., & Werning, M. (2016). Investigating scalar implicatures in a truth-value judgement task: Evidence from event-related brain potentials. *Language, Cognition, and Neuroscience, 31*, 817-840.

[10] Politzer-Ahles, S., & Husband, E. M. (2018). Eye movement evidence for context-sensitive derivation of scalar inferences. *Collabra: Psychology*, *4*(1):3, 1–13,

[11] Branigan, H. & Pickering, M. (2017). An experimental approach to linguistic representation. *Behavioral and Brain Sciences, 40*, e282.

[12] Kotchoubey, B. (2006). Event-related potentials, cognition, and behavior: a biological approach. *Neurosci. Biobehav. Review, 30*, 42–65.

[13] Bornkessel -Schlesewsky, I. & Schlesewsky, M. (2019). Towards a neurobiologically plausible model of language-related, negative event-related potentials. *Frontiers in Psychology, 10*, 298.

[14] Bornkessel-Schlesewsky, I & Schumacher, P.B. (2016). Towards a neurobiology of information structure. In C. Féry & S. Ishihara (eds.), *The Oxford Handbook of Information Structure*, 581-598. Oxford: Oxford University Press.

[15] Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology, 62,* 621-647.

[16] Holcomb, P. (1993). Semantic priming and stimulus degradation: implications for the roles of the N400 in language processing*. Psychophysiology, 30*, 47-61.

[17] Szewczyk, J. & Schriefers, H. (2017). The N400 as an index of lexical preactivation and its implications for prediction in language comprehension. *Language, Cognition, and Neuroscience, 33,* 665-686

[18] Paller, K. & Kutas, M. (1992). Brain potentials during memory retrieval provide neurophysiological support for the distinction between conscious recollection and priming. *Journal of Cognitive Neuroscience, 4*, 376-393.

[19] Kutas, M. & Federmier, K. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Psychology, 4*, 463-470.

[20] Ledoux, K., Traxler, M., Swaab, T. (2007). Syntactic priming in comprehension: Evidence from event-related potentials. *Psychological Science, 18*, 135-143.

[21] Tooley, K., Traxler, M., & Swaab, T. (2009). Electrophysiological and behavioral evidence of syntactic priming in sentence comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*, 19-45.

[22] Klepousniotou, E., Pike, G.., Steinhauer, K., & Gracco, V. (2012). Not all ambiguous words are created equal: An EEG investigation of homonymy and polysemy. *Brain and Language*, *123*, 11-21.

[23] Huynh, H., & Feldt, L. (1970). Conditions under which mean square rations in repeated measurements designs have exact F-distributions. *Journal of American Statistics Association*, *65*, 1582-1589.

[24] Rouder, J., Speckman, P., Sun, D., Morey, R., & Iverson, G. (2009). Bayesian t tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16*(2), 225-237.

[25] Dienes, Z. (2014). Using Bayes to get the most out of non-significant results. *Frontiers in Psychology, 5,* 1–17.

[26] Ganis, G., Kutas, M., & Sereno, M. I. (1996). The search for "common sense": An electrophysiological study of the comprehension of words and pictures in reading. *Journal of Cognitive Neuroscience, 8(2)*, 89-106.

[27] Lüdtke, J., Friedrich, C. K., De Filippis, M., & Kaup, B. (2008). Event-related potential correlates of negation in a sentence–picture verification paradigm. *Journal of cognitive Neuroscience, 20(8)*, 1355-1370.

[28] Sitnikova, T., Holcomb, P. J., Kiyonaga, K. A., & Kuperberg, G. R. (2008). Two neurocognitive mechanisms of semantic integration during the comprehension of visual real-world events. *Journal of Cognitive Neuroscience, 20(11*, 2037-2057.

[29] Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118,* 2128-2148.

[30] Donchin, E., & Coles, M. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*, 355-425.

[31] Bott, L. & Noveck, I. (2004). Some utterances are underinformative: The onset and time course of scalar inferences. *Journal of Memory and Language, 51,* 437-457.

[32] Bott, L., Bailey, T., & Grodner, D. (2012). Distinguishing speed from accuracy in scalar implicatures. *Journal of Memory and Langauge, 66,* 123-142.

[33] Ferreira, F., Engelhardt, P. & Jones, M. (2008). Good enough language processing: A satisficing account. *Proceedings of the annual meeting of the cognitive science society, 31*

[34] Huang, Y. & Snedeker, J. (2008). Online interpretation of scalar quantifiers: insight into the semantics-pragmatics interface. *Cognitive Psychology, 58*, 376-415.

[35] Degen, J. & Tanenhaus, M. (2015). Processing scalar implicature: a constraint-based approach. *Cognitive Science, 39*, 667-710.

[36] Horn, L. (1984). Toward a new taxonomy for pragmatic inference: Q-based and R-based implicature. Meaning, form, and use in context: *Linguistic Applications, 11,* 42.

[37] Levinson, S. C. (2000). Presumptive meanings: The theory of generalized conversational implicature. MIT press: Massachusetts.

[38] Geurts, B. (2006). Exclusive disjunction without implicature. Ms. University of Nijmegen. URL: https://bfb0d279-a-62cb3a1a-s-sites.googlegroups.com/site/brtgrts/exor.pdf

[39] Zondervan, A. (2010). Scalar implicatures or focus: an experimental approach. Ph.D. thesis, Utrecht University. URL: https://dspace.library.uu.nl/bitstream/handle/1874/43820/zondervan.pdf?sequence=2

[40] Chemla, E., & Bott, L. (2014). Processing inferences at the semantics/pragmatics frontier: disjunctions and free choice. *Cognition, 130(3*), 380–396.

