# Testing whether the social N400 effect indexes integration- or inhibition-processes

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## Experiment 1: Introduction

- The **social N400 effect** is an enhancement of the small amplitude of the N400 ERP that is evoked by semantically primed words. This enhancement occurs when participants know that a person next to them did *not* receive the semantic priming information [1,2,3].
- Prior social N400 studies interpret this enhancement as an increase in the **difficulty to integrate** semantic information in the social context of an uninformed person who cannot integrate this information due to the lack of priming [4,5,6].

- On the contrary, the **N400 inhibition hypothesis** stipulates that this enhancement indexes **inhibition** of what was primed so that the participant can also have a theory of what is in the mind of the confederate.
- According to this inhibition hypothesis, the social N400 effect should not occur in the case of indeterminacy, that is, when the system cannot determine what has to be inhibited, such as when both of the following conditions are met:
  1. the task does not constrain semantic processing, e.g., a simple memorization task
  2. this task is performed in an unknown social context, like in the presence of a stranger and when participants have no way to know for sure what information/stimulus this stranger is receiving.

- This prediction can be made not only for the N400, but also for the N300 elicited by pictures, which has been shown to index the inhibition of actions that are systematically activated by certain stimuli (e.g., faces, tools, etc.) [7,8,9].
- In contrast, according to the integration hypothesis, indeterminacy should increase integration difficulty and boost N400 amplitudes.

## Experiment 1: Methods

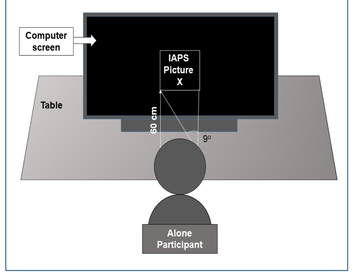
- 30 **Alone participants** (controls)
- 36 Participants in presence of their **friends**
- 29 Participants in presence of a **stranger**

**Stimuli:**
- 280 images (70 in each of the 4 blocks with a short break) from the International Affective Picture System (IAPS) [10] for the friends and strangers; and 400 for the alone
- *Partners had no way of seeing what was presented on their partner's half of the screen*. (The curtain remained closed during EEG recording. Participants were not allowed to talk to each other).

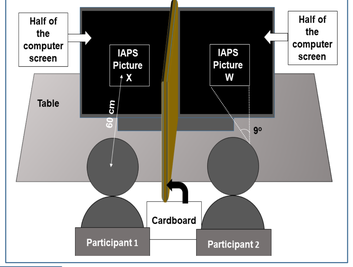
- **For pairs:** At every trial, on each half of the screen, one image was presented. These two images occurred simultaneously. They were randomly either identical or different.
- **For alone (controls):** They viewed a sequence of IAPS images by themselves.

**Task**: try to memorize the images.

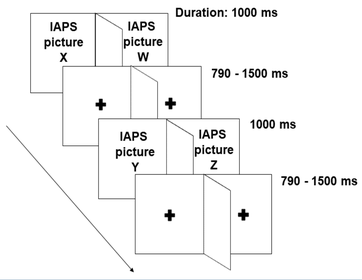
Experimental setup for alone participants




Experimental setup for friends and strangers




Stimulus presentation sequence




**EEG recordings & signal processing**

- Impedance < 5 kΩ.,
- EEG Amplification: 10,000 times.
- High- and low-pass filter half-amplitude cut-offs: .01 & 100 Hz
- 60-Hz electronic notch filter.
- Channels of trials with amplifier saturations or analog-to-digital clippings removed off-line by automatic rejection criteria:
- if clipping > 100 ms duration or if amplitude out of the ±100 µV range.

## Acknowledgment

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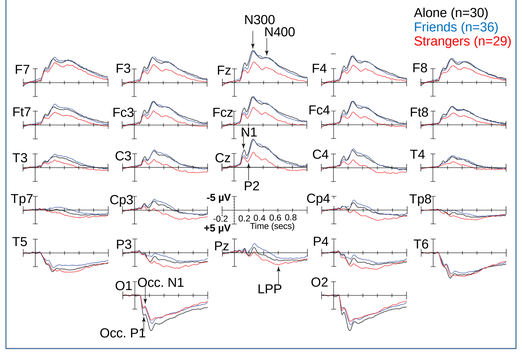
## Experiment 1: Results

