Can arbitrary places receive meaning: An ERP study

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Abstract

Electroencephalography (EEG) was recorded while participants viewed silent videos of an actor placing two objects in two different locations after which the objects disappeared and the actor pointed to one of the two empty locations. Subsequently, participants saw either the congruent object for that location or the incongruent object presented on a neutral background. Event-related potentials (ERPs) elicited by the presentation of the picture of the object showed an increased negativity for the incongruent objects compared to the congruent object, significant in the time window 300 to 400 ms. The topographical distribution if this negativity effect resembled an N400 effect. Findings show that adults process empty places in terms of absent objects, revealing a semantic processing underlying attention to empty places, even in the absence of language.

Keywords: place, point, meaning, EEG, N300, N400

Introduction

Can an empty place be meaningful? Consider the situation where a child has learned to take off his shoes when he enters the house. One day he forgets and his mother points to an empty space next to the door on the floor. Will the boy understand he must take off his shoes? Has the place been assigned the meaning of ‘designated location for shoes’? Thus, the question is whether a seemingly arbitrary place can be assigned meaning.

The described situation uses both the act of pointing and placing. Important for the present proposal is that both the placing of the object and the pointing are recognized as communicative acts. There seems to be consensus on the latter act being communicative. A definition of pointing is given by Kita (2003): "The prototypical pointing gesture is a communicative body movement that projects a vector from a body part. This vector indicates a certain direction, location, or object." Clark and Brennan (1991) argue deictic gestures are important in the process of grounding. The authors describe grounding as the mutual belief between a speaker and addressees that the latter have understood what was meant well enough for current purposes. In many instances, conversations are about objects and it is of importance to quickly identify the referent. One way to establish this is by using a gesture. In other words, pointing is a way to ground a reference. Eye tracking data support the idea that pointing is one instance to establish a referent, similar to a verbal description. Louwerse and Bangerter (2005) showed that when a feature description was accompanied by either a deictic gesture or a deictic expression, accuracy in target identification increased. Their study also provided evidence that pointing helps establish a joint focus of attention between speaker and hearer. When the pointing preceded speech, participants were faster to identify the target. Deictic gestures are part of an attention system as they guide the hearers gaze to the target.

Clark (2003) argues that placing should be considered a communicative act: like pointing it is an indicative act. Whereas language is based on arbitrary connections between the symbol and its object, an index is based on intrinsic connections. When pointing, there is a transparent connection between the gesture and the object to which this is directed. Indexing is a way of signalling that the addressee must focus attention on the object. Clark argues that pointing and placing differ in what speakers try to manipulate. Pointing directs the addressee's attention to the

object whereas placing tries to move the object into the addressee's attention. According to Clark, the difference between the two signalling methods is that pointing creates an indexing site that is connected with the object whereas placing exploits a pre-existing indexing site and connects the object with it. Clark distinguishes three phases of placement. First there is initiation where the object is placed. The second phase is maintenance: maintaining the object in place. And finally termination: replacing, removing, or abandoning the object.

Interestingly, pointing does not only occur in the presence of objects. People often point at an empty space when referring to absent entities (e.g. Bavelas, Gerwing, Allison, & Stutton, 2011). Pointing to an empty location can be meaningful if the location has been established as the place for an object. Such pointing to absent referents is thought to be uniquely human. Liszkowksi, Schäfer, Carpenter and Tomasello (2009) showed that chimpanzees pointed to an object in a known but occluded location. They did not point to a location from which the object had just been removed. This is in contrast to 12-month-old infants who point to both the location of occluded and absent objects (see also Liszkowski, Carpenter, & Tomasello, 2007).

One question is whether empty places are processed as standing in for the absent entities, similar to semantic processing of words. Words can also be thought of as standing in for an entity. One way semantic processing of words has been examined is by using electrophysiological methods, such as electroencephalography (EEG). EEG measures the brain's electrical activity by electrodes placed on the scalp. The electrical activity reflects the summation of spatially aligned and synchronously firing neurons. EEG has excellent temporal resolution, giving information about the onset and duration of neuronal firing which allows for inferences about the timing of the measured cognitive process.

Averaging across trials results in an event-related potential (ERP). The N400 effect, a negative-going ERP component that peaks around 400 ms after stimulus onset with a centroparietal scalp distribution, is thought to be an index of semantic processing. The N400 effect was first discovered for language processing by Kutas and Hillyard (1980a): the N400 was more negative for semantically incongruent words compared to congruent words. They also showed that the N400 is modulated by the degree of mismatch, a larger mismatch leads to a larger N400 (Kutas & Hillyard, 1980b). The N400 effect is not only restricted to processing of semantic

anomalies, it is also found for instance for less-expected sentence endings compared to expected endings (Kutas & Hillyard, 1984). The authors conclude that the N400 indicates the ease with which a word is accessed and/or integrated into context.

Since the discovery of the N400 effect many studies have followed to determine what this ERP component actually represents. It has been shown that the N400 effect does not only appear for incongruencies at the sentence level, but also at the discourse level. For instance, Van Berkum, Zwitserlood, Hagoort and Brown (2003) compared the electrophysiological response to words that either were coherent or anomalous with the previous discourse. Importantly, these words were equally acceptable on the local sentence level. The discourse-anomalous words, relative to the coherent words, elicited an N400 effect with a similar time course and scalp distribution as the original N400 effect found by Kutas and Hillyard. This result indicates that listeners use discourse information rapidly in the semantic comprehension process, just like sentence information. The N400 seems to be an index of semantic processing, independent of the level from which the information is retrieved.

