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"Are we still talking about the same thing?" MEG reveals perspective-taking in response to pragmatic violations, but not in anticipation

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Abstract

The current study investigates whether mentalizing, or taking the perspective of your interlocutor, plays an essential role throughout a conversation or whether it is mostly used in reaction to misunderstandings. This study is the first to use a brain-imaging method, MEG, to answer this question. In a first phase of the experiment, MEG participants interacted "live" with a confederate who set naming precedents for certain pictures. In a later phase, these precedents were sometimes broken by a speaker who named the same picture in a different way. This could be done by the same speaker, who set the precedent, or by a different speaker. Source analysis of MEG data showed that in the 800 ms before the naming, when the picture was already on the screen, episodic memory and language areas were activated, but no mentalizing areas, suggesting that the speaker's naming intentions were not anticipated by the listener on the basis of shared experiences. Mentalizing areas only became activated after the same speaker had broken a precedent, which we interpret as a reaction to the violation of conversational pragmatics.

Keywords: Language; Pragmatics; Precedents; Common Ground; Conversation; MEG.

Introduction

Humans have the special capacity to think about what others are thinking or feeling (Tomasello et al., 2005) and employ such "mentalizing" in everyday conversations. In the current study, we employ Magneto encephalography (MEG) to investigate the neural basis of mentalizing and how this process interacts with other brain areas during interactive language use. We focus on the critical question of whether mentalizing plays an immediate and constant role in conversation, or whether it mainly comes into play to enable interlocutors to detect and recover from misunderstandings.

In a conversation, it is important to know what is in "common ground" between you and your interlocutor. For example, you need to make sure that you are talking about the same thing, when referring to an object. One of the strategies interlocutors use in this situation is to establish conceptual pacts (Brennan & Clark, 1996) or conversational precedents (Barr & Keysar, 2002). This entails that, once they have agreed on (or "grounded", Clark & Brennan, 1991) a certain referential expression for the object (e.g., 'salami' for a particular piece of meat), interlocutors in a certain conversation will continue referring to that same referent with the same term. Listeners generally expect speakers to adhere to this strategy. Thus, if a speaker "breaks" the precedent and suddenly uses a different term (e.g., 'sausage') for the same referent, this is expected to confuse the listener; perhaps the speaker now refers to a different object? Such confusion, resulting in longer latency times to look at objects, has indeed been attested in eye-tracking studies (Brown-Schmidt, 2009; Metzing & Brennan, 2003; Kronmüller & Barr, 2007). However, to test whether this confusion was not just related to "egocentric" processing, because this was the last name the listener heard for this object, a second speaker was introduced. This second speaker, unaware of the precedent that the first speaker had set, also breaks the precedent. This situation should be much less confusing to the listener as there has never been a common ground with the second speaker. All studies cited above consistently showed evidence of perspective-taking at some point after breaking the precedent; listeners were slower to look at the intended object when the same speaker broke a precedent than when a different speaker did so. However, the eye-tracking studies did not conclusively distinguish between two different theoretical accounts. First, a shared perspective could be maintained throughout the conversation. In that case, listeners can easily anticipate speaker's naming intentions, if the object and its name are in common ground. Thus, breaking a precedent would immediately lead to confusion, but only by the same speaker. This was supported by some research (Metzing & Brennan, 2003), whereas other research suggests that, in first instance, breaking a precedent leads to confusion regardless of the speaker (Kronmüller & Barr, 2007). This latter result implicates that listeners might not use common ground in the form of a shared perspective with the speaker by default, instead, only when it becomes necessary due to a pragmatic violation. According to this view, the speaker's referential intentions would not be anticipated based on the previously shared perspective (i.e., mentalizing), but rather, perspective-taking would only be engaged after a violation has taken place.