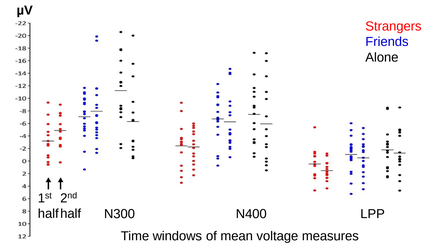
**Measures**
- ERP mean voltages within the time-windows of the N300 (200-350 ms), of the N400 (350-550 ms) and of the LPP (650-900 ms)

**Analyses**
- Repeated measures ANOVAs for each time-window, using social context (group) as a between-subjects factor.
- post-hoc (independent sample t-test) at Pz between alone and friends to find the source of interaction between group and electrodes at sagittal subset.

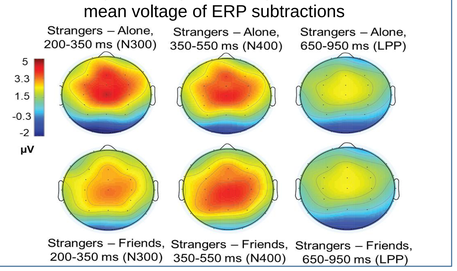
Grand average of ERPs elicited by the IAPS images for controls (alone) and participants with friends and strangers



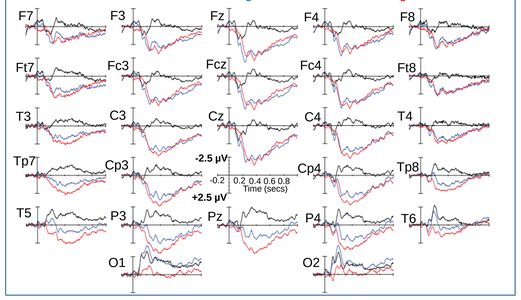

Replicability across 1st & 2nd half of the participants: Scatter plots of mean voltages of the 3 groups at Cz




Spline Interpolated maps of the mean voltage of ERP subtractions




Subtractions of the grand averages (GAs) of controls (alone) from GAs of participants with friends and strangers




ANOVA results for Friends vs. Strangers
(ns: not significant)

| Mean voltages within time window | Set of Electrodes (SoE) | Main effect of social contexts (groups) df | F | P | $\eta_p^2$ | social contexts × electrodes df | F | P | $\eta_p^2$ | ε | social contexts × electrodes × hemiscalp df | F | P | $\eta_p^2$ | ε |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N1 (110-160 ms) | Sagittal | 1,63 | 0.73 | ns | ns | 3,189 | 0.12 | ns | ns | 0.42 | – | – | – | – | – |
| | Parasagittal | 1,63 | 0.73 | ns | ns | 5,315 | 0.19 | ns | ns | 0.22 | 5,315 | 1.10 | ns | ns | 0.31 |
| | Lateral | 1,63 | 1.35 | ns | ns | 4,252 | 0.06 | ns | ns | 0.28 | 4,252 | 0.59 | ns | ns | 0.31 |
| N300 (200-350 ms) | Sagittal | 1,63 | 13.74 | $44\times10^{-5}$ | 0.18 | 3,189 | 1.5 | ns | ns | 0.46 | – | – | – | – | – |
| | Parasagittal | 1,63 | 12.3 | $1\times10^{-3}$ | 0.16 | 5,315 | 5.6 | $13\times10^{-3}$ | 0.08 | 0.26 | 5,315 | 0.32 | ns | ns | 0.34 |
| | Lateral | 1,63 | 12.45 | $1\times10^{-3}$ | 0.16 | 4,252 | 0.58 | ns | ns | 0.28 | 4,252 | 3.38 | $56\times10^{-3}$ | 0.05 | 0.34 |
| N400 (350-550 ms) | Sagittal | 1,63 | 20.34 | $29\times10^{-6}$ | 0.24 | 3,189 | 0.9 | ns | ns | 0.43 | – | – | – | – | – |
| | Parasagittal | 1,63 | 20.9 | $23\times10^{-6}$ | 0.24 | 5,315 | 3.94 | $33\times10^{-3}$ | 0.06 | 0.27 | 5,315 | 0.89 | ns | ns | 0.34 |
| | Lateral | 1,63 | 15.61 | $19\times10^{-5}$ | 0.19 | 4,252 | 0.15 | ns | ns | 0.28 | 4,252 | 3.38 | ns | ns | 0.34 |
| LPP (650-950 ms) | Sagittal | 1,63 | 8.34 | 0.005 | 0.12 | 3,189 | 0.34 | ns | ns | 0.45 | – | – | – | – | – |
| | Parasagittal | 1,63 | 6.46 | 0.014 | 0.09 | 5,315 | 3.04 | ns | ns | 0.28 | 5,315 | 1.16 | ns | ns | 0.42 |
| | Lateral | 1,63 | 3 | ns | ns | 4,252 | 0.21 | ns | ns | 0.3 | 4,252 | 2.84 | ns | ns | 0.36 |

