The Effects of Creating a Cooperative or Competitive Environment on P600

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Abstract

A study conducted by Rueschemeyer et al. (2015) established a social N400 effect. We attempted to replicate and extend these results by dividing participants into a competitive and a cooperative group. We found that participants did not experience an N400, but instead had a strong P600 response to semantically plausible and implausible sentences. Participants in the cooperative group experience a higher P600 in response to plausible sentences than participants in the competitive group. Our results suggest that the meaning of the P600 needs to be reevaluated beyond our current understanding of it as a marker for syntactic accuracy.

The Effects of Creating a Cooperative or Competitive Environment on Social Sentence Comprehension

In the mid 1950s scientists began using electrodes attached to the scalp in order to measure electrical activity in the brain. Neuronal electrical activity is characterized by Event Related Potentials (ERPs), waveforms representing neural activity associated with cognitive processes (both simple and complex). In this way, scientists found a new way to view the brain from the outside (Kutas & Federmeier 2011).

ERP data has been extensively used in the world of language processing. Specifically, two different waveforms are highly studied: N400 and P600. The N400 waveform is traditionally associated with semantic errors (Kutas & Federmeier 2011), while the P600 is traditionally associated with syntactic errors (Osterhoud & Holcomb 1992; Hagoort, Brown, & Groothusen 1993; Friederici, Hahne, & Mecklinger 1996).

Researchers Rueschemeyer et al. (2015) utilized ERP data to conduct a study on social interactions from a neurobiological and behavioral standpoint. They were specifically looking at the N400 waveform associated with semantic anomalies. Rueschemeyer et al. presented three different trials to participants: plausible, implausible, and contextual trials. In the plausible trial participants received a sentence that was plausible to both them and what they believed was another participant in the room (the second person was actually a member of the research team posing as a confederate). In the implausible trial participants received a sentence that was implausible to both them and the confederate. In the contextual trial participants received a sentence that was plausible to them, but not to the confederate.

Rueschemeyer et al. measured N400 at the final word of each sentence, and found that the N400 effect was greater in both the implausible and contextual conditions than the plausible condition. When Rueschemeyer et al. presented both the plausible and contextual conditions to one participant with no other participant in the room (the contextual condition presented additional information to the participant without the expectation that they were receiving more information than anybody else) Rueschemeyer et al. found that the resulting N400 effects were equal.

Rueschemeyer et al. hypothesize the existence of a social N400 in order to justify these results. This explains why participants reacted more aversely to contextual information than plausible information, even though both sentences were equally plausible to them. Participants adopted the point of view of the confederate and reacted to stimuli partially from the confederate’s point of view.

We wanted to further study the possibility of a social N400, and did so by drawing inspiration from Rueschemeyer et al. (2015), as well as Lanzetta and Englis (1989). Researchers Lanzetta and Englis (1989) observed people in a complex social interaction in which they created the expectation of cooperation or competition. They found a direct correlation between the expected relationship, and participants’ physiological reactions to coactors’ emotional expressions; in other words, the high-level social expectations of the subject influenced their autonomic low-level reactions. This suggests the direct integration of social situations into the perception and action systems of the body.

We combined the purposes of Rueschemeyer et al. (2015) and Lanzetta & Englis (1989) to determine the effect of a cooperative or competitive scenario on subjects’ ERP and behavioral reactions. We created a cooperative and a creative scenario between one participant and one confederate through the use of a game. We then tested participants’ comprehension of plausible, implausible, and contextual sentences as well as their ERP data. We hypothesized that the cooperative or competitive perspective of the participant would influence their accuracy on these questions, as well as the presence or absence of an N400 peak.

**Method**

**Participants**

26 participants were recruited from the student body of Vassar College. Out of those 26 students, 5 were excluded due to technical difficulties in data collection. Of the remaining 21, 9 were excluded due to excess ocular artifacts in their EEG data. Therefore, 12 participants worth of EEG data was recorded and utilized in statistical analysis.

**Stimuli and Materials**

This study utilized a game of JengaTM. This is a game consisting of 54 blocks arranged in layers of three blocks, with each layer facing a different direction (figure 1).

