The Social N400 effect: how the presence of other listeners affects language comprehension

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**Abstract**:

During conversation it is necessary to keep track of what others can and cannot understand. Previous research has focused largely on understanding the timecourse along which knowledge about interlocutors influences language comprehension/production rather than the cognitive process by which interlocutors take each other’s perspective. In addition, most work has looked at the effects of knowledge about a speaker on a listener’s comprehension, and not on the possible effects of other listeners on a participant’s comprehension process. In the current study we introduce a novel joint comprehension paradigm that addresses the cognitive processes underlying perspective taking during language comprehension. Specifically we show that participants who understand a language stimulus, but are simultaneously aware that someone sitting next to them does not understand the same stimulus, show an electrophysiological marker of semantic integration difficulty (i.e., an N400-Effect). Crucially, in a second group of participants we demonstrate that presenting exactly the same sentences to the participant alone (i.e., without a co-listener) results in no N400-effect. Our results suggest that (1) information about co-listeners as well as the speaker affect language comprehension, and (2) the cognitive process by which we understand what others comprehend mirrors our own language comprehension processes.

**Keywords**

Language Comprehension, Communication, Conversation, Joint Action, Social Interaction

**Introduction**

In the past decade much research has looked at how interlocutors take each other’s perspective during communication. Knowledge about speakers clearly influences how listeners interpret utterances (reviews e.g., Barr & Keysar, 2006; Brennan, Galeti, Kuhlen, 2010). Much of that literature addresses the question of *when* information about speakers influences a listener’s interpretation of what has been said (e.g., Keysar et al., 2000; Kronmueller & Barr, 2007; Brown-Schmidt et al., 2008; Hanna et al., 2003). Less prominent in the current debate is the issue of *how,* i.e.,through what cognitive process information about others influences a listener’s comprehension. In addition, the literature to date predominantly focuses on the influence of background knowledge about the speaker on a listener’s comprehension. It does not address how/whether other listeners in the environment, e.g., other people at a dinner table or in a classroom, may also influence the ways in which language is interpreted by a listener. These two topics, i.e., the cognitive process by which perspective taking modulates comprehension, and the influence of co-attenders, on comprehension, are addressed in the current study.

Conversation has been described in the past as a form of joint action, as two people engaged in conversation monitor each other’s language use and make adaptations to their own speech based on the language used by interlocutors (Clark, 1996; Garrod & Pickering, 2004). Research on joint actions other than conversation has shown that jointly-acting participants share mental task sets; i.e., participants incorporate the requirements of their partner’s task into their own mental task set, even if this is entirely irrelevant for their own performance. For example, Sebanz and colleagues (2005) show that classic stimulus-response spatial compatibility effects can be spread across two participants (Sebanz, Knoblich, & Bekkering, 2006; Sebanz, Knoblich, & Prinz, 2003; 2005). In a similar vein, research on action observation has shown that participants’ performance of actions is influenced by observing others perform actions (Brass & Heyes, 2005; Griffiths & Tipper, 2009). Thus in the action literature, more is known about the cognitive processes underlying joint actions: we act efficiently together because we mentally represent the task sets of other co-acting individuals.

In the current study, we borrow the logic of the joint action paradigms and apply them directly to communicative situations in order to investigate the cognitive processes underlying the joint action of communication. In contrast to most of the literature on perspective taking in communication, we focus on situations in which two people are involved in jointly comprehending a third party. This paradigm parallels the logic of the paradigms that have been used in the joint action literature, and provides a novel and unique way of assessing the cognitive processes underlying comprehension in social situations. Note this work bears some relation to previous research on overhearers, i.e., unintended addressees in triadic communicative settings (e.g., Schober & Clark, 1989; Wilkes-Gibbs & Clark, 1992); however it differs fundamentally from this earlier work in two important respect. First, there is no *un*intended addressee in our paradigm, i.e., both parties are *intended receivers* of an utterance in our study. Secondly, we are not interested in the later interaction between speaker and one of the recipients (as in many overhearer studies), but rather we focus on the effect that knowledge about one listener can have on the other listener’s comprehension.