Using MEG within a "precedents" paradigm offers unique insights into whether mentalizing is used to interpret language throughout a conversation, or whether it is only engaged in reaction to pragmatic violations. Like eye-tracking research, MEG has an excellent temporal resolution that allows effects to be localized in time, while also localizing these effects in the brain. We devised a paradigm that allowed for live interactive dialog between a participant in the MEG scanner with two different (confederate) speakers. The speakers and the participant/listener viewed pictures of everyday objects on separate computer monitors (see Figure 1). The experiment was divided into a series of blocks, each consisting of an "interactive" phase in which precedents were established for various pictures, and a later "test" phase in which some of these pictures were named once again by either the same or a different speaker. For example, in the test phase, the listener might see a picture of a piece of meat (see Figure 1, right) that had been called 'salami' during the interactive phase, but now hears the (same or different) speaker say 'sausage'. Based on how the test-phase speaker named their object, listeners had to decide whether or not the speaker saw the same object as them. This task provided a cooperative reason why the (same) speaker might break the precedent, namely to signal that this was a different sausage than the salami that they saw together before. This "broken precedent" condition was contrasted with a baseline "no precedent" condition in which the picture named in the test phase had been referred to by its location (i.e., not named), during the interactive phase (see methods). Importantly, in the test phase, listeners viewed the picture for 800 milliseconds before the object was named. Also, the speaker for a particular block of test-trials was announced in advance. Thus, listeners could anticipate the referential expression based on the picture and the speaker, before the name was actually given.

We hypothesized that listeners would engage episodic memory areas (medial temporal lobe, e.g., Baddeley, 2000; lateral prefrontal cortex, Sakai & Passingham, 2004; Kessler & Kiefer, 2005) together with language areas (e.g., temporal pole, Imaizumi et al., 1997) in this anticipation period and possibly after naming. Especially objects that had been named during the interactive phase (in contrast to objects without a precedent) should engage these areas, since the picture would serve as a retrieval cue for retrieving the precedent. Episodic memory might be activated even more for objects that had been named by the same speaker, if speaker identity is used as a further retrieval cue.

For our research question, the involvement of mentalizing networks (i.e., temporo-parietal junction: TPJ, ventro-medial prefrontal cortex: vmPFC, and possibly precuneus: PC; e.g., van Overwalle & Baetens, 2009) and the timing of such involvement was of particular importance. The "anticipation" account would predict that episodic retrieval of common ground information while viewing the picture would lead to anticipation of the speaker's naming intentions, by employing mentalizing areas, already before naming. Crucially, such anticipation of naming intentions is only very meaningful when the current speaker has named this picture before. In contrast, the "egocentric" account would predict that, despite episodic retrieval of common ground information, mentalizing areas would not be employed to anticipate naming preferences based on these memories. Instead, this account would predict late, deliberate, post-naming activation of the mentalizing network, suggesting that it is only called upon to make sense of the experienced violation.

Methods

Participants

Seventeen British students from Glasgow University (8 males) with English as their native language participated in the MEG experiment, with approval of the local ethics committee. They were paid for their participation and gave their informed consent. One female participant was excluded from the analyses because she clicked the wrong picture too often in the interactive phase (22 times).

Materials and Apparatus

Materials consisted of 320 experimental pictures that could be named in two roughly equivalent ways (based on a pilot study) and 640 filler pictures. The names for the test phase (320 experimental names and 190 filler names) were recorded beforehand, divided equally among the two confederates. Some of the filler names were presented with a hesitation, to make naming on-the-spot more plausible. The experimental names were always preceded by 800 ms of recording noise (600 to 1200 ms for the fillers).

MEG data were acquired using a 248-channel 4D-Neuroimaging magnetometer system, sampled at 508.63 Hz and band-pass filtered between 0.1 and 400 Hz.

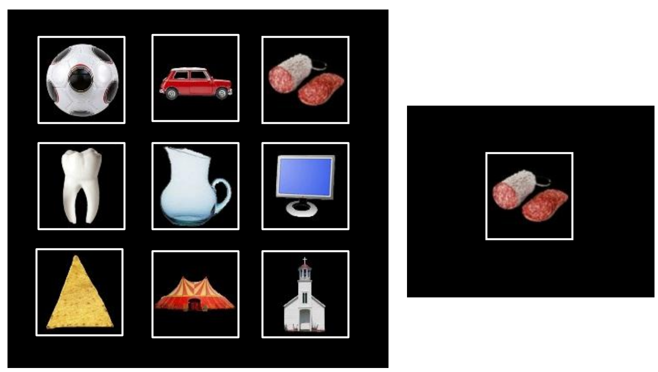

Figure 1: Example of the participants' screen in the interactive phase (left) and the test phase (right).