This is confirmed by studies investigating the contribution of world knowledge. Hagoort, Hald, Bastiaansen and Petersson (2004) measured EEG while presenting sentences as "the Dutch trains are *yellow/white/sour* and very crowded": the first critical word being correct, the second a violation of world knowledge and the latter a semantic violation. The standard N400 effect was found for the semantic violations, but interestingly also for the world knowledge violations, with a similar time course and topographic distribution. This is clear evidence for a similar mechanism for the integration of semantic and world knowledge in sentence comprehension.

In the absence of a sentential context a similar impact of world knowledge can be seen. Chwilla and Kolk (2005) studied the processing of script knowledge, sets of expectations build on past experience, by presenting triplets of words. These triplets were all associatively or semantically unrelated, but could be script-related (e.g. DIRECTOR - BRIBE - DISMISSAL) or script-unrelated. The script-unrelated words resulted in larger negative-going waveforms than the script-related words, the N400 effect. Script knowledge can also play a role in semantic processing.

So far, the discussed studies all investigated the processing of stored knowledge in long-term memory (LTM), albeit at different levels of comprehension.

Chwilla, Kolk and Vissers (2007) presented participants with a context followed by a sentence that included a novel situation that was either sensible or senseless after the introduction. The results showed an N400 effect for novel senseless words compared to novel sensible words. This indicates not only stored knowledge is integrated during semantic processing, but there is also immediate integration of novel situations never experienced before.

Özyürek, Willems, Kita and Hagoort (2007) examined how gestures are integrated into a sentence and what happens to comprehension when a gesture mismatches with the expectation raised by the semantic content of the sentence. They found that gesture mismatches resulted in an N400 effect with similar onset latency, amplitude and topographical distribution as found for word mismatches. Thus, the N400 is not only sensitive to words but also to other symbols that carry meaning.

More evidence comes from a study by Wu & Coulson (2007) who investigated the processing of gestures in the absence of linguistic context. Participants were presented with video clips of iconic gestures after which a probe word followed. The amplitude of the waveform was reliably more negative to the unrelated probe compared to when it was related to the gesture, again showing what looks like an N400 effect.

The N400 effect is also found in processing of non-linguistic stimuli. Nigam, Hoffman and Simons (1992) compared the response to all-word-sentences and sentences for which the final word was replaced with a picture. In both conditions, an anomalous ending resulted in a more negative waveform compared to the correct ending; the N400 effect for both conditions was similar in amplitude, latency and scalp distribution. The N400 therefore seems to be an index of processing of all types of meaningful stimuli, suggesting there is an amodal conceptual system accessed by both words and pictures.

The N400 has also been investigated in the absence of language. West and Holcomb (2002) did not use any linguistic stimuli. Instead they showed picture stories for which the final picture could either be congruent or incongruent with the storyline. A more negative-going waveform around 400 ms was also evident in this study, although the topography was more anterior than what is found for the N400 effects for linguistic stimuli. In addition, the authors found an increased negativity with a peak at around 300 ms, called the N300. This effect was frontally distributed and might reflect activation of image-based representations.

Willems, Özyürek and Hagoort (2008) also examined word versus picture integration by presenting a critical word together with a picture. A mismatch in either or both the word and picture with previous context resulted in a frontally distributed N400 effect. The authors suggest that the mere presence of visual material results in a shift in the scalp distribution to more frontal areas.

Sitnikova, Holcomb, Kiyonaga and Kuperberg (2008) presented participants with movie clips to investigate violations of action sequences. Contextually inappropriate information in movie endings resulted in both an N300 effect and an N400 effect, both in anterior regions. This replicates the results found for static pictures, now with moving stimuli. The N300 is again taken as an index of activation of visual based representations whereas the N400 is seen as activation of meaning representations. The N400 effect was prolonged in comparison to N400 effects found for words, most likely due to the fact that the movie clips unfold over time whereas visually presented words are abruptly presented.

The present proposal is interested in whether a similar effect is also present for empty places that previously held an object. Participants are presented with video clips where two objects are each coupled to a location. Then they are presented with the same scene, however both objects have been removed. The experimenter points to one location, after which one of the two objects is shown. This is either congruent with the previous placement or it is incongruous. The question is whether an increased negativity is visible in the EEG signal for the incongruent object compared to the congruent condition. If so, it would provide evidence for the hypothesis that an empty place can be assigned a meaning.

Our understanding of semantic processing has increased vastly, as many studies have been done in the last thirty years. As described in the previous paragraphs not only meaning processing in language is the subject of interest; non-verbal situations have also been increasingly studied. However, in most studies the context or prime is still linguistic in some form. Only the Sitnikova et al. (2008) study is completely devoid of linguistic stimuli and focuses on action processing. The present study follows their paradigm and only uses moving stimuli and no linguistic stimuli whatsoever. It resembles the discourse study by Van Berkum et al. (2003), but now the context is created non-verbally with the placement of the objects. By using this experimental set-up, we aim to increase our understanding of place and point comprehension.

