What do "two times four", "2 x 4", and "cat" have in common?
An event-related potential study of arithmetic processing and language in children

Amandine E. Grenier[1] & Nicole Y.Y. Wicha[1,2]
[1]The University of Texas at San Antonio, [2]UT Health San Antonio

UTSA
DEPARTMENT OF BIOLOGY
NEUROSCIENCES INSTITUTE

INTRODUCTION

Multiplication problems can be represented in several ways, like Arabic digits or spoken number words. Models of arithmetic have proposed that children rely on verbal rehearsal to encode these facts into memory, suggesting that the format of the encoded problems could influence solution retrieval.

Access to semantic memory is reflected on the amplitude of the N400 [1]. Our previous work showed that when children verify the correctness of simple multiplication problems presented as Arabic digits, a robust N400 is elicited with larger amplitude for incorrect than correct problems. In contrast, the effect observed in adults who completed the same task was a target P300 to correct solutions only [2,3,4].

The current study measured the effect of operand format on multiplication fact verification in children to determine if memory access differs for words and digits. We compare our findings to a word-picture verification task to determine if math and language engage similar brain processes.

METHODS

Participants: 55 elementary school children (grade 3-5; 27 female)

Standardized Measures: math fluency (WIAT-III), working memory (WJIII) and phonological awareness (WJIII).