ANOVA results for Alone vs. Strangers
(ns: not significant)

| Mean voltages within time window | Set of Electrodes (SoE) | Main effect of social contexts (groups) df | F | P | $\eta_p^2$ | social contexts × electrodes df | F | P | $\eta_p^2$ | ε |
|---|---|---|---|---|---|---|---|---|---|---|
| N1 (110-160 ms) | Sagittal | 1,57 | 7.39 | 0.009 | 0.12 | 3,171 | 4.76 | 0.022 | 0.07 | 0.44 |
| | Parasagittal | 1,57 | 2.43 | ns | ns | 5,285 | 7.51 | 0.006 | 0.12 | 0.22 |
| | Lateral | 1,57 | 4.94 | 0.003 | 0.08 | 4,228 | 2.6 | ns | ns | 0.27 |
| N300 (200-350 ms) | Sagittal | 1,57 | 11.4 | 0.001 | 0.17 | 3,171 | 11 | $21\times10^{-5}$ | 0.16 | 0.52 |
| | Parasagittal | 1,57 | 7.52 | 0.008 | 0.11 | 5,285 | 12.08 | $28\times10^{-5}$ | 0.175 | 0.26 |
| | Lateral | 1,57 | 8.68 | 0.005 | 0.13 | 4,228 | 3.5 | ns | ns | 0.28 |
| N400 (350-550 ms) | Sagittal | 1,57 | 12.36 | 0.001 | 0.17 | 3,171 | 5.75 | 0.009 | 0.09 | 0.51 |
| | Parasagittal | 1,57 | 11.16 | 0.001 | 0.16 | 5,285 | 9.45 | 0.001 | 0.14 | 0.27 |
| | Lateral | 1,57 | 10.69 | 0.002 | 0.16 | 4,228 | 1.28 | ns | ns | 0.28 |
| LPP (650-950 ms) | Sagittal | 1,57 | 10.84 | 0.002 | 0.16 | 3,171 | 4.64 | 0.021 | 0.075 | 0.5 |
| | Parasagittal | 1,57 | 6 | 0.017 | 0.095 | 5,285 | 8.72 | 0.002 | 0.13 | 0.28 |
| | Lateral | 1,57 | 3.88 | 0.054 | 0.06 | 4,228 | 1.69 | ns | ns | 0.3 |

ANOVA results for Alone vs. Friends
(ns: not significant)

| Mean voltages within time window | Set of Electrodes (SoE) | Main effect of social contexts (groups) df | F | P | $\eta_p^2$ | social contexts × electrodes df | F | P | $\eta_p^2$ | ε |
|---|---|---|---|---|---|---|---|---|---|---|
| N1 (110-160 ms) | Sagittal | 1,64 | 5.82 | 0.019 | 0.08 | 3,192 | 7.02 | 0.006 | 0.09 | 0.41 |
| | Parasagittal | 1,64 | 0.83 | ns | ns | 5,320 | 7.79 | ns | ns | 0.24 |
| | Lateral | 1,64 | 1.66 | ns | ns | 4,256 | 3.24 | ns | ns | 0.28 |
| N300 (200-350 ms) | Sagittal | 1,64 | 0.29 | ns | ns | 3,192 | 5.98 | 0.008 | 0.08 | 0.48 |
| | Parasagittal | 1,64 | 0.06 | ns | ns | 5,320 | 2.3 | ns | ns | 0.26 |
| | Lateral | 1,64 | 0.15 | ns | ns | 4,256 | 1.64 | ns | ns | 0.28 |
| N400 (350-550 ms) | Sagittal | 1,64 | 0.03 | ns | ns | 3,192 | 3.78 | 0.042 | 0.05 | 0.45 |
| | Parasagittal | 1,64 | 0.48 | ns | ns | 5,320 | 1.37 | ns | ns | 0.25 |
| | Lateral | 1,64 | 0.43 | ns | ns | 4,256 | 0.89 | ns | ns | 0.28 |
| LPP (650-950 ms) | Sagittal | 1,64 | 0.56 | ns | ns | 3,192 | 3.08 | ns | ns | 0.45 |
| | Parasagittal | 1,64 | 0.04 | ns | ns | 5,320 | 2.29 | ns | ns | 0.25 |
| | Lateral | 1,64 | 0.12 | ns | ns | 4,256 | 0.94 | ns | ns | 0.28 |