One previous study looked at point comprehension using EEG. Gredebäck, Melinder and Daum (2010) showed participants a target at the top or at the bottom of the screen followed by a pointing gesture to the same or different location. Adults showed a larger N200 effect for the incongruent trials compared to the congruent trials, indicating pointing direction is processed as a referential cue. We like to go one step further and examine the comprehension of pointing to an empty place in relation to semantic processing of object representations.

The ERP will be time-locked to the onset of the presentation of the object. We expect to find a congruency effect, with the incongruent objects resulting in more negative waveforms than the congruent object. This would indicate that the point to the empty place is interpreted as referring to the currently absent objects. This negativity could resemble the traditional N400 effect with the negativity peaking at around 400 ms. If found, the N400 effect will most likely have a frontal distribution, as found for other studies using visual stimuli. Possibly, the N400 will be prolonged, as reported by Sitnikova et al. (2008), as the video clips unfold over time. The N300 effect might also be present, which would reflect the activation of the visual object representations.

We also tested for difference in the N100 and P200 time window. The N100 and P200 are both thought to reflect selective attention processes (e.g. Hillyard, Hink, Schwent, & Picton, 1973; Luck, & Hillyard, 1994). We expect no difference in these early perceptual time windows as there should be no difference in attention in the two conditions. The previous N400 studies do not find a difference here either (e.g. Sitnikova et al, 2008; Özyürek et al., 2007). The two conditions should only differentiate from each other at a later time window.

2. Methods

2.1 Participants

Twenty-four right-handed students of the Radboud University Nijmegen or Hogeschool van Arnhem en Nijmegen (fifteen female) took part in the experiment (average age: 21,2 years, range: 18-27). All participants were native speakers of Dutch, and had normal or corrected-to-normal vision. Participants received 14 to 16 euro's as a financial reward depending on the duration of the experiment.

2.2 Materials

The stimuli were 160 pairs of videoclips. Each videoclip followed the same format. In the initial scene a female actor was holding two objects with both arms downwards. The actor first looked at the camera and then the first object was raised and subsequently placed, either on a table or on the floor. As the object was placed, the actor looked back into the camera. When returning to the middle of the scene, eye gaze to the camera was maintained. The second object was then shown and placed on the other side of the room. Again, the actor made eye contact with the camera as the object was placed and then returned to the centre of the room. Half of the videos started with raising the left arm and placement of the object on the left side of the room, the other half started with the right arm and right side of the room.

After a blank screen of one second a new scene started. The actor pointed to one of the locations, this scene was always five seconds long. First, the actor looked in the camera and then to the location after which the point was initiated. The scene ended with the arm extended. See Figure 1 for some stills.

The videos were edited with Adobe Premiere Pro CS4 (www.adobe.com). On average, the videos were 16.58 seconds long (range: 14.15 to 20.20 seconds). The video ended with a blank screen. The final part consisted of the image of either the object belonging to the pointed-to location (congruent trials) or the other object (incongruent condition). This image was created by taking pictures from the objects used and editing them using the program Adobe Photoshop CS4 (www.adobe.com). This image was presented in the middle of the screen with a black background for two seconds. Note that the videos were of exactly the same duration for both the congruent and incongruent condition. Eighty placement scenes were recorded and thus 160 objects were used. We created different settings to add some variation to the videos. So for instance, a scene could represent a kitchen and the two objects used were semantically related to this setting and easily distinguishable from each other. For a full list of scenes and objects, see Appendix I.

Each participant saw the 80 different scenes with 40 of these trials with a point to the left location and the other to the right location. For each location, half the trials were congruent and the other 20 incongruent. In total, each participant was presented with 40 congruent and 40 incongruent trials. The pointed-to location and congruency

were counterbalanced across four groups. Each participant received a pseudo-randomized order of the trials. No setting was presented twice in a row (i.e. kitchen), no more than four points to one location followed each other nor more than four trials of the same congruency were presented after one another.