Math Tasks: Judge the correctness of solutions to multiplication problems with operands presented as either Arabic digits, or spoken words. Solutions are always presented as Arabic digits and are 50% correct and 50% table-related incorrect (e.g., 2 4 8 versus 2 4 12).
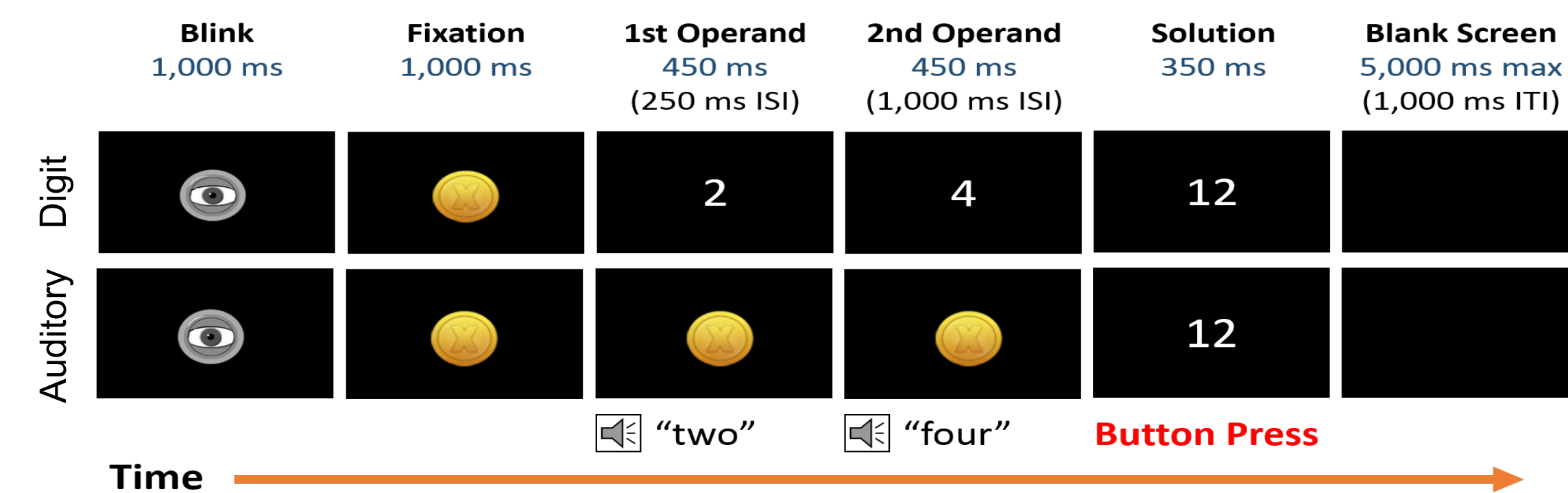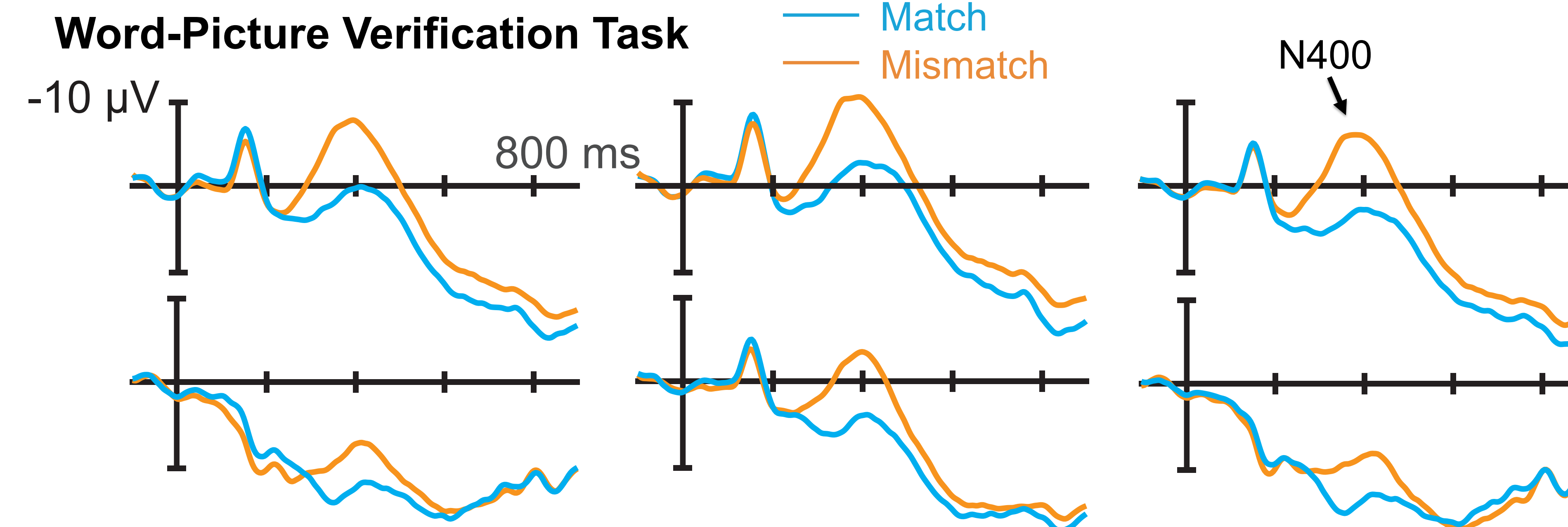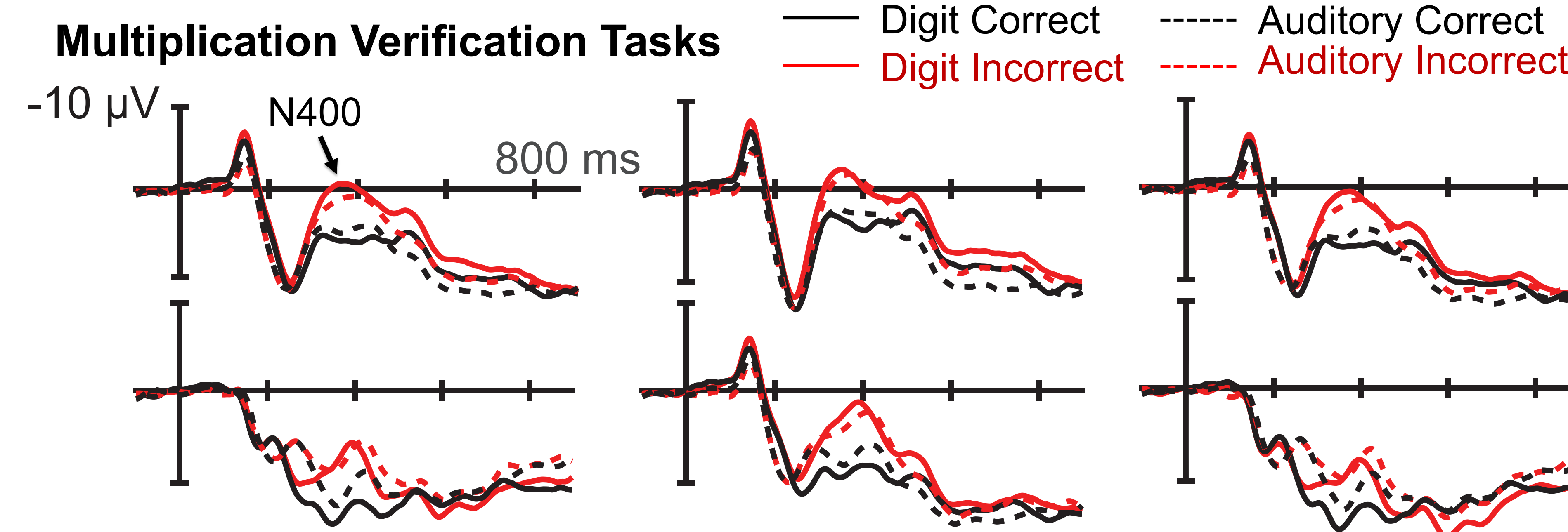