Procedure

Participants were first prepared for the MEG, including head digitization, in about 45 minutes. They were introduced to the confederates ("the speakers"), who would talk to them from separate rooms and were not able to hear each other. Participants had the role of listener. After two practice blocks in which the participants had the role of listener and speaker, 20 experimental blocks followed, all consisting of an interactive and a test phase, divided into 5 parts of 20 minutes each, with breaks in between. In the interactive phase, participants saw 9 pictures on the screen at a time (see Figure 1, left). In each interactive phase, one speaker asked them to click on one of these pictures, for a total of 42 times. Each critical picture was clicked on twice by the participants, using a trackball. Eight critical pictures were named and another eight were referred to by their location (e.g., 'top left'; participants were told that the speaker saw a question mark in place of these pictures). Participants could freely interact with speakers in this phase. In the test phase, the speaker was the same as for the preceding interactive phase in half of the cases and different in the other half. Participants saw one picture at a time on the screen (see Figure 1, right) and were told that the speaker also saw one picture and had to name that picture. Participants had to indicate whether the speaker saw the same or a different picture than they, with a button press. The listeners were instructed not to interact with the speaker in this phase as they were unaware of hearing recorded utterances. Each phase consisted of 8 broken precedent trials (named differently than in the interactive phase), 8 no precedent trials (indicated by their location in the interactive phase), 4 maintained precedent fillers (named the same way in the interactive phase) and some new fillers.

Data analysis

Pre-processing and statistical analysis of MEG data was conducted using the Fieldtrip Matlab® toolbox (Oostenveld, Fries, Maris, & Schoffelen, 2011). We extracted epochs from 500 ms before the picture was shown until 500 ms after the response for all test trials. These epochs were detrended, denoised, and subjected to ICA to remove eye, heart, and movement artefacts. For evoked responses (ERF), trials of the same condition were averaged per participant, with a baseline of 200 ms prior to picture onset and a band-pass filter between 0.5 and 35 Hz. For these averages, planar gradient representations were calculated prior to sensor level analysis. For time-frequency representations, the power of frequencies between 2 and 30 Hz was calculated over time using a Hanning taper with a window of 4 cycles. For statistical analysis, we used the cluster-based approach implemented in the Fieldtrip toolbox (Maris & Oostenveld, 2007), to circumvent the multiple-comparisons problem. We employed 2-step analyses for emulating the interaction between two factors. We first calculated a t-statistic for the difference between two conditions per participant and then included these t-values into a group statistic that compared a second difference. To identify sources underlying the sensor-level effects, individual single-shell head models were generated based on the individual MRI (6 mm voxel size) aligned with the MEG sensor array, subsequently normalized to a standard brain. A Linearly Constrained Minimum Variance (LCMV) beam former (van Veen and Buckley, 1988), common for all conditions (to increase SNR), was used for ERFs to transform individual conditions into source space for comparisons between conditions. Dynamic Imaging of Coherent Sources (DICS) beam formers (Gross et al., 2001) were used for theta source analysis. In this case we used condition-specific spatial filters to reveal qualitative differences between conditions.

Results

Behavioural results

As shown in Figure 2, the proportion of "different picture" responses was increased when a precedent was broken by both same ($t(15) = -5.63$, $p < .001$) and different speakers ($t(15) = -3.97$, $p = .001$), but this was more pronounced for same speakers ($F(1,15) = 21.15$, $p < .001$). Participants were slower when an established precedent was broken, but only when the same speaker broke the precedent ($t(15) = 3.47$, $p = .003$), resulting in an interaction ($F(1,15) = 8.43$, $p = .011$). Thus, listeners experienced greater confusion when a speaker broke his or her own precedent than when a speaker broke another's precedent (confirming Metzing & Brennan, 2003; Kronmüller & Barr, 2007). Note that this does not imply that common ground is considered by default or in anticipation, since it might also mean that listeners still experience conflict when a different speaker breaks the precedent, but resolves the conflict more quickly and/or in a different way than when the same speaker does so.