In the current study we investigate how participants process sentence stimuli they attend to alongside another individual (i.e., a confederate). We were interested in how an electrophysiological marker associated with semantic integration (the N400-component, review Kutas & Federmeier, 2011) is modulated by a participant’s perception of a *confederate’s* ability to grasp sentence content. Our hypotheses were the following: first, in line with previous studies on semantic integration, a robust N400-effect was expected for target sentences that were implausible for both participant and confederate vs. plausible for both. Secondly, in line with the literature on joint action, we hypothesized that a robust N400-effect would also be elicited by sentences that were *semantically plausible for the participant* if they were semantically implausible for the confederate (see CONTEXT condition in materials).Finally, we hypothesized that if a second group of participants were presented with these exact same CONTEXT sentences in isolation (i.e., without a confederate present), no N400-effect would be elicited since the sentences were semantically plausible for the participant alone (see also Filik, 2008; Nieuwland & van Berkum, 2006). This is critical, as it shows that the N400-effect elicited by the CONTEXT sentences is linked to the presence of the naive confederate rather than any anomaly within the sentence alone.

**Material and Methods**

Forty-two participants were recruited through the psychology department at the University of York and assigned randomly to one of two experimental groups: the Joint Group and the Alone Group. All participants were native English speakers.

The experimental set-up differed for participants in the two groups only with respect to the presence/absence of a confederate. Participants in the Joint Group were seated next to a confederate in front of a computer monitor. Once the EEG cap had been fitted, participants were given headphones and made explicitly aware of the fact that the confederate would not be privy to any information received via the headphones. Participants in this group were asked after every trial to indicate with a discrete yes/no response (1) whether the confederate could have understood the written sentence, and (2) whether they themselves understood the sentence. These two sentences appeared sequentially in the order presented here after each trial. Participants in the Alone Group were seated alone in front of the computer monitor. They received exactly the same sentence stimuli, but following each trial were asked only whether or not they themselves had understood the written sentence.

Forty-two trials were created for each of three experimental conditions. Each trial consisted of one spoken sentence (presented to the participant over headphones) and one written sentence (presented over three screens for 1 second each with the critical target word presented in isolation on the third screen). The three experimental conditions were the following (examples see Table 1, complete list of stimuli is available from the authors).

* PLAUS: trials in which the written target sentence was semantically plausible with or without the preceding sentence context.
* IMPLAUS: trials in which the target sentence was semantically implausible irrespective of the preceding context.
* CONTEXT: trials in which the target sentence was semantically implausible alone, but was rendered plausible in light of the preceding sentence context

**Table 1.** Examples of experimental stimuli. Participants heard spoken sentences via headphones. The confederate did not hear the spoken sentence. Following the spoken sentence, both the participant and the confederate read the written sentence on a monitor. Note that written sentences become anomalous only on the final word (underlined in the examples).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Spoken Sentence (S1)**  (heard via headphones by participant) | **Written Sentence (S2)**  (seen on monitor by both) | **Participant’s perception of S2** | **Confederate’s perception of S2** |
| **PLAUS** | *The fishmonger prepared the fish.* | *The fish had gills.* | plausible | plausible |
| **IMPLAUS** | *The boy woke up at dawn.* | *The boy had gills.* | implausible | implausible |
| **CONTEXT** | *In the boy’s dream, he could breathe under water.* | *The boy had gills.* | plausible | implausible |

The stimuli were counterbalanced such that the same critical word was used in each of the three experimental conditions; therefore stimuli were perfectly matched against each other across conditions in the experiment. All participants saw all stimuli, i.e., participants saw the same target word three times, however the order in which the participant saw the target word in one condition vs the other two conditions was counterbalanced. Lastly, the critical word that rendered the sentence anomalous was always the sentence final word.

The EEG was recorded in a quiet room from 64 shielded active electrodes placed in a 10-20 montage (recording reference = average, ground = forehead, VEOG and HEOG included, electrode impedances < 10 kΩ). The signal was preprocessed using Brain Vision Analyzer (re-reference to average of mastoids, segmentation = -200 to 1500 ms around target word onset, baseline correction = -200 ms., semi-automatic artifact rejection for eye movements, electrode drifting, EMG artefacts). In the Joint Group 5.23% of the data was discarded in the artefact rejection. The number of trials that remained after artefact rejection per condition were as follows: PLAUS: *M* = 33.6, range = 20-42; IMPLAUS: *M* = 32.4, range = 23-41; CONTEXT: *M* = 34.13, range = 23-39)=. In the Alone Group 9.53% of the data was discarded during artefact rejection. The number of trials that remained after artefact rejection per condition were as follows: PLAUS: *M* = 35.9, range=35-42; IMPLAUS: *M* = 36.2, range=23-42; CONTEXT: *M* = 35.3, range= 22-42. The data from 4 participants in the Joint Condition was discarded, as over 30% of trials contained artefacts, in addition 1 participant who provided incorrect responses on >50% trials was removed from the analysis. The data from 4 participants in the Alone Condition was discarded due to artefacts. In addition one participant who made 50% errors in one condition was excluded. Thus data from 15 participants in the Joint Group and 17 participants in the Alone Group entered the final analysis.