Word-Picture Verification Task: Judge the semantic fit of pictures to preceding spoken English word; 50% match/mismatch ("airplane" – airplane/umbrella)
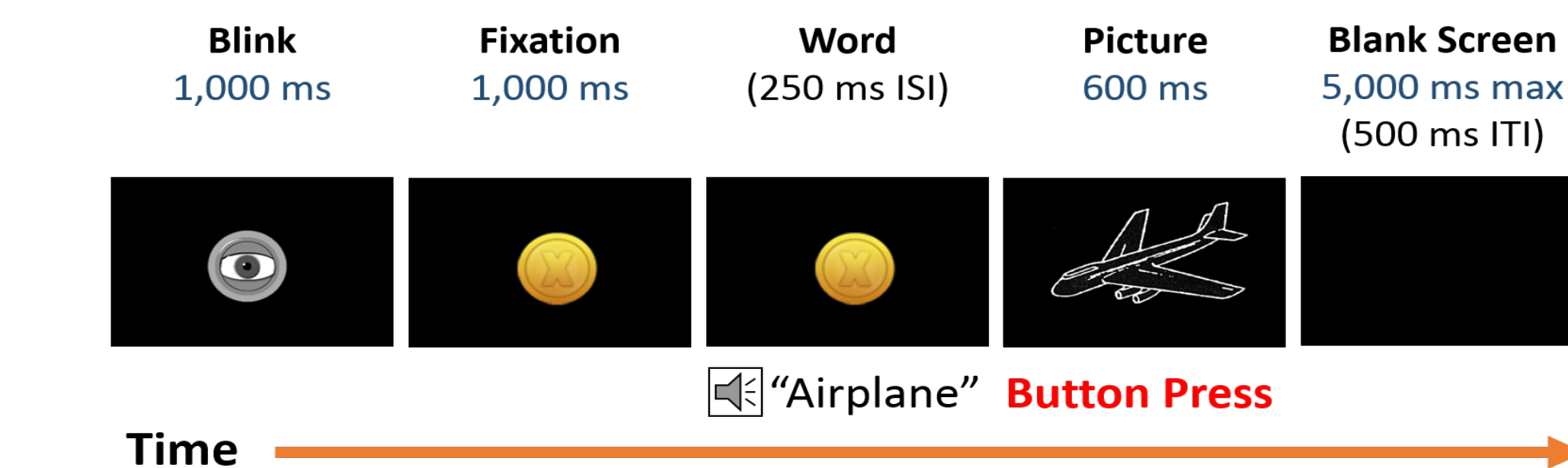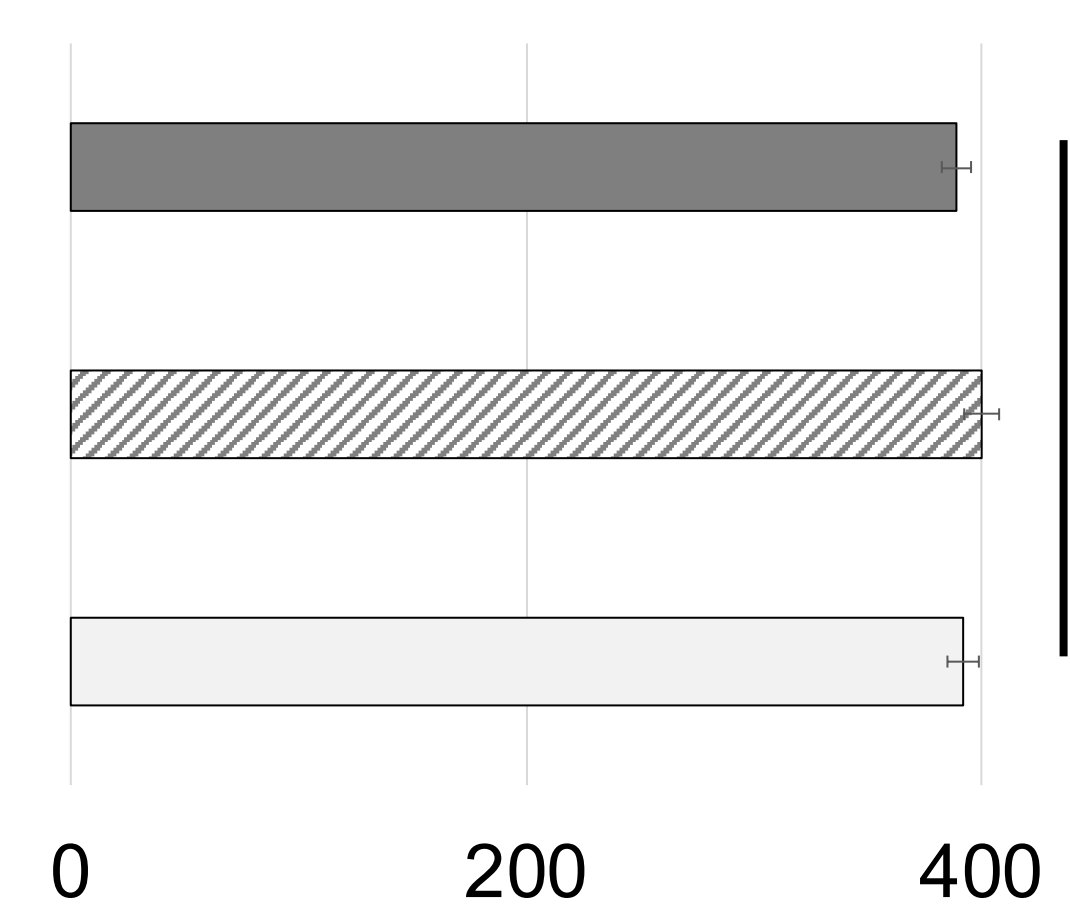