Post-hoc: independent sample t-test for Alone vs. Friends N400 at Pz

t(64)=1.78 and p=0.038

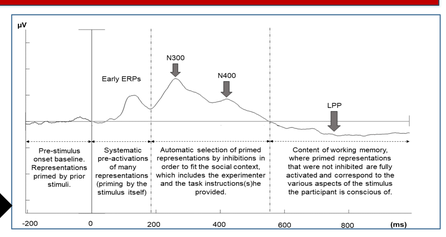
(not significant in N300 and LPP time-window)

## Experiment 1: Conclusions

1. Our results clearly favor the inhibition hypothesis against the integration hypothesis: smaller N300 and N400 ERPs in case of indeterminacy.

2. Significant difference between alone and strangers groups; and also between friends and stranger groups.

Schema of the theoretical framework including the N400 inhibition hypothesis




## Experiment 2: Introduction

Following the experiment 1 results, we aimed at testing whether inhibition differed within the friends group who 'felt together' (FT) in the presence of their friend and those who 'felt alone' (FA) despite that presence. We predicted that FT subgroup will have larger N300 and N400 i.e., more inhibition processes due to greater impact of social contexts on cognitive processes than in the FA subgroup.

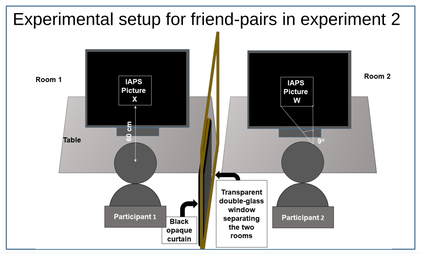
## Experiment 2: Methods

Pairs of closely related individuals (n=86)

**Stimuli**: same as in experiment 1
**Procedure: s**ame as in Experiment 1
**Instruction**: to maintain the feeling of the presence of their partner.

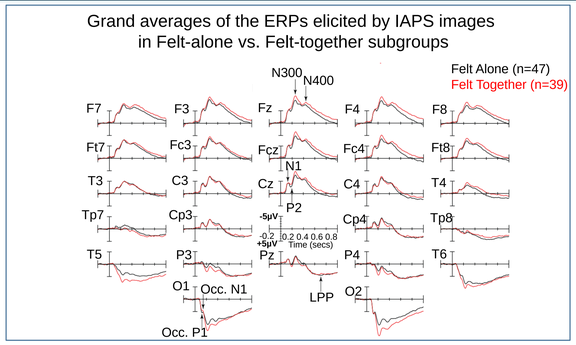
**Debriefing:** "did you feel together?" or not during most of the stimulus sequence, and then they were split into two subgroups: 1.Felt-alone (FA) , 2.Felt-together (FT)

Experimental setup for friend-pairs in experiment 2




## Experiment 2: Results

Grand averages of the ERPs elicited by IAPS images in Felt-alone vs. Felt-together subgroups




ANOVA results: Felt Alone vs. Felt Together
(ns: not significant)