In holding with previous studies, the N400-component was assessed as the mean amplitude in the time window between 350 and 550 ms post target word (i.e., final word of written sentence) onset across 3 central electrodes (Fz, Cz, Pz) (review Kutas & Federmeier, 2011). Signal from the midline electrodes was pooled as there was no hypothesis with respect to topographical features of the N400-Effect. Mean amplitude was entered into a 3x2 ANOVA with the within-group factor Condition (PLAUS, IMPLAUS, CONTEXT) and the between-groups factor Group (Joint, Alone).

**Results**

Behavioral

In order to ensure that our sentence stimuli were correctly perceived to be either sensible or anomalous by all participants performance rates were entered into a 3x2 ANOVA with the within-subjects factor Condition (PLAUS, IMPLAUS, CONTEXT) and the between-subjects factor Group (Joint, Alone). Performance for participants in the Joint Group was assessed with respect to their answer to *both* questions, i.e., whether they understood the sentence themselves and whether the confederate could have understood the sentence; performance for participants in the Alone Group was calculated on the basis of responses to one question only, e.g., whether the participant could understand the stimulus him/herself. Performance rates for both Groups were high, indicating that participants judged PLAUS and CONTEXT sentences to be correct and IMPLAUS sentences to be incorrect. Importantly, there was no significant difference in the pattern of performance across Conditions between the two Groups, as indicated by the lack of a significant Group x Condition interaction, *F*(2,62)=2.16*, p*>.1. Furthermore no one condition was more difficult than any other, as indicated by the lack of a main effect of Condition (*F* < 1). Participants in the Joint Group made significantly more errors than participants in the Alone Group on all conditions, as indicated by a significant main effect of Group *F*(1,31)=37.91, *p*<.001. This pattern indicates that the mere presence of another person in the Joint condition incurred a processing cost.

Performance rates were analyzed in order to ensure that participants understood the task. Because participants in the two groups had slightly different tasks (i.e., Joint = two questions, Alone = 1 question) we ran two separate ANOVAs assessing (1) how plausible participants in the Joint Group judged sentences to be for him/herself vs. the confederate across the three experimental conditions and (2) how plausible participants determined sentences in each of the conditions to be for him/herself across the two experimental Groups. Performance rates were transformed to arcsine values before running ANOVAs; performance rates for all Groups and Conditions can be seen in Table 2.

The first ANOVA tested for an interaction between Condition (PLAUS, IMPLAUS, CONTEXT) x Question (Self, Other). There was no main effect of either Condition or Question (all *F*s < 1, ps>.1), however participants performed differently on the two questions across the conditions, *F*(2,28)=8.45; *p*=.001, *η2* = .37. Resolution of the interaction showed that when participant responded to PLAUS sentences they were more accurate in determining their own ability to understand than determining whether the confederate could understand, *t*(14)=3.40, *p*<.005. When presented with IMPLAUS sentences, however, they were more accurate in determining the confederate’s ability to comprehend than comprehending sentence content themselves, *t*(14)=2.61; *p*<.05. There was no difference in accuracy on the two questions in response to CONTEXT sentences.

The second ANOVA tested for an interaction between Group (Joint, Alone) and Condition (PLAUS, IMPLAUS, CONTEXT) only on accuracy for the Self Question. There was no interaction between Group x Condition, *F*(2,60)<1,p>.1. A main effect of both Group, *F*(1,30)=5.53; *p*<.05, *η2* = .15 (Alone > Joint) and Condition, *F*(2,60)=3.59; *p*<.05; *η2* = .10 were seen. Post-hoc analyses of the difference across Conditions revealed that participants were more accurate in responding to PLAUS and IMPLAUS sentences than CONTEXT sentences, *t*(31)=2.36, *p*<.05; *t*(31)=2.31, *p*<.05).