[41] van Tiel, B. & Schaeken, W. (2016). Processing conversational implicatures: alternatives and counterfactual reasoning. *Cognitive Science, 41*, 1119-1154.

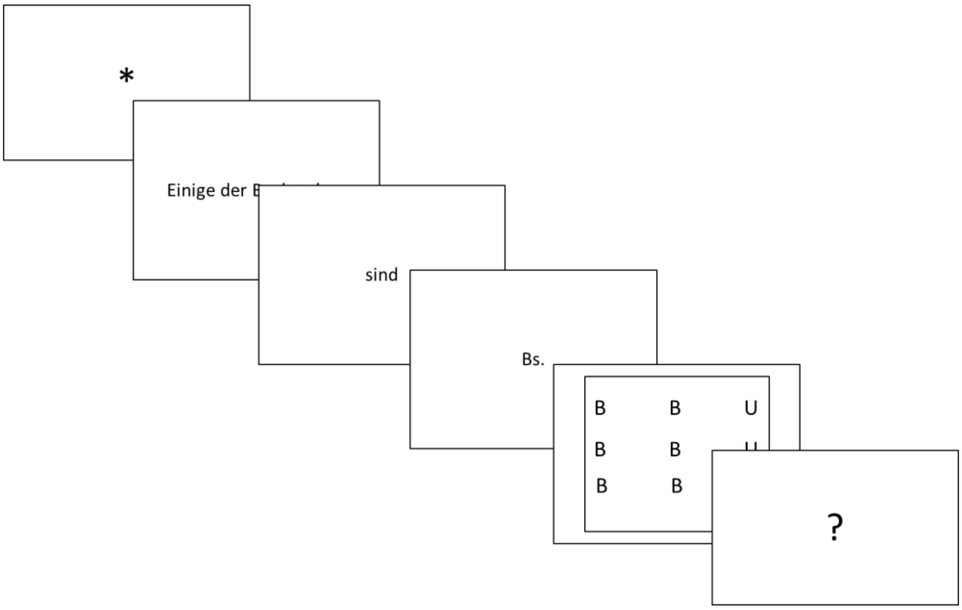

Figure 1. Example trial sequence. True colours were white letters on a grey background.

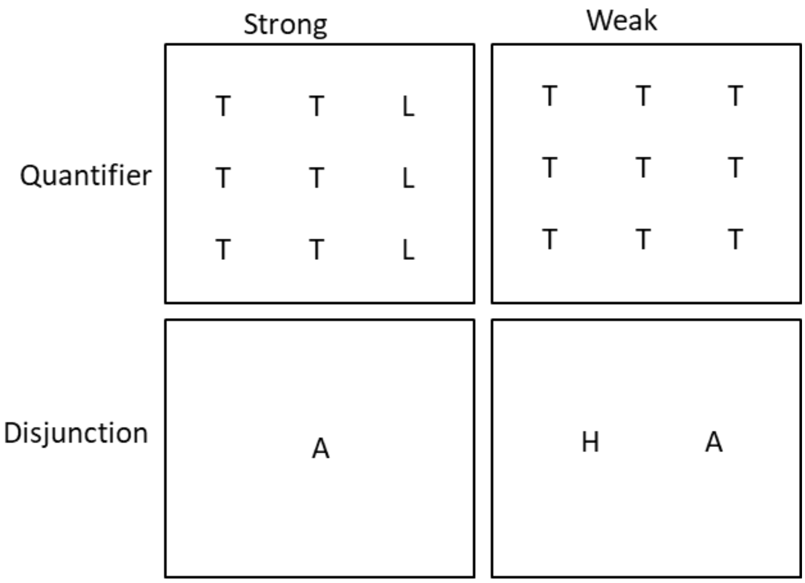

Figure 2. Example stimuli. Top left to right: Quantifier strong, weak for "Some of the letters are Ts." Bottom left to right: Disjunction strong, weak for "There is an A or a H." True colours were white letters on grey background.

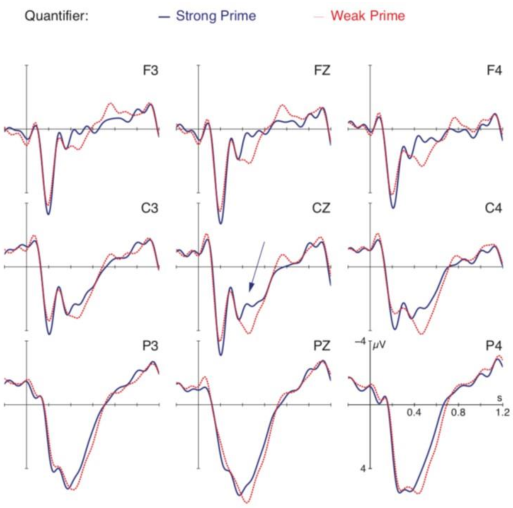

Figure 3. Grand mean averages time locked to picture onset. Left panel shows waveforms for quantifiers and right panel shows disjunctions. Negative polarity is plotted upwards. Arrow marks difference between weak and strong prime condition.