| Mean voltages within time window | Set of Electrodes (SoE) | Interactions of social contexts with electrodes df | F | P | $\eta_p^2$ | ε | Interactions of social contexts with electrodes and hemiscalp df | F | P | $\eta_p^2$ | ε |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N300 (200-350 ms) | Sagittal | 3,252 | 4.97 | 0.018 | 0.05 | 0.44 | – | – | – | – | – |
| | Parasagittal | 5,420 | 4.74 | 0.020 | 0.05 | 0.28 | 5,420 | 2.88 | 0.034 | 0.03 | 0.62 |
| | Lateral | 4,336 | 7.4 | 0.003 | 0.08 | 0.36 | 4,336 | 0.66 | ns | ns | 0.45 |
| N400 (350-550 ms) | Sagittal | 3,252 | 2.02 | ns | ns | 0.49 | – | – | – | – | – |
| | Parasagittal | 5,415 | 2.03 | ns | ns | 0.29 | 5,415 | 2.32 | ns | ns | 0.29 |
| | Lateral | 4,336 | 4.06 | 0.033 | 0.04 | 0.35 | 4,336 | 1.36 | ns | ns | 0.35 |
| LPP (650-950 ms) | Sagittal | 3,252 | 2.34 | ns | ns | 0.49 | – | – | – | – | – |
| | Parasagittal | 5,420 | 2.77 | ns | ns | 0.3 | 5,420 | 2.71 | 0.039 | 0.03 | 0.66 |
| | Lateral | 4,336 | 3.49 | 0.05 | 0.04 | 0.34 | 4,336 | 0.82 | ns | ns | 0.52 |

Post-hoc at N300: Felt Alone vs. Felt Together

| Set of Electrodes (SoE) | Electrode | Felt Alone (FA) (Mean,SD) | Felt Together (FT) (Mean,SD) | F | df | t(df) | P | Effect size (Cohen's D) |
|---|---|---|---|---|---|---|---|---|
| Sagittal | Fz | (-7.99, 3.98) | (-9.48, 3.64) | 0.54 | 84 | 1.79 | 0.035 | 0.38 |
| Parasagittal-right hemiscalp | O2 | (9.04, 6.13) | (12.79, 7.95) | 1.78 | 84 | -2.48 | $75\times10^{-4}$ | -0.53 |
| Lateral-right hemiscalp | F8 | (-6.34, 3.03) | (-7.44, 3.66) | 0.5 | 84 | 1.76 | 0.042 | 0.33 |
| Lateral-left hemiscalp | Tp7 | (-1.19, 2.7) | (0.04, 3.65) | 3.41 | 84 | -1.8 | 0.038 | -0.38 |
| | T5 | (3.76, 4.23) | (6.56, 4.73) | 1.37 | 84 | -2.89 | $25\times10^{-4}$ | -0.62 |

Post-hoc at N400:Felt Alone vs. Felt Together

| Set of Electrodes (SoE) | Electrode | Felt Alone (FA) (Mean, SD) | Felt Together (FT) (Mean, SD) | F | df | t(df) | P | Effect size (Cohen's D) |
|---|---|---|---|---|---|---|---|---|
| Lateral-left hemiscalp | T5 | (4.39, 4.27) | (6.34, 4.5) | 1.19 | 84 | -2.06 | 0.022 | -0.44 |

Post-hoc at LPP: Felt Alone vs. Felt Together

| Set of Electrodes (SoE) | Electrode | Felt Alone (FA) (Mean, SD) | Felt Together (FT) (Mean, SD) | F | df | t(df) | P | Effect size (Cohen's D) |
|---|---|---|---|---|---|---|---|---|
| Parasagittal-right hemiscalp | F4 | (1.52, 4.16) | (-3.52, 3.34) | 2.04 | 84 | 2.42 | $85\times10^{-4}$ | 1.32 |
| Lateral- right hemiscalp | F8 | (-1.61, 2.94) | (-2.74, 3.38) | 0.22 | 84 | 1.66 | 0.05 | 0.35 |
| | Ft8 | (-0.39, 2.62) | (-1.52, 3.16) | 0.35 | 84 | 1.82 | 0.036 | 0.39 |
| | T4 | (1.66, 2.58) | (0.46, 2.25) | 0.005 | 84 | 2.26 | 0.013 | 0.49 |
| Lateral- left hemiscalp | T5 | (4.08, 3.19) | (5.28, 3.19) | 0 | 84 | -1.74 | 0.043 | -0.37 |

## Experiment 2: Conclusion

1. At central and anterior sites, the N300 and N400 ERPs are less positive in FT than in FA subgroup: more inhibitions of frontal-central representations (e.g., affordances of the IAPS images) in FT subgroup.
2. Larger positivities at the parietal and occipital-temporal sites in FT: no inhibitions of representations, e.g., visual features, position of objects in the IAPS images; more conscious of the stimuli.

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