**Table 2**

Performance Rates (i.e., accuracy rates) (and Standard Error of the Mean) for responses to stimuli that were semantically plausible (PLAUS), semantically implausible (IMPLAUS) and semantically plausible only if preceded by a disambiguating context (CONTEXT). Mean performance rates are shown for participants in the Joint and the Alone conditions. Participants in the Joint Condition responded to two questions, i.e., one regarding whether the sentence was plausible or implausible to the participant him/herself (SELF) and one regarding whether the participant thought the sentence was plausible for the confederate (OTHER). Participants in the Alone Condition responded only to the question about plausibility for oneself.

|  |  |  |  |
| --- | --- | --- | --- |
|  | JOINT | | ALONE |
|  | OTHER | SELF | SELF |
| PLAUS | 87 (2.63) | 94 (0.87) | 94 (1.03) |
| IMPLAUS | 93 (1.90) | 85 (2.17) | 95 (1.22) |
| CONTEXT | 92 (1.84) | 93 (1.30) | 92 (1.23) |

Event-related potentials (ERPs)

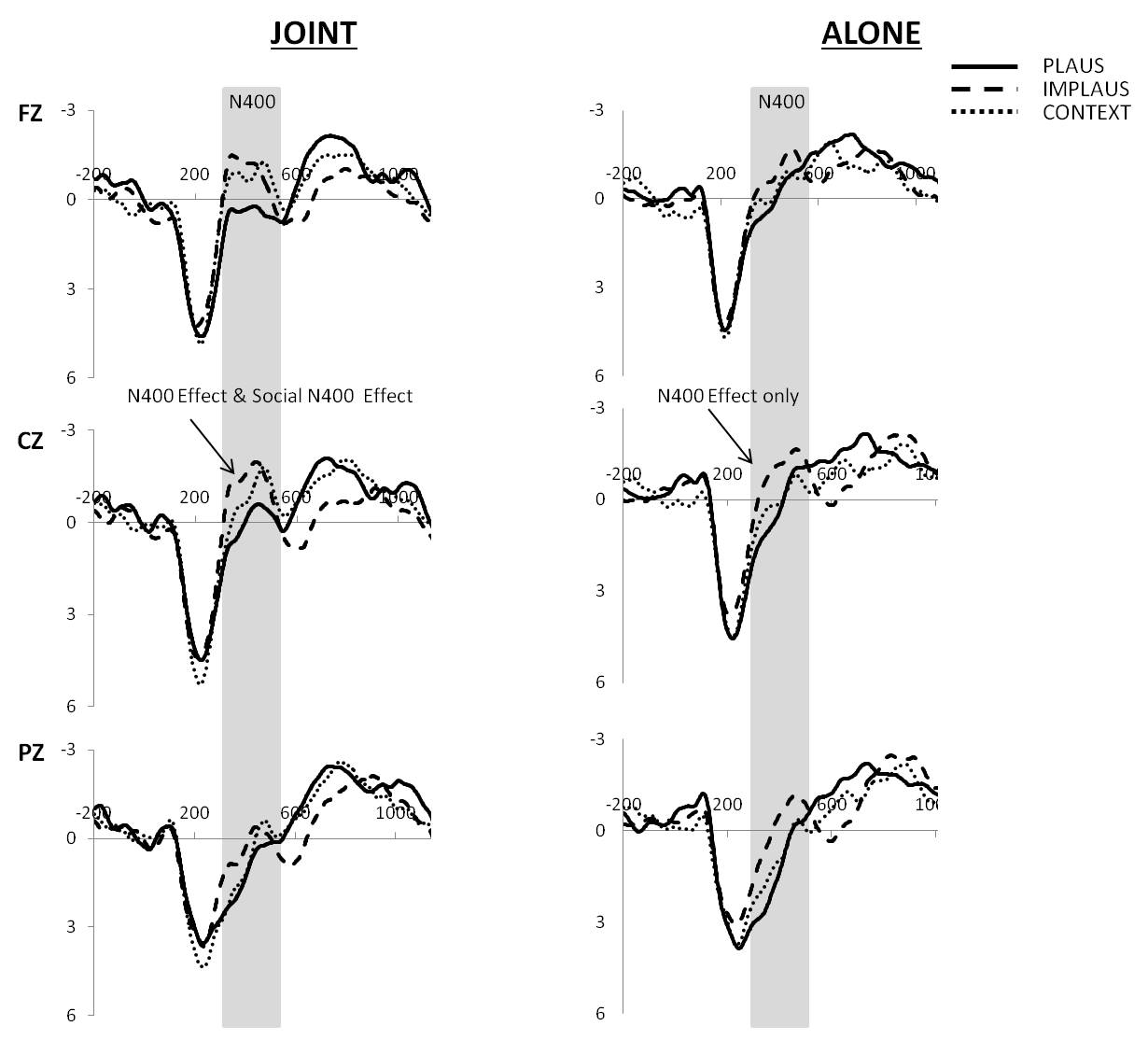
In order to assess the cognitive processes underlying sentence comprehension ERPs elicited by the critical word in each sentence condition were analyzed. In particular we analyzed changes in the N400, a component known to be sensitive to the difficulty with which word meaning can be integrated into a preceding language context.

