Subitizing Small Quantities Recruits Semantic Knowledge About Numbers

Gillian S. Starkey, Christina Grow, Fiona Livelsberger, Daniela Bedon, & Jolie Price
Center for Psychology, Goucher College, Baltimore, Maryland

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Background

- **Subitizing** (the exact enumeration of small quantities[1]) is a foundational ability in the development of math cognition[2]. Most adults subitize with ease, and subitizing is often thought to be automatic[3], but the neural activity underlying this task is not well understood.
- Using **event-related potential (ERP)** measures, this preliminary study investigated the presence of the N400 component (a negative-going waveform occurring around 400ms) in subitizing in a small sample of adults.
- N400 indicates **recruitment of semantic knowledge** for words, phonemes[4], and tasks involving symbolic numbers[5], and has been demonstrated in prior studies of subitizing[7].
- We tested whether this neural activity reflects the recruitment of semantic numerical knowledge when subitizing during a visual matching task, or whether it is also present in non-numerical versions of the task.

Methods

Participants:
- 7 adults, aged 20-22 years, with normal vision

ERP visual matching task:
- 64-channel EEG nets (Electrical Geodesics, Inc.) recorded neural activity from the scalp; electrode impedances were kept under 50 kΩ
- Participants viewed arrays of green and red dots *(Fig. 2)*; red dots were the target dots.
  - Total number of red dots ranged from 0 to 6; **2, 3, and 4 dots** were the quantities of interest.
  - Target dots appeared either in left or right visual hemifield.
- **First half: "Side-Matching" (non-numerical) task.** Dot arrays were followed by a fixation cross, then a white arrow. Participants pressed "Yes" or "No" buttons to indicate whether the arrow matched the side where red dots appeared.
  - All participants reported that they did not think about the quantity of dots during the non-numerical task.
- **Second half: "Digit-Matching" (numerical) task**. Dot arrays were followed by a fixation cross, then a white digit. Participants pressed "Yes" or "No" buttons to indicate whether the digit matched the quantity of red dots.

Methods (continued)

Figure 1. A 64-channel Hydrocel sensor net (Electrical Geodesics, Inc.) used to record electrical activity from the scalp.
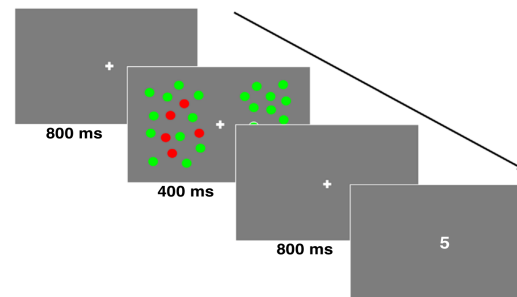

800 ms
400 ms
800 ms
5

Figure 2. ERP task procedure for the "Digit-Matching" (numerical) version. For the "Side-Matching" (non-numerical) version, participants saw a white arrow pointing right or left, rather than a digit.
(Figure adapted from Pagano, Lombardi, & Mazza, 2014)

Data Analysis

- EEG recordings were filtered to reduce electrical noise, and segmented around the presentation of the target stimuli (dot arrays). Segments contaminated with physical artifacts were removed. Recordings were averaged across target dot quantity and hemifield (contralateral vs. ipsilateral).
- **N400** was defined as the mean amplitude across **350-550ms** for **parietal** electrode groups.[4,5]
- Data for the non-numerical and numerical tasks were submitted separately to 3 (Numerosity: 2, 3, and 4) x 2 (Hemisphere: Contralateral and Ipsilateral) ANOVAs to identify main effects and interactions.

Results

Side-Matching (non-numerical) task:
- No significant main effects of Numerosity or Hemisphere
- No significant Numerosity*Hemisphere interaction
No N400 was detected during the non-numerical task.

Digit-Matching (numerical) task:
- Main effect of Numerosity, $F(2,12) = 3.94$, $p < .05$
- No significant main effect of Hemisphere or Numerosity*Hemisphere interaction
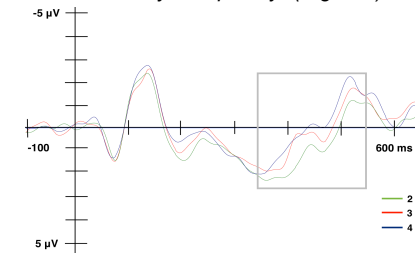*The N400 was detected during the numerical task, and amplitude was modulated by dot quantity (Figure 3).*

-5 µV
-100
5 µV
600 ms

Figure 3. Grand-averaged N400 waveforms elicited for 2, 3, and 4 dots. *(Figure adapted from Gyimesi, Young, & Starkey, 2018).*

2
3
4

Discussion

- An N400 was observed during a visual subitizing task, suggesting that adults access semantic knowledge of numbers even during basic enumeration of small quantities.
- N400 amplitude increased as dot quantity increased, suggesting greater cognitive effort for larger quantities.
- Critically, no N400 was observed during a similar but non-numerical task, suggesting that this recruitment of semantic knowledge may be specific to the numerical demands.
- This preliminary study is limited by a small sample size; it is possible that failure to detect an N400 in the non-numerical task is due to underpowered analyses.

References

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