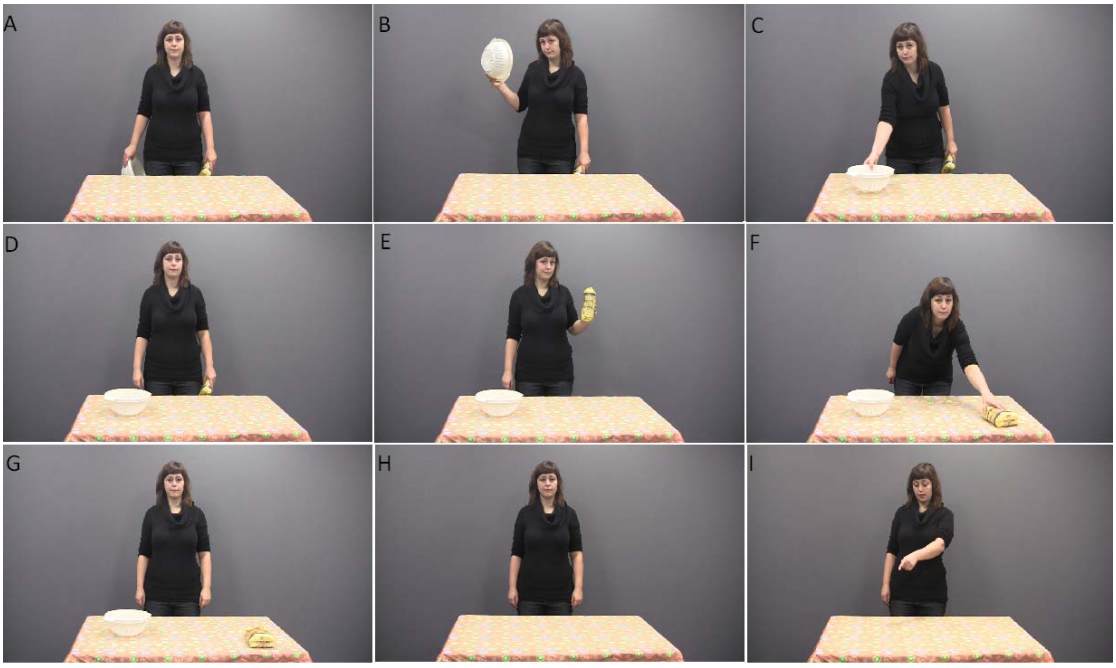

Figure 1. Stills from one of the kitchen scenes. ***A.*** *Start of the scene.* ***B.*** *The first object is held up.* ***C****. The first object is placed.* ***D****. Return to centre of room.* ***E****. Second object is presented.* ***F****. Second object is placed.* ***G****. End of placement scene.* ***H****. Start of pointing scene, both objects are absent.* ***I****. Point to one of the locations.*

2.3 Procedure

Participants were individually tested in a dimly lit booth while seated in front of a computer screen of 24 inch. Viewing distance was approximately 100 cm. Stimuli were presented using Presentation software (version 14.9, www.neurobs.com). Instructions and characters were always presented in white lower case Arial letters (20 point font size) on black background. Each trial was initiated by a fixation cross of one second. The video was then played, thus the participant saw an actor placing two objects followed by a point to one of the locations - the two acts divided by a blank screen lasting one second. Another blank screen of one second signaled the end of the video after which a fixation cross was presented with a variable duration between 500 and 1000 ms. The picture of the object was presented for two seconds. Participants

were instructed to try not to blink during the presentation of the fixation cross and the picture of the object. The end of the trial was indicated by a blank screen of one second after which a black screen with three hash tags was shown. This screen was presented for three seconds and allowed the participants to blink and move a little before the new trial. Finally a blank screen of one second was presented. The test session consisted of four experimental blocks, each consisting of 20 trials, with short breaks in between.

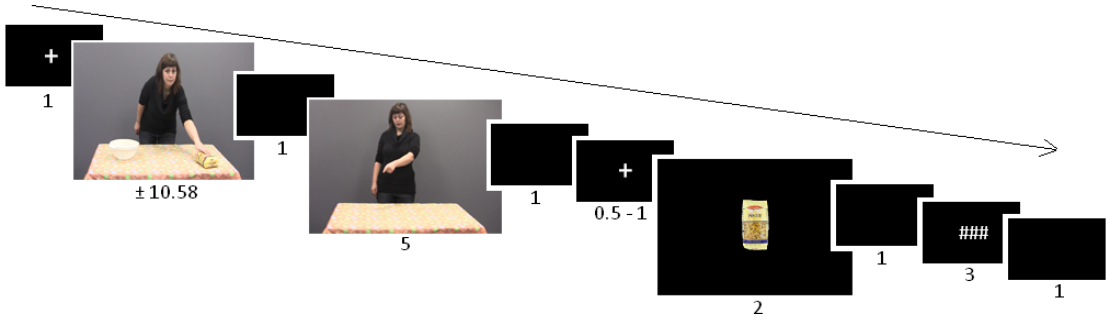

Figure 2. Overview of the procedure. Duration of each screen is printed below the respective screen in seconds.

2.4 EEG Recording and Analysis

The electroencephalogram (EEG) was continuously recorded using an EEG cap containing 32 electrodes (Ag/AgCl) mounted according to the extended International 10-20 system. The 32 scalp locations were Fp1, Fp2, AF3, AF4, F3, Fz, F4, F7, F8, FC1, FC2, FC5, FC6, C3, Cz, C4, T7, T8, CP1, CP2, CP5, CP6, P3, Pz, P4, P7, P8, PO3, PO4, O1, Oz, O2. Six additional electrodes were placed on the participant's head as follows. The EEG was offline referenced to the two mastoids. Lateral eye movements were measured using a bipolar montage with one electrode next to the left eye and the other beside the right eye. Vertical eye movements were measured using electrodes above and below the right eye.

The EEG was collected by BioSemi ActiView, the EEG was digitized at a rate of 256 Hz. Before segmentation, a high pass filter with a low cut-off of 0.1 Hz was applied to the EEG data. A high cut-off of 30 Hz was used for the low pass filter. The EEG was then segmented in epochs from -200 ms to + 1.000 ms relative to the stimulus onset. The pre-stimulus time of 200 ms served as the baseline. The EEG signal was corrected for ocular artifacts, using the Gratton and Coles (1989) correction. Finally, trials with an amplitude voltage over 50 μV or a change in

amplitude between adjacent samples of more than 200 µV were rejected. This led to 2.7% of the data to be rejected (*SD* = 5.7%, range: 0–26%). Rejected trials were equally distributed across conditions ($F < 1$).

