



Hemispheric Differences in EEG Activity During Enumeration are Related to Subitizing Ability

Anna N. Young; John Gyimesi; Gillian S. Starkey
Center for Psychology, Goucher College, Baltimore, Maryland

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Background

- Humans have the ability to quickly and accurately enumerate (determine the quantity of) 1-3 or 4 objects¹; this skill is known as subitizing². The slope across reaction times for enumerating these quantities (a measure that controls for individual differences in processing time) is known as a person's subitizing fluency.
- Research with event-related potentials (ERPs, a type of EEG) has also shown that the "N2pc" component marks the attentional process of individuation^{3,4}, the identification of target objects among distractors (a key element of visual enumeration tasks).
 - The N2pc is calculated as the difference in amplitude between contralateral and ipsilateral hemispheres. This has been shown to be sensitive to the number of target items present in the visual field, but this sensitivity is limited to about 4 target items⁵.
- The current study is an extension of research by Pagano, Lombardi, and Mazza (2014)⁶.
 - Our findings corroborate results from previous enumeration studies suggesting that the N2pc component is present in enumeration tasks that require subitizing.^{3,4,5,6}
 - Furthermore, this study builds upon these findings to show that the N2pc component is related to behavioral measures of subitizing fluency.

Methods

Participants:

- 19 adults over the age of 18 (12 participants identified as female and the remaining 7 identified as male)
- Recruited through flyers posted around campus, and through word of mouth
- All participants completed the behavioral task and the ERP task

Task One (Behavioral):

- Arrays of 1-9 black dots appeared on a gray screen (Figure 1)
- Participants reported how many dots they saw, as quickly and as accurately as possible, by pressing the corresponding number on a standard number pad
- Numerosities were presented in random order
- Dot size and density were both systematically varied to control for non-numerical perceptual features



Figure 1. Sample stimuli from the behavioral task.

Methods (Cont.)

Task Two (EEG):

- Participants were fitted with a 64-electrode EEG net (Electrical Geodesics, Inc.), which non-invasively recorded neural activity
- Participants viewed arrays of 28 or 32 green and red dots (Figures 2 and 3)
- Target dots to enumerate were red; total number of target dots ranged from 0 to 6
 - 2, 3, and 4 dots were the numerosities of interest
 - Appeared either in left or right visual hemifield
 - 70 trials per numerosity per hemifield
- Arrays were followed by a fixation cross, then a white digit
- Participants pressed "Yes" or "No" buttons to indicate whether the digit matched the number of red dots
- Electrode impedances were kept under 50 kΩ

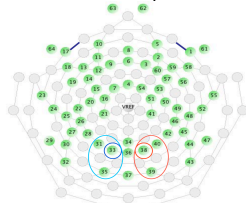


Figure 2. Parietal-occipital electrode groups used for analysis. Figure 4 presents data from 33 and 38.

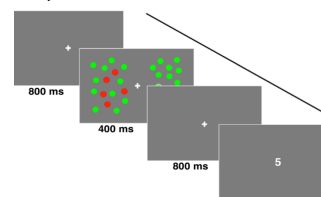


Figure 3. ERP task procedure with sample stimuli. (Adapted from Pagano, Lombardi, & Mazza, 2014)

Data Analysis

Subitizing Fluency for each participant:

- Slope across median reaction times for 1, 2, and 3 dots (correct responses only) for Task One
- Each participant was assigned to a **High** or **Low Subitizing Fluency** group based on a mean split (High Subitizing Fluency = flatter slope)

N2pc:

- EEG recordings were filtered to reduce electrical noise, and segments contaminated with physical artifacts were removed. Recordings were averaged across numerosity and hemifield.
- N2pc** was defined as the difference in mean amplitude between contralateral and ipsilateral waveforms measured at parietal-occipital electrode sites (Figures 2 and 4)
- Data were submitted to an ANOVA to investigate the effect of numerosity on the N2pc

Links between Subitizing Fluency and N2pc:

- The slope across the N2pc for 2, 3, and 4 dots was calculated (Figure 5)
- A t-test compared N2pc slopes between Low and High Subitizing Fluency groups

Results

- Main effect of Numerosity, $F(2, 36) = 4.00, p = .027$.
 - The N2pc increased in amplitude as numerosity increased (Figure 5)
- For the High Subitizing Fluency group, the slope across the N2pc for numerosities 2, 3, and 4 was steeper than for the Low Subitizing Fluency group, $t(17) = -2.38, p = 0.029$
 - A steeper N2pc slope suggests greater sensitivity to numerosity

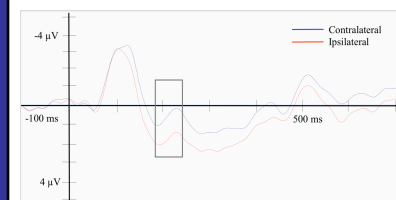


Figure 4. Grand-averaged waveforms for each hemisphere at numerosity 4; N2pc = difference in amplitude (contralateral minus ipsilateral)

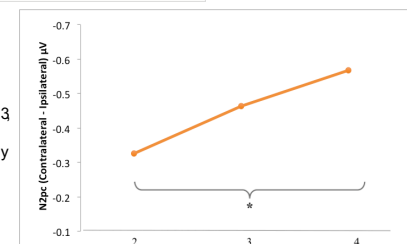


Figure 5. Mean N2pc across numerosities 2, 3 and 4; N2pc amplitude increases as numerosity increases.

Discussion

- These findings demonstrate that an N2pc hemispheric difference is elicited when adults subitize during enumeration tasks. Furthermore, the N2pc is modulated by numerosity; the difference in amplitude increases as the number of items to enumerate increases. This finding converges with previous research studies.
- We also found a difference in the extent to which the N2pc changes with numerosity for individuals with high and low subitizing fluency. This finding expands on previous research, suggesting that this neural marker may be linked to subitizing ability.

References

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