Task Order: All children performed the Arabic digit task during Session 1 and the Auditory tasks (spoken number word and word-picture verification tasks) during Session 2.

- On average, the time difference between Session 1 and Session 2 was 5 months (range: 2 days – 17 months).

- 21 children moved up one grade level between Session 1 and Session 2 (average time between sessions: 7 months; range: 3 – 17 months).

- 34 children were in the same grade level for the two Sessions (average time between sessions: 3 months; range: 2 days – 10 months).
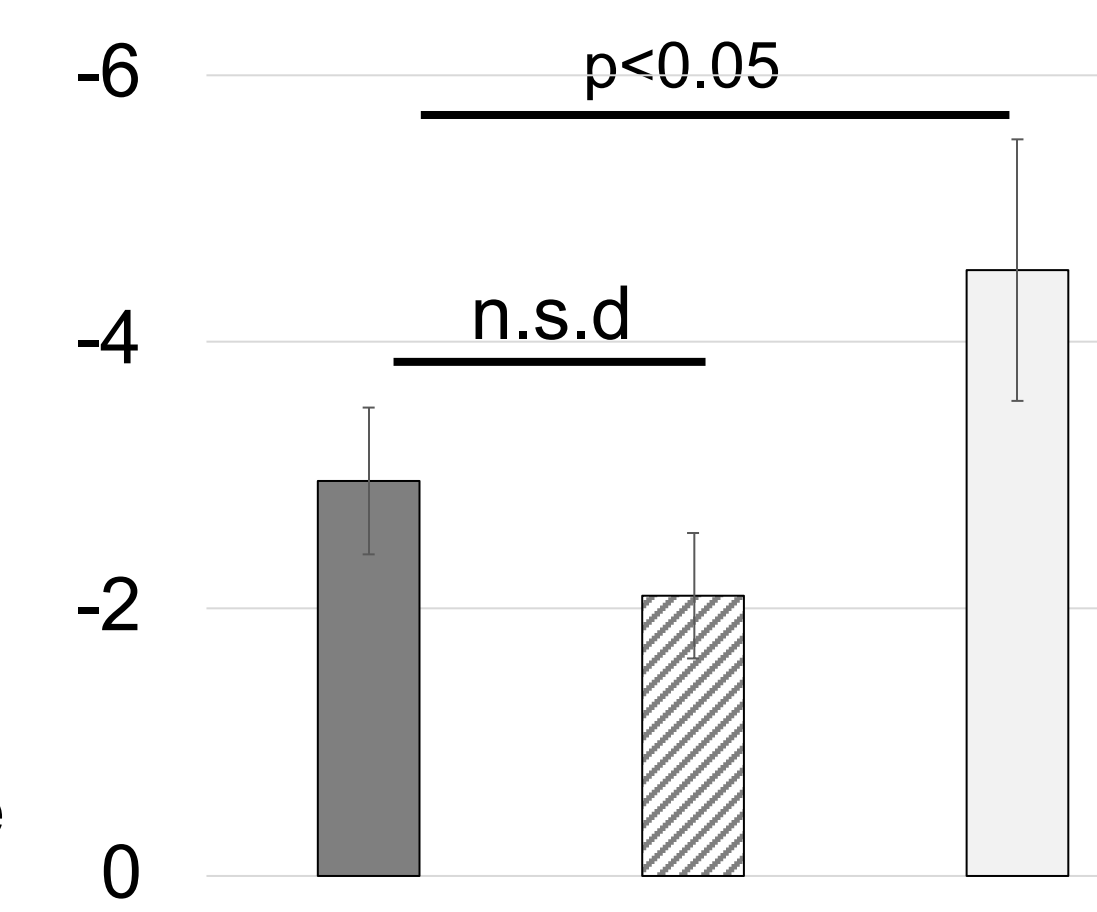