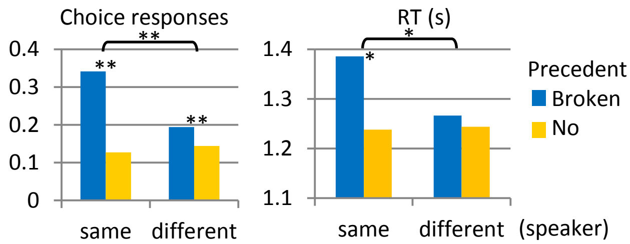

Figure 2: Behavioural responses in the test phase: proportion of "different" responses (left) and RTs (right).

These behavioural data confirmed our approach to look at the interaction effect in the MEG data (using the two-step analysis, see Data analysis), which we did for the theta source analysis (see Theta Oscillatory Results). Furthermore, on the basis of these behavioural data, it is most likely that mentalizing occurred for trials in which a precedent was broken by the same speaker and where participants responded to have seen a different picture. By this behavioural response, they show that they are aware of the conflict between the precedent and the new term and have resolved this by deciding that the speaker probably sees a different picture now. Next to that, especially slow responses, probably reflecting confusion upon hearing the new term, could also reflect the engagement of mentalizing processes. In contrast, in trials that elicited a quick "same picture" response, listeners might not even be aware of the conflict. Thus, we selected the "different"-responses plus one third of the slowest "same"-responses for the same speaker/broken precedent condition and refer to them as "deliberation trials". We used separate analyses of these trials as corroborative evidence when necessary (see ERF Results), next to analysing all trials of this condition.

ERF Results

In a cluster analysis between 300 and 500 ms after naming (on the basis of visual inspection), a significant cluster was found for same speaker between 318-454 ms ($p = .009$) and a marginally significant cluster for different speaker between 300-415 ms ($p = .048$) (see Figure 3, panel A). The topography of the effects was slightly more anterior (left) for the same speaker and more posterior (left) for the different speaker. However, a direct comparison between the two contrasts did not reveal significant clusters. We also analysed the deliberation trials between -800 and 1000 ms. This revealed a cluster with a similar topography and timing of peak activity as the previous analysis (67-680 ms after naming, $p < 0.00001$, Figure 3, panel B right) plus two clusters in an early time interval before naming, when the target object was visually presented, (550 to 23 ms before naming onset, $p = .004$, and 306 to 0 ms before naming onset, $p = .004$; Figure 3, panel B left). This strongly suggests anticipatory processing in deliberation trials.

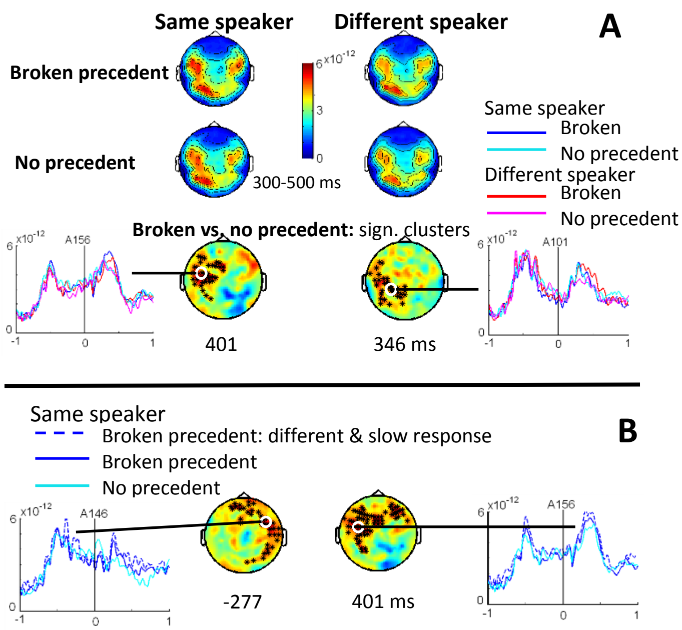

Figure 3: Sensor level ERF. A: comparisons for "broken – vs. no precedent" for same speaker (left column) and different speaker (right column). B: comparisons for the deliberation trials (dotted dark blue line) compared to the no precedent trials (light blue line), within the same speaker condition. Significant clusters for this contrast are indicated pre-naming (left) and post-naming (right).