Repeated measures analysis of variance (ANOVAs) with the factors condition (congruent or incongruent) and quadrant (left anterior: Fp1, AF3, F3, F7, FC1, FC5; right anterior: Fp2, AF4, F4, F8, FC2, FC6; left posterior: CP1, CP5, P3, P7, PO3, O1; right posterior: CP2, CP6, P4, P8, PO4, O2) were conducted for three peaks: N1, P2 and N3 - both the amplitude and the latency were analyzed. A separate ANOVA was conducted for the midline electrodes Fz, Cz, Pz and Oz (following the method used by Özyürek et al., 2007; Willems et al., 2008).

Similarly, RM-ANOVAs were conducted for four time windows each of 100 ms; the first three around the three peaks and the latter was included to test for an extended N400 effect. Thus, the first time window was around the first negative peak, between 100 and 200 ms. The second was the P2 time window, from 200 to 300 ms. The third window followed the second negative peak, from 300 to 400 ms. The final time window was from 400 to 500 ms to test whether the negative waveform extended further. Greenhouse-Geisser correction for violation of sphericity was applied when appropriate.

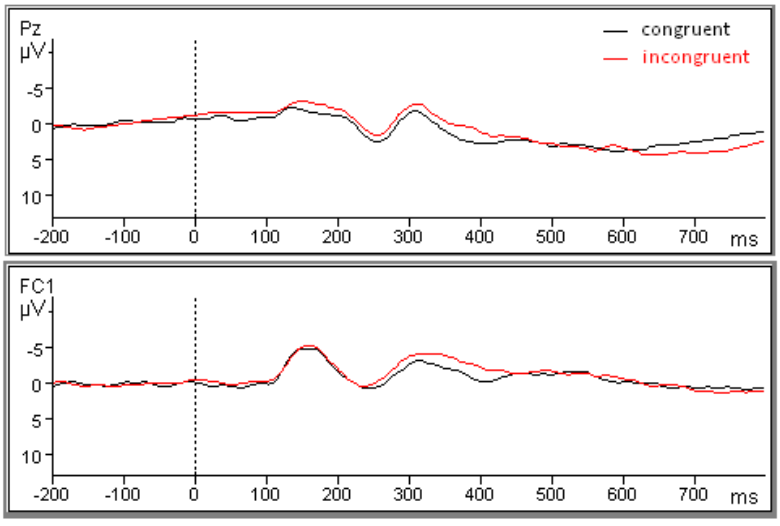

Figure 3. Grand average event-related potentials for the two conditions for the midline electrode Pz and the left anterior electrode FC1.

3. Results

The averaged ERPs time-locked to presentation of congruous and incongruous objects are shown in Figure 5. The waveforms revealed three peaks, an N1, a P2 and an N3. Waveforms for the congruous and incongruous condition were equivalent from stimulus onset, but seemed to diverge at around 120 ms at which time the waveform for the incongruent objects became more negative-going before returning to the same value as the congruous object at around 200 ms, for some electrodes. The waveform for the incongruous object again diverged from the congruous object starting at approximately 300 ms lasting till 500 ms.

None of the analyses for the peak amplitude and latency reached significance. For the peak amplitude and latency analyses, see Appendix II. Here only the time window analyses will be reported.

3.1 Time window 100-200 ms

The main effect of condition was not significant for both the quadrant analysis ($F(1,23) = 1.24$, $p = .277$) and the midline ANOVA ($F(1,23) = 1.08$, $p = .309$). The interaction between quadrant and condition did not show an effect either ($F < 1$).

3.2 Time window 200-300 ms

The main effect of condition was not significant for either the quadrant analysis ($F(1,23) = 1.40$, $p = .248$) or the midline electrodes ($F(1,23) = 1.16$, $p = .293$). The interaction between quadrant and condition did not show an effect either ($F(3,69) = 1.50$, $p = .237$).

3.3 Time window 300 - 400 ms

The main effect of condition was significant for both the quadrants ($F(1,23) = 4.50$, $p = .045$) and the midline electrodes ($F(1,23) = 4.82$, $p = .038$). There is a more negative-going waveform for the incongruent condition compared to the congruent condition. For the exact values see Table 1.

The interaction effect between quadrant and condition was not significant ($F < 1$) indicating a widespread effect over all electrodes. See Figure 4 for a map showing the difference in voltage for the incongruent objects compared to the congruent words for this time window as a result from the difference waves. The largest effect seemed to be left anterior, the widespread spatial distribution is clearly evident.