96 stimulus sentences (s) and 96 non-stimulus sentences (ns) were adapted from the sentences of Rueschemeyer et al. (2015). The stimulus sentences were encoded into visual sentences through the use of E-Prime software, while the non-stimulus sentences were encoded as auditory sentences used through the E-Prime software. The stimulus sentences consisted of three different types of sentences: Plausible, Implausible, and Contextual sentences. Plausible sentences were plausible without the additional information provided by the non-stimulus sentence. For example, a plausible non-stimulus and stimulus sentence pairing would be, “The air traffic controller was at the airport (ns). The air traffic control helped land an airplane (s)”. Implausible sentences were implausible even with the additional information provided auditorily to the subject. For example, an implausible non-stimulus and stimulus sentence pairing would be, “the bears were catching salmon (ns). The smallest bear started flying (s)”. Contextual sentences were plausible only with the additional information provided by the non-stimulus sentences. For example, a contextual non-stimulus and stimulus sentence pairing would be, “In the game, the horse was a banker (ns). The horse was given money (s)”. Each stimulus sentence concluded with a target word, which is when we recorded ERP data. The same target word was used three times, once for each type of sentence. The stimulus sentence was split into three parts, and each of the three parts of the sentence was presented for 1000 ms. The non-stimulus sentences were played for 5500 ms and were recorded by a member of the research team not involved with the experiment implementation. These sentences were presented and tracked using the software E-prime.

**Procedure**

Subjects entered the testing room where the confederate and experimenter were already seated. Subjects were told that the confederate was their fellow subject and had arrived early and already filled out a consent form. Subjects then completed a consent form. Confederates were randomly designated as competitive or cooperative before the experiment began, which determined the following procedures. In the cooperative setting participants were seated next to each other at a table in front of a tower of JengaTM blocks. They were informed that they would be working together as a team in a game of JengaTM, having five minutes to pull out as many blocks as possible and place them on top of the tower. During the course of the game a five-minute timer was projected in front of both participants. The experimenter counted the blocks pulled out, and they received a prize of candy if they pulled out 15 blocks; if they pulled out 25 blocks the prize was doubled. An additional JengaTM tower was provided if the first one fell before the five minutes were up.

In the competitive condition the subject was placed across the table from the confederate, each person had their own Jengatm tower. They had five minutes to pull out as many tiles as possible and place them into a bin provided by the experimenter. There was an additional tower provided for participants to use in case their first tower fell before the five minutes were completed. Once time was completed the experimenter counted the blocks removed. The winner received a candy prize.

After the JengaTM game both the participant and the confederate were taken into another room and fitted with a HydroCel 128-channel, Geodesic Sensor Net to record their ERP data. Subsequently. the participant was moved into another room and seated in front of a computer screen. They were told that they would be receiving a sentence comprehension task. A stimulus sentence was displayed on the screen for both the confederate and the subject to see. This sentence was displayed in three parts, with the final part being the critical word of the sentence. Additionally, subjects were told that one of them had been randomly chosen to wear headphones to receive additional information. In reality, the subject had previously been chosen to always wear the headphones. Before each sentence was shown to both the subject and confederate on the screen, the subject heard the non-stimulus sentence

After each sentence provided on the screen, the subject was asked (via a question on the screen) whether they themselves found the sentence plausible or not, given the context. Subjects were instructed to press y for yes, or n for no on the keyboard in front of them with their dominant hand.

The experimenter then stepped out of the room, supposedly in order to explain to the other subject their task. After an appropriate amount of time, the experimenter reentered the room with the confederate and placed the confederate next to the subject in front of the screen. The subjects were instructed to press the space bar in order to begin the test.

Participants were presented with six practice trials, two of each type of sentence. They were then provided with 54 experimental trials, with equal numbers of Plausible, Implausible, and Contextual sentences. The order of these sentences was counterbalanced, ensuring that two sentences of the same type were never presented consecutively.

After the sentence comprehension task was completed the subject was given a survey to complete about the cooperative and competitive aspects of the task (figure 2). They were told that the confederate was completing the same survey in the other room. Finally, subjects were debriefed and released.