In order to assess whether participants in the two groups responded to the different sentence conditions differently a 3x2 ANOVA with the within subject factor Condition (PLAUS, IMPLAUS, CONTEXT) and the between subjects factor Group (JOINT, ALONE) was calculated. This analysis revealed a significant main effect of Condition, *F*(2,60)=7.40; *p*=.001; *ηp2*=.19, and a significant Condition x Group interaction, *F*(2,60)=3.44; *p*<.05; *ηp2*=.10. In order to be sure that the significant Condition x Group interaction was not carried by a difference in the IMPLAUS condition between the Groups, we also carried out a 2x2 ANOVA with the within subject factor Condition (PLAUS, CONTEXT) and the between subjects factor Group (JOINT, ALONE). The results of this analysis also revealed a significant main effect of Condition, *F*(1,30)=4.67, *p*<.05, *ηp2*= .14, and a significant Condition x Group interaction, *F*(1,30)=4.14, *p*<.05, *ηp2*= .13.

Motivated both by our apriori hypotheses and the significant interaction reported above, we looked at the differences between Conditions in each Group. Our first hypothesis was that participants in the Joint Group would show a robust N400-effect when the signal elicited by correct (PLAUS) sentences was compared to that elicited by anomalous (IMPLAUS) sentences. This hypothesis was confirmed in a paired samples t-test, IMPLAUS < PLAUS, *t*(14)=2.48, *p* ,< .05, *r2*=.31.

Our second hypothesis was that participants in the Joint Group would show a robust N400-effect when the signal elicited by PLAUS sentences was compared to that elicited by sentences the participant judged to be sensible, but suspected that the confederate would find anomalous (CONTEXT). This hypothesis was also confirmed in a paired samples t-test, CONTEXT < PLAUS, *t*(14)=2.58, *p* < .05, *r2*=.32.

Our third hypothesis was that participants in the Alone Group would show a robust N400-effect in response to the same PLAUS and IMPLAUS sentences presented to the Joint Group, but that in the absence of the confederate, participants in the Alone Group would show no N400-effect for CONTEXT sentences vs. PLAUS sentences. This hypothesis was confirmed in two paired samples t-tests indicating a significant effect for IMPLAUS sentences, IMPLAUS < PLAUS, *t*(16)=3.62, *p* < .005, *r2*=.45, but no significant effect for CONTEXT sentences vs. PLAUS sentences, *t*(16)=-.50, *p*=.61.



**Figure 1**. Event-related potentials (ERPs): The left panel shows the ERPs elicited by target words (onset of critical word = 0 ms) in the Joint Group plotted for the midline electrodes (Fz, Cz, Pz). The right panel shows the ERPs elicited by target words in the Alone Group. In both panels the solid like shows the ERP elicited by plausible sentence stimuli (PLAUS), the dashed line shows the ERP elicited by semantically implausible sentences (IMPLAUS); the dotted line shows the ERP elicited by sentences that were plausibly only with the help of the disambiguating context sentence (CONTEXT). The N400 time window (350-550 ms after target word onset) is shaded grey in both panels. A significant difference in amplitude (an N400-Effect) is seen for the comparison between PLAUS and IMPLAUS sentences in both groups (a classic N400-Effect) and between PLAUS and CONTEXT only in the Joint Group (the novel Social N400-Effect). Crucially there is no significant difference between PLAUS and CONTEXT in the N400 time window in the Alone Group.

**Discussion**

In the current study we show that a reliable N400-effect (i.e., a neural correlate of failure to comprehend) is elicited by sentence stimuli that are *correct* for a participant but incorrect for a jointly attending other (the confederate). Importantly, this Social N400-effect is elicited by the constraints of the social situation—if the confederate is removed from the room, exactly the same sentence stimuli fail to elicit an N400-Effect. Additionally, we show that the canonical N400-Effect in response to semantically implausible sentences is attenuated with only one sentence of disambiguating context.