Source analysis was employed for the comparison between deliberation and no-precedent trials within the same speaker for both time intervals. The post-naming analysis between 300 and 500 ms revealed one significant, spatially distributed cluster ($p < 0.00001$) and the pre-naming analysis between -350 and -150 ms also revealed one significant, spatially distributed cluster, ($p < 0.00001$). Table 1 lists the brain areas included in the pre- and post-naming clusters. See Bögels et al. (submitted), for figures and a more detailed description of these source-level results.

In both intervals, we found activation related to episodic memory processing, suggesting that participants were continuously retrieving the episodic context for a particular target object. Parahippocampal gyrus has been associated primarily with episodic encoding of the visuo-spatial context (e.g., Epstein & Kanwisher, 1998), but more recently also with integration of social, communicative, and paralinguistic context (e.g., Rankin et al., 2009). Thus, this activation might reflect retrieval of the episodic context of the interaction with the target object, including information about the speaker and the used name. We also found language-related areas, possibly indicating retrieval of the referent established during the interaction (in the pre-naming interval, cf. Duff & Brown-Schmidt, 2012) and semantic matching processes between the object and the used name (in the post-naming interval, e.g., Grabowski, Damasio et al., 2001; Pobric et al., 2007). We found differences in visual (attention) areas in the early interval which could suggest more visually detailed episodic retrieval of previously named objects, when anticipating a naming by the same speaker. In the late interval, we found activation of motor areas which could reflect more intense or more conflicting motor preparation. Anterior cingulate cortex activity was found in both intervals, suggesting an anticipation of conflict in the early and monitoring of conflict during the late interval. Most importantly for our research question, we found activation of so-called "mentalizing" areas only after naming. These areas have been found to be part of a mentalizing network, for example involved in social judgments (van Overwalle & Baetens, 2009), in visuo-spatial perspective taking tasks (Blanke et al., 2005), and in reasoning about other's beliefs (Samson et al., 2004).

Table 1: Brain areas involved in the pre- and post-naming interval for ERFs in the deliberation trials vs. no precedent same speaker comparison (l/r: left and right hemispheres).

Brain areas	**Pre-naming**	**Post-naming**
Episodic memory	Parahippocampal gyrus (l), dorsolateral prefrontal cortex (r)	Parahippocampal gyrus (l)
Language	Temporal cortex (r)	Temporal pole (l)
Visual (attention)	occipital cortex (r), occipital temporal cortex (r), parietal occipital cortex (r)	
Motor (conflict)	Anterior cingulate cortex (ACC) (r)	ACC(l), premotor cortex(l), supplementary motor area(l)
Mentalizing		TPJ (r), vmPFC (l/r)

Theta Oscillatory Results

Time-frequency analysis (-800 to 1000 ms) revealed a significant cluster ($p = .012$) in the theta range (4-6 Hz) for "same speaker, broken precedent" compared to "same speaker, no precedent" in a time window around 350-650 ms after naming onset. No results were found in the corresponding comparison for different speaker.

We localised the sources of this theta effect in a post-naming time-window (200-800 ms) for 3 to 7 Hz, using a two-step analysis to look at the speaker by precedent interaction (p<.008; see Bögels et al. (submitted) for more details and figures). In Figure 4, results are displayed of another two-step analysis within same speaker, comparing anticipatory and reactive intervals (p<.01).

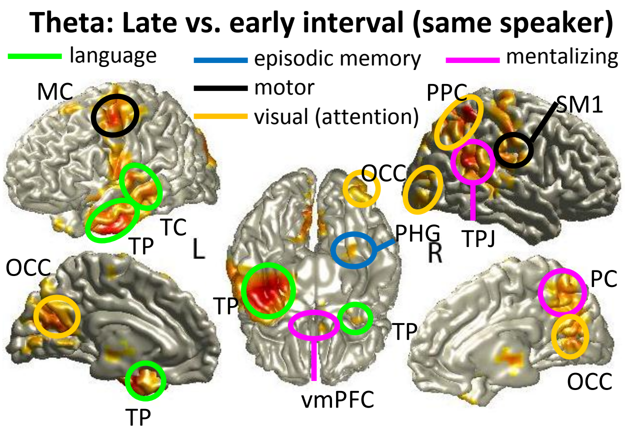

Figure 4: Theta sources comparing same speaker (broken vs. no precedent) effects before and after naming.