**Electrophysiological Recording**

We utilized a HydroCel 128-channel, Geodesic Sensor Net in order to record EEG data in participants. We collected ERP data at a sampling rate of 1000 samples/s. Impedances for the electrodes to be used for analysis were kept below 50 kΩ initially. EEG data was processed offline by applying a high pass filter at 0.1 Hz and a low pass filter at 30 Hz. Data were segmented into 1100 ms segments starting 100 ms prior to the sentence final word and ending 1000 ms after sentence final word onset. Any segments containing artifacts or eye blinks were excluded from further analyses, as were any segments that had more than 10 bad channels. Data in bad channels was replaced using spherical interpolation. EEG data were re-referenced using an average reference and were baseline corrected to the 100 ms prior to stimulus onset.

The minimum number of good segments (after they were already screened for accuracy) per trial type per participant was 14. Based on this criterion, 12/21 participants’ EE data were available for subsequent analysis. Based on Rueschemeyer et al. (2015) and established findings, the N400 time window was defined as 350-550 msec following target word onset. Mean amplitude was determined by averaging over the 19 electrodes that constitute the centroparietal region where N400 effects are typically found.

**Results**

**Survey data**

Survey data was analyzed with a Mann Whitney test. There is a direct correlation between the rating of cooperative or competitive by the subject and the actual experimental category the subject was placed into (*MdnComp* = 2.5, *MdnCoop* = 10)*, U* = 32 *, p* = 0.026). No other results were significant (*p* > 0.05). Ratings of motivation, familiarity with JengaTM and skill of the other player were the same across both experimental conditions.

**Accuracy data**

Accuracy of participants’ responses was measured. Where relevant, the Greenhouse-Geisser p values are reported. A two way ANOVA was conductive between trial type (plausible/implausible/contextual), and group (cooperative/competitive). There was no effect of trial type (comp/coop) (F(2,20) = 2.192, p = .138). There was a marginally significant interaction between trial type and group (P, I, & C) (*F*(2,20) = 2.603; *p* = 0.099, *η2* = 0.180) (figure 3).

**ERP data**

A visual inspection of grand average waveforms showed an obvious lack of an N400 effect (figure 4). However, an obvious P600 effect occurred. Therefore, mean amplitudes in the standard P600 time window of 550 to 850 msec (Swaab et al. 2012) were analyzed. There was a main effect of trial type (*F*(2,20) = 11.592); *p* < .001; *η2* = 0.537; *MP* = 1.896, *SDP* = 1.501; *MI* = 3.783, *SDP* = 2.203; *MC* = 2.367, *SDC* = 1.581) and an interaction of trial type and group (*F*(2,20) = 3.564; *p* = 0.047; *η2* = 0.263) (figure 5).

**Discussion**

Our results revealed a marginally significant interaction of trial type and group for accuracy data as well as an interaction for P600 ERP data. We conducted a pairwise comparison for the interaction of trial type and group for the accuracy data and found that there is a statistically significant difference between the competitive and cooperative groups in the plausible trial type (*p* = 0.021), but not in the implausible and contextual trials (*p* > 0.05); in this comparison participants answered questions about a plausible sentence more accurately if they were in the cooperative group than the competitive group. Additionally, participants in the cooperative group answer plausible questions more accurately than implausible sentences (*p* = 0.021). Therefore, the difference between groups in the plausible condition seems to be due less to participants of the competitive condition being less accurate, and more due to members of the cooperative condition being more accurate in answering questions about plausible sentences. We also conducted a pairwise comparison of the P600 interaction and found that P600 amplitudes in response to plausible sentences were significantly greater in the cooperative group than in the competitive group. Therefore, we have to conclude that there is a correlation between an increase in P600 amplitude and an increase in accuracy.

Interestingly, our P600 results correlate to results of a study conducted by Vissers, Chwilla, Egger, and Chwilla (2013). Vissers et al. (2013) found that participants in a happy mood condition expressed a P600 effect but participants in a sad mood condition did not. If we assume that members of our cooperative group are comparable to members in the happy mood condition of Vissers et al. (2013) then our results demonstrating that members of the cooperative group showed a higher P600 peak than members of the competitive group correlate with the results of Vissers et al. (2013). Obviously, happy mood is directly correlated with an increased ability to perceive the linguistic intricacies that cause a P600. This could be the cause of the additional increase in accuracy in participants in the cooperative group when answering questions about a plausible sentence as compared to participants in the competitive group. Because of the elevated mood of these participants, they were more able to perceive the linguistic intricacies of the sentence and therefore more able to accurately answer the question about plausibility. However, because the plausible sentences are both semantically and syntactically plausible, there should have been no P600 peak at all in response to the sentence. We therefore have to reevaluate our initial definition of the P600 as a response to syntactic error.