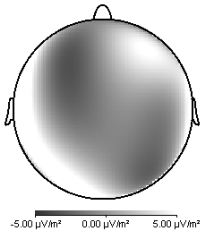

Figure 4. CSD map congruency effect

3.4 Time window 400 - 500 ms

The main effect of condition was not significant for either the quadrant analysis or the midline electrodes; the interaction between quadrant and condition did not show an effect either (*F < 1).*

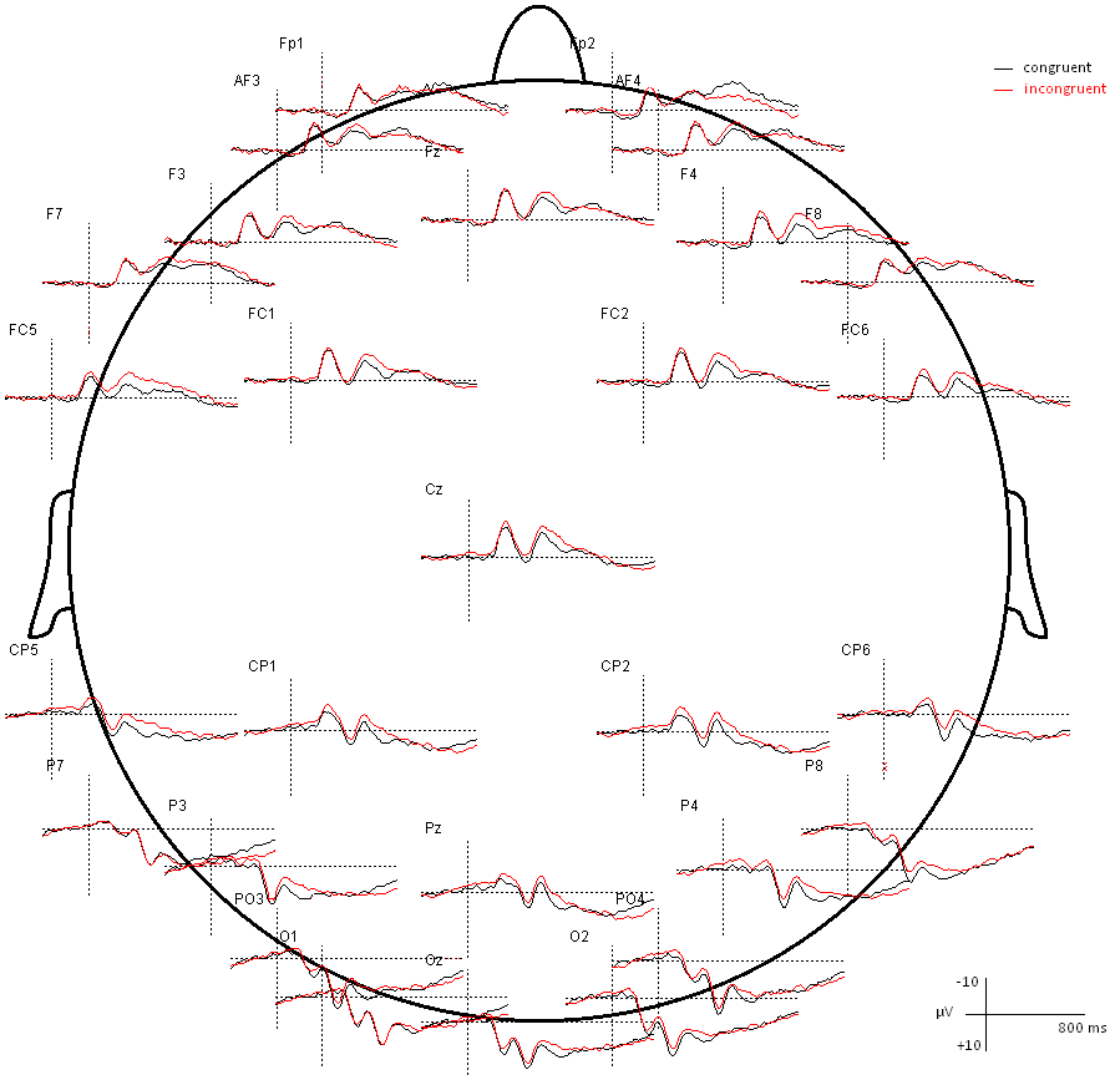

Figure 5. Grand average event-related potentials for the two conditions for all 28 electrodes included in the analyses.

N4 analyses	Condition	Mean Amplitude (μV)	SE
Quadrant	Congruent	.75	.53
	Incongruent	-.49	.77
Midline	Congruent	.01	.70
	Incongruent	-1.38	.83

Table 1. Mean amplitude and standard errors in μV for both the quadrant and midline analyses in the 300 to 400 ms time window, separated for the congruent and incongruent condition.

4. Discussion

The question we set out to investigate was whether an empty place can be assigned a meaning: we wanted to know whether adults understand that certain objects have certain places. In other words, is an empty place meaningful in terms of the object which was previously there? When an object has been placed and then removed, will it be understood that when pointed to the location it is actually the object that is being referred to? This study approached the question by presenting participants with videos where an actor placed two objects at different locations after which the objects disappeared and the actor pointed to one of the locations.

Electrophysiological evidence for the processing of empty places in terms of absent objects was collected with the ERP method widely employed to examine semantic processing in adults. The question was whether there was a difference visible in the EEG signal when presented with the incongruent object (the object that belonged to the non-pointed-to location) compared to the congruent object (the object that was previously placed at the now pointed-to location). If the empty place is meaningful in respect to what was previously there, presentation of an incongruous object should result in increased negativity. This effect could possibly be akin to the N400 effect found for semantic incongruences in language. Thus we set out to extend what is known so far about meaning processing to pointing comprehension.