Again, both analyses show episodic (working) memory areas (parahippocampal gyrus: blue circle in Figure 4; prefrontal cortex). Together with stronger activation of visual (attention) areas (occipital cortex: yellow circles in Figure 4) in the early than the late interval, this suggests stronger episodic retrieval in the right hemisphere along with stronger visual reactivation in response to the naming. In both analyses, we also see language (green circles in Figure 4) and motor areas (black circles in Figure 4) again, as in the ERF analysis. Importantly, mentalizing areas in right TPJ, right precuneus and vmPFC showed stronger theta effects for the same speaker contrast than the different speaker contrast, but also within the same speaker contrast in the post- vs. the pre-naming interval (pink circles, Figure 4).

Discussion

Our results indicate that brain areas related to language, vision, episodic (working) memory, and mentalizing are dynamically and jointly involved in encountering and resolving conflict after a previously negotiated precedent is broken by the same speaker, and more so than when it is broken by a different speaker.

Episodic memory (together with language and vision) areas were engaged already in anticipation, suggesting a retrieval of the circumstances in which this picture was encountered before. Specifically, seeing a picture that was named before by the same speaker resulted in a stronger involvement of episodic memory (Theta localisation results), suggesting that the name was retrieved based on the picture and the identity of the speaker. We found especially strong anticipatory episodic memory activation for the trials in which listeners later on decided that the speaker saw a different picture ("deliberation trials", only for the time domain). Successful retrieval of the name and speaker on the basis of the picture probably allowed listeners to notice the conflict with the actual name that was given by the speaker and decide that the speaker might see a different picture.

With regards to our main research question, we found (both in the time and the frequency domain) that mentalizing areas were clearly more engaged in response to the violation than in response to the other conditions (in accordance with Kronmüller & Barr, 2007; Metzing & Brennan, 2003). Crucially for our research question, however, mentalizing was not engaged more strongly in the anticipatory time interval in the condition in which the same speaker was going to name an object he or she had named before. Thus, while retrieval of the precedent and probably the speaker associated with that precedent took place on the basis of the picture, this did not lead to inferences of the current speaker's naming intentions using mentalizing. One might argue that listeners will try to infer the speaker's intentions in every condition. However, only in the case in which the same speaker has named this object before, does the listener really have grounds to use the speaker's perspective for this anticipation. Therefore, we argue that it would be expected, under the anticipation view, that mentalizing areas should be involved more strongly in precisely that condition, but this is not corroborated by our findings. Even when focussing only on "deliberation" trials (only for the time domain), where mentalizing was most likely to occur, since listeners show that they are aware of the conflict, we found no evidence for anticipation of the speaker’s referential intentions (mentalizing).

These findings are in accordance with earlier eye-tracking results by Kronmüller and Barr (2007), showing that common ground is not taken into account by default since a broken precedent at first leads to confusion regardless of the speaker. In this context, recent approaches involving a second-person perspective (e.g., Schilbach et al., 2012) could also be of interest. A different processing "mode" and differential activation of brain areas is assumed for observation of others or "third person perspective" (as was used in most previous research) and for direct interaction with others, or "second person perspective". The latter type of processing (which might involve the posterior temporal sulcus; Tylén et al., 2012), related to fine temporal coordination during interaction, might be involved throughout a conversation, dealing for example with building up common ground by setting up new precedents. In the current study, all conditions probably involve such processes, resulting in no differential effects. In contrast, the pragmatic violations listeners encounter in the current study could invoke a mode that resembles the third person perspective, since listeners try to infer why the speaker breaks the precedent, involving the "classic" mentalizing areas (e.g., vmPFC; Tylén et al., 2012).

In conclusion, anticipating the speaker’s referential intentions based on previously established common ground does not seem to be a default process. In contrast, anticipation seems to rely only on episodic retrieval of visual and linguistic associations without any inference of the speaker's current mental states. Mentalizing about the other's perspective seems to be engaged "on demand" once a pragmatic violation or misunderstanding has occurred.

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