The lack of an N400 in our ERP results was at first very surprising. Our primary goal was to induce a social N400 effect (as found by Rueschemeyer et al. (2015)) as a reaction to semantically implausible sentences. Paradoxically, our results demonstrated a P600 effect, which is traditionally seen as a response to syntactic errors, not semantic errors (Swaab et al. 2012). However, in recent years it has become clear that the P600 is involved in much more than simple syntactic analysis. ERP research has uncovered a Semantic Illusion Effect (SIE); this occurs when a semantically anomalous, but syntactically well-formed sentence elicits a P600 effect instead of an N400 effect (Brouwer, Fitz, & Hoeks 2012).

Researchers Kuperberg, Sitnikova, Caplan. and Holcomb (2003) conducted a study in order to further research the SIE. They presented the hypothesis that the SIE occurs because of semantic attraction. When there is a semantic attraction between words the brain does not believe that the semantics of the word can be incorrect; therefore, it interprets a grammatically correct sentence as being ungrammatical. In other words, the inaccuracy cannot be due to the semantics of the sentence, therefore it must be the syntax; this reinterpretation of the sentence produces a P600 reaction to a syntactically correct and semantically incorrect sentence. They found that sentences containing thematic role animacy violations produced a P600 effect. They explained that this effect occurred because the semantic attraction between the words caused a reevaluation of the initial understanding of the syntactic form of the sentence, and therefore produced a P600 peak. Their theory successfully held up against testing and could accurately explain the SIE. However, it is not the only theory in place that attempts to explain the SIE.

Brouwer et al. (2012) review five different models that attempt to explain this SIE. Each model adopts the hypothesis that there are multiple streams processing linguistic information, and that a disagreement in these streams produces a P600 effect. For example, the monitoring theory as proposed by van Herten, Kolk, and Chwilla, (2005) proposes two streams that control linguistic production and comprehension: one stream is syntax driven, while the other is semantics driven. The syntactic stream receives the linguistic information and reworks it into a syntactically correct representation of the input. The semantic stream receives the information and draws on world knowledge in order to create a semantically correct representation of the input. For example, if the system received the sentence “the fox hunted the poacher” the syntactic stream would recognize that the sentence is syntactically accurate and internally represent it in the same way that it was inputted, as “the fox hunted the poacher”.

However, the semantic stream would utilize world knowledge to comprehend that the sentence was not semantically accurate and internally represent the sentence in the most semantically accurate way, as “the poacher hunted the fox”. When there is a mismatch between the two streams (as with this example), this causes a reanalysis of the information and therefore an increase in P600 amplitude. An N400 is produced if both streams create internal representations of the sentence that are inaccurate. This system would explain the SIE; if the representation created by the syntax stream is inaccurate while the representation of the semantic stream is accurate (demonstrating syntactic plausibility and semantic implausibility of the sentence) the system increases the amplitude of the P600 in an effort to resolve the conflict between the two streams.

Interestingly, Brouwer et al. (2015) disagree with the assumption that linguistic processing is a multi-stream process. Instead of hypothesizing multiple streams to explain the anomalous P600 results of the SIE, they believe that we have to reinterpret the functions of N400 and P600. They believe that the N400 is in fact not only involved in semantic processing, but more importantly in memory retrieval. They hypothesize that the amplitude of N400 reflects the mental processes that accompany retrieval of lexical information from long-term memory.

More importantly, they believe that P600 is involved in the composition of mental representations. When comprehending linguistic input, we construct a mental representation of what is communication (MRC). Brouwer et al. (2015) hypothesize that P600 effects arise in the construction, revision, or updating of the MRC. As each word in an input sentence activates corresponding lexical information, that information is then integrated into the current mental representation. As each word undergoes integration the P600 component is evoked. If the current mental representation has to be changed in order to integrate the new lexical information, this corresponds with an integration difficulty and therefore an increase in P600 amplitude.