The results indicate there is indeed a difference between processing of incongruous objects compared to congruous objects. Unlike in most studies of semantic processing of linguistic material, the negative waveform did not have its maximum at around 400 ms but had an earlier peak at 340 ms. One could argue that perhaps we are looking at an N300 effect instead of an N400 effect. The N300 effect

has been found in semantic processing studies using visual stimuli, such as in the study by West and Holcomb (2002) and Sitnikova et al. (2008). In the study by West and Holcomb picture stories were presented where the final picture could be congruous or incongruous with the story, with the latter producing a more negative waveform already starting from 300 ms lasting till 600 ms after picture onset. The authors argue there are two distinct processes taking place between 300 and 400 ms and 400 and 600 ms. The first congruency effect peaked at around 325 ms evident for central and frontal midline electrodes. The second congruency effect had its peak at 500 ms and showed a more widespread spatial distribution - albeit with an anterior focus. The different scalp distributions suggest different underlying neural sources. The authors suggest that the first negative component represents a strictly pictorial effect that activates image-based representations while the second negativity reflects the activation of an amodal system where the image based representation is integrated with the conceptual representation into a context. The N300 reflects a non-verbal semantic mechanism whereas the N400 reflects a semantic process accessed by both verbal and non-verbal stimuli.

Similarly, Sitnikova and colleagues argue for the same distinct semantic processes for real-life events. The first negativity they detect is between 150 and 250 ms with a frontal and central distribution whereas the negative component between 250 and 600 ms has a more widespread activation maximal over anterior and central regions. The authors argue that these negativities reflect the N300 and N400 and thus mimic the results found by West and Holcomb, even though the negative components have an earlier onset. The authors argue that the early start is due to the fact there is a drastic change in the visual information from the context to the final scene. They follow West and Holcomb's interpretation that the first negativity reflects the process of visual images accessing their corresponding representations in semantic memory whereas the later negativity represents the semantic integration of these representations in the previous context.

No matter whether our negativity between 300 and 400 ms should be classified as an N300 or N400, based on the interpretation of both these components, the negativity reflects semantic processing of the point to the empty location. In accordance with the previous findings one could argue that the waveform is indeed more like the N400 than N300 as the widespread activity of the negativity effect found for the incongruent objects compared to the congruent objects is more similar to

the widespread activity for the N400 effect found by the previous studies using visual stimuli than to the N300 effect. The widespread activity had its maximum for the left anterior site, showing the frontal activity as in the other studies using visual stimuli as compared to the original centro-parietal activity found for linguistic stimuli.

The absence of the N300 is surprising, but it is not the first study using visual stimuli that does not find this early negativity. Willems and colleagues did not find a separate N300 effect either. Participants were presented with a spoken sentence where a critical word was either visually presented with a matching picture or a mismatch. This resulted in a negative waveform already starting from 225 ms until 550 ms with a widespread distribution. The authors found no interactions between quadrant and condition, just like the present study. They argue that the absence of the N300 is due to the fact that the picture had to be integrated in a sentence context. Nigam et al. also studied picture integration in a sentence context and failed to find an N300 effect. This explanation does not hold for the present study. One possible explanation could be that in the present study it is not necessary to activate the image based representations as in the video clip there are only two objects introduced and these two representations could easily be maintained throughout the duration of the entire trial. Therefore the only process that needs to take place at the moment the picture of one of these objects is presented is the integration of the representation in the previous context.

We did not find a prolonged effect of the N400. This prolongation has been found for studies using visual stimuli in comparison to experiments only containing linguistic material. It has been reasoned that more complex stimuli produce more long-lasting effects. The increased duration might be due to an increase in processing load to integrate the object representation in the previous context. Our results do not indicate a prolonged N400 effect suggesting our stimuli were not as complex as those used in previous studies using visual stimuli. Processing costs for the present experiment may have been relatively low, as participants only had to integrate objects they had just seen.

Regardless of what exactly corresponds to the present negativity effect - an N300 or an N400 effect - it demonstrates that congruent objects are indeed processed differently from incongruent objects. By using established paradigms that have examined semantic processing, we have tried to shed some light on the comprehension of communication without any language. Placement is used to create

the context in the experiment. Following Clark (2003), placement is thought to be a communicative act that exploits a pre-existing site and connects the object to it. The point that followed the placement scene then directed the participant's attention to the index site. The placement and pointing in this experiment seem to be more than part of the attentional system and can create symbolic meaning, as the results indicate that even in absence of the object, pointing to such an indexing site activates the object representation. Empty places can thus receive meaning in respect to what these indexing sites were connected to previously.

The question we would like to answer in a follow-up study is whether it is the identical object that is being represented or whether it is the category of the object that is activated. If the effect is similar for a different exemplar of that object it would provide evidence for activation of the concept of the object. Consider the example that started this paper of the child that learned to take off his shoes when entering the house. When the mother points to an empty space next to the door on the floor, is it understood by the child that he needs to take off his shoes, no matter which pair he is wearing? Has the place been assigned the meaning of ‘designated location for all types of pairs of shoes’? Whether this generalized meaning is possible remains to be seen; the present study has been the first step in answering that question.