The results of this study indicate that understanding someone else’s inability to grasp language content elicits a neural marker of semantic integration difficulty that is comparable to that elicited by failing to grasp something oneself. It is important to note that this study does not speak to how automatically we track the comprehension of others during communication—it provides information only about the cognitive process underlying those moments in which we *do* track knowledge about others (i.e., because of experimental task requirements). Further research is necessary to show how automatic the Social N400-Effect is, as well as how one’s propensity to track the knowledge of other listeners is related to individual differences in personality (e.g., empathy) and related cognitive abilities (e.g., working memory, inhibition).

The current study shows that *when participants do* attend to the ability of a confederate to comprehend language stimuli, semantic mismatches for the confederate elicit a pattern of neural activation that is comparable to what is seen for semantic mismatches for the participant him/herself. The fact that detecting implausibility for another results in changes in the ERP signal that are temporally and spatially comparable to detecting implausibility for oneself lends weight to accounts suggesting that knowledge about others plays a primary role in language comprehension. In addition, this finding is in line with what has been reported in the joint action literature, namely that participants simulate the task demands of jointly acting others. The result opens questions about how two conflicting interpretations of sentence content are maintained and managed by the participant. Clearly participants are capable of simultaneously entertaining multiple interpretations of the stimulus, as the confederate’s interpretation does not override the participant’s own understanding of the sentence. In many ways this situation is akin to what happens when two meanings of an ambiguous word or homophone are simultaneously understood in a pun (e.g. The Cane and Able at the name of a health care centre)—the pun is only funny if both meanings are entertained (see e.g., Coulson & Severens, 2007). We suggest that keeping track of one’s own vs. another’s interpretation of a sentence will work in a similar fashion, and will certainly draw on additional cognitive processes such as working memory and inhibition (see also Lin, Keysar, & Epley, 2010; Brown-Schmidt, 2009).

The results of this study may differ from some previous reports highlighting egocentric processing biases (e.g., Keysar et al., 2000) because participants in our study were engaged in a true *joint comprehension* task. Previous experimental paradigms have investigated situations in which speaker and listener are united in dialogue (i.e., also a form of joint task), but share no immediate common action within the dialogue (i.e., speaker and listener tend to do different things at any given moment to achieve their common goal). Note that current theories suggest that language production and comprehension involve similar mechanisms (Pickering & Garrod, 2013), thus the distinction between speaker and listener may be less clear cut than previously envisioned. Nevertheless it is clear that the overall process of producing an utterance vs. understanding an utterance is different even if both draw on some common cognitive and neural processes. In contrast in our study participants jointly attended spoken stimuli alongside another. This means that the cognitive task of participant and confederate were better aligned than in previous studies, as both simultaneously perceived language input. When the cognitive tasks of participants are aligned, direct effects of one person’s knowledge are seen on the ability of the other to perform. When the cognitive tasks are misaligned (i.e., one person speaks while the other listens) the effects of knowledge about others may have a relatively later effect, as the primary cognitive tasks of speaker and listener are actually quite different.

In addition this study provides converging evidence in support of the strong effect that discourse can have on lexical-semantic processing. In previous research Nieuwland & van Berkum (2006) showed that the N400-effect is attenuated after participants are presented with three to five sentences of disambiguating context (i.e., attenuation of lexical-semantic expectations is slow, see also Warren, McConnell & Rayner, 2008). In the current study the N400-effect is attenuated with only *one* disambiguating context sentence. We suggest that attenuation may have been so much stronger in the current paradigm, as the first sentence explicitly pointed out how the second sentence could be rendered plausible, i.e., in contrast to previous research, the first sentence of discourse was not implausible in itself (e.g., *In the cartoon the dog worked in a bank.*), therefore it does not require the participant to come up with a situation model in which dogs wear suits, but rather it provides one explicitly. By explicitly describing the context in which the target sentence can be seen as plausible we see a more or less immediate effect of discourse on the processing of target sentences. In support of this idea, Filik and colleagues have shown that when an already well-known context provides disambiguating information (e.g., information about a cartoon character, like the Incredible Hulk) attenuation of the N400-effect is also very fast (Filik, 2008; Filik & Leuthold, 2008).

Our results have broad implications for understanding not only how we take others into account during conversation, but also how we theorize about others’ mental states in general. While a great deal of research has been done on the behavioural consequences and neural correlates underlying theory of mind abilities, understanding the time course of mentalizing has proven to be difficult (Apperly, 2011;2012; Sabbagh & Taylor, 2000). The use of joint comprehension paradigms like the one introduced here has the potential to give excellent insight into the time course along which we take knowledge about others into consideration.

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