Under the single-stream model of Brouwer et al. (2015), there is no such thing as the semantic illusion effect. Instead, participants simply have difficulty integrating new information into their mental representation of the situation. Apparently, this is what occurred in our current study. A possible hypothesis is that in our experimental setting participants created a mental representation of a world in which most things do not make sense. Two-thirds of the information presented to participants was either completely or partially incorrect; although contextual sentences were technically plausible, the non-stimulus sentences preceding them put them into the context of a world in which implausibility is acceptable (for example, a dream world). Therefore, the minority information that participants received was actually plausible. It is possible that participants created a mental representation based on this in which plausible sentences were actually anomalous. This could explain the P600 reactions to these sentences in the cooperative condition—when participants attempted to integrate the plausible sentences into their mental representation they encountered difficulties that involved a reinterpretation of their mental representation.

The results of a study conducted by Davenport and Coulson (2011) also support this conclusion. Davenport and Coulson (2011) found that low cloze novel sentences (unpredictable sentences) elicited a higher P600 than high close conventional sentences (predictable sentences). If we continue with our theory that the world model of participants in our study is of an inaccurate world, the plausible sentences would be actually be unpredictable, while the implausible sentences would be predictable. Therefore, we would expect an increased P600 in plausible sentences over implausible sentences, which is what we find (Davenport & Coulson 2011).

Additionally, researchers van de Meerendonk, Kolk, Vissers, and Chwilla (2008) propose a theory of SIE that supports our conclusions. Van de Meerendonk et al. (2008) propose that a strong conflict between what is expected in the current context and what is perceived causes a reanalysis of the input to check for possible processing errors; this in turn is reflected in an increased amplitude of P600. They conducted a study in order to prove their theory and found that deeply implausible sentences trigger reanalysis, and thus an increase in the amplitude of the P600. Because plausible sentences in our situation are actually considered implausible, they support the conclusions of van de Meerendonk et al. (2008) through the increase in plausible P600s over implausible P600s for the cooperative group.

Although our results were highly unexpected, upon further interpretation they actually seem to correspond with recent findings in the world of ERP studies. The MRC of participants represented the experimental world as an implausible place in which plausible sentences are actually implausible. Additionally, as is demonstrated by Vissers et al. (2013) participants in the cooperative condition are more sensitive to P600 effects, which explains why they are the only group in which we see a difference in P600 amplitude and accuracy. The results of this study suggest an interpretation of P600 far beyond our current comprehension of ERP, and we therefore suggest further study on this subject.

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*figure 1***.** A JengaTM tower as it was presented to participants

1. In your own words, how would you describe how you felt during the experiment as a whole?
2. Would you describe the game of JengaTM as being cooperative or competitive?
3. Would you describe the sentence comprehension task as being cooperative or competitive?
4. How motivated were you during the experiment?
5. What is your previous familiarity with JengaTM?
6. How much worse or better did you feel the other player did in the game than you? A score of 3 signifying equally as good as you.

*figure 2***.** After participants completed the sentence task they were asked to complete a survey consisting of these questions. We found that answers to the first question (either competitive or cooperative) correlated directly with the intended group manipulation.

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*figure 3***.** Accuracy data expressed as mean percent correct for each question type answered by each group. In answering questions related to plausible sentences members of the cooperative group were more accurate than members of the competitive group. Members of the cooperative group were more accurate in answering questions related to plausible sentences than related to implausible sentences. (\* p < 0.05)

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*figure 4***.** A sample of waveform graphs collected from a variety of scalp sites from participants in both the cooperative (coop) and competitive (comp) groups. There is an evident lack of N400 peak and the presence of a P600 peak.

*figure 5***.** P600 amplitude data expressed in μV. Participants in the cooperative condition expressed a higher P600 amplitude in reaction to plausible sentences than participants in the competitive condition. Participants in the competitive condition expressed a lower P600 amplitude in reaction to plausible sentences than to implausible sentences (\* p < 0.05).