5. Conclusion

Can an empty place be meaningful? We aimed to answer this question by investigating whether an empty place is processed in terms of what was previously held in that location. While recording EEG, participants saw videos of an actor placing two objects after which the objects were removed and the actor pointed to one of the now empty locations. We found an increased negativity for incongruent objects compared to congruent objects, supporting the idea that adults do indeed process empty places.

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Appendix I - Object List

Scene	Room	Object Left	Object Right	Placed First
1	kitchen	frying pan	rice	right
2	kitchen	potholder	coaster	left
3	kitchen	pan	ladle	right
4	kitchen	colander	pasta	left
5	kitchen	rinsing tub	dish towel	right
6	kitchen	cake tin	grater	left
7	kitchen	egg carton	mixer	right
8	kitchen	drink glass	ice cube tray	left
9	kitchen	pasta	oven dish	right
10	kitchen	cutting board	potato masher	left
11	kitchen	teabox	cornflakes	right
12	kitchen	sponge	detergent	left
13	kitchen	rolling pin	blender	right
14	kitchen	dishcloth	dishwashing brush	left
15	kitchen	kitchen paper	cooker	right
16	kitchen	potatoes	apples	left
17	bathroom	razor	blowdryer	right
18	bathroom	toiletbag	washcloth	left
19	bathroom	hairbrush	deodorant	right
20	bathroom	straightening iron	toothpaste	left
21	bathroom	makeup brush	mascara	right
22	bathroom	glasses	toothbrush	left
23	bathroom	necklace	nailpolish	right
24	bathroom	sponge	showerbrush	left
25	bathroom	toilet roll	toilet cleaner	right
26	bathroom	scale	slippers	left
27	bathroom	trash can	liquid soap	right
28	office	tape	holepuncher	right
29	office	ordner	marker	left
30	office	penholder	letter tray	right
31	office	mouse	notebook	left
32	office	cd	headphones	right
33	office	typpex	glue	left
34	office	scissors	stapler	right
35	office	pencase	blocnote	left
36	office	envelopes	pens	right
37	office	laptop	phone	left
38	dining room	bread basket	placemat	left
39	dining room	cookies	drinkcarton	right
40	dining room	teapot	etagere	left
41	dining room	salt and pepper	cutlery	right
42	dining room	bowl	plate	left
43	dining room	carafe	wine	right
44	dining room	vase	candlestick	left
45	dining room	fruitbowl	napkins	right
46	tools	wrench	filler	left
47	tools	ruler	saw	right
48	tools	bike lights	bike pump	left
49	tools	hammer	screwdriver	right
50	tools	flashlight	ducktape	left
51	tools	pliers	screws	right

52	tools	paint	spatula	left
53	tools	paintbrush	drill	right
54	hallway	shoes	umbrella	left
55	hallway	keys	mp3 player	right
56	hallway	handbag	scarf	left
57	hallway	gloves	hat	right
58	hallway	umbrella	wallet	left
59	living room	remote control	dvd	right
60	living room	candle	bag of crisps	left
61	living room	magazine	table lamp	right
62	living room	newspaper	cup of coffee	left
63	living room	stool	plant	right
64	party	garland	straws	left
65	party	plastic cups	cake	right
66	party	cuddly toy	christmas tree	left
67	party	party hat	present	right
68	cleaning	cleaning gloves	bucket	left
69	cleaning	mop	cleanser	right
70	cleaning	feather duster	broom	left
71	sport	dustpan and brush	squeegee	right
72	sport	tennis balls	sportsdrink	left
73	sport	tennis shoes	racket	right
74	garden	wateringcan	pruning shears	left
75	garden	shovel	rake	right
76	garden	flower pot	gardening gloves	left
77	bedroom	alarm clock	mirror	right
78	bedroom	photo frame	book	left
79	laundry	flat-iron	washing powder	right
80	laundry	coat-hanger	clothes-pins	left

Appendix II - Analyses peak amplitude and peak latency

N1

The first negative peak, on average at 174 ms after stimulus onset with an amplitude of -4.0 μV, did not significantly differ for the two conditions congruent and incongruent for neither latency nor amplitude ($F < 1$). An interaction effect between condition and quadrant was also absent ($F < 1$).

P2

The positive peak had an average latency of 250 ms and 3.5 μV amplitude. There was no main effect of condition, neither for latency ($F < 1$) nor for amplitude (quadrant: $F(1,23) = 1.84$, $p = .188$; mid: $F(1,23) = 1.52$, $p = .231$). The interaction between condition and quadrant was not significant either (latency: $F(3,69) = 1.34$, $p = .258$; amplitude: $F(3,69) = 2.00$, $p = .154$).

N3

The second negative peak reaches it maximum on average at 339 ms with a negative amplitude of -2.8 μV. Latency analyses showed no main effect for condition nor for the interaction between condition and location (all $F < 1$). For the peak amplitude, the main effect of condition almost reached significance for the quadrant analysis: $F(1,23) = 3.96$, $p = .059$. The midline electrodes showed a similar effect: $F(1,23) = 4.16$, $p = .053$. The incongruent condition has a more negative peak amplitude than the congruent condition. The interaction effect between condition and quadrant was not significant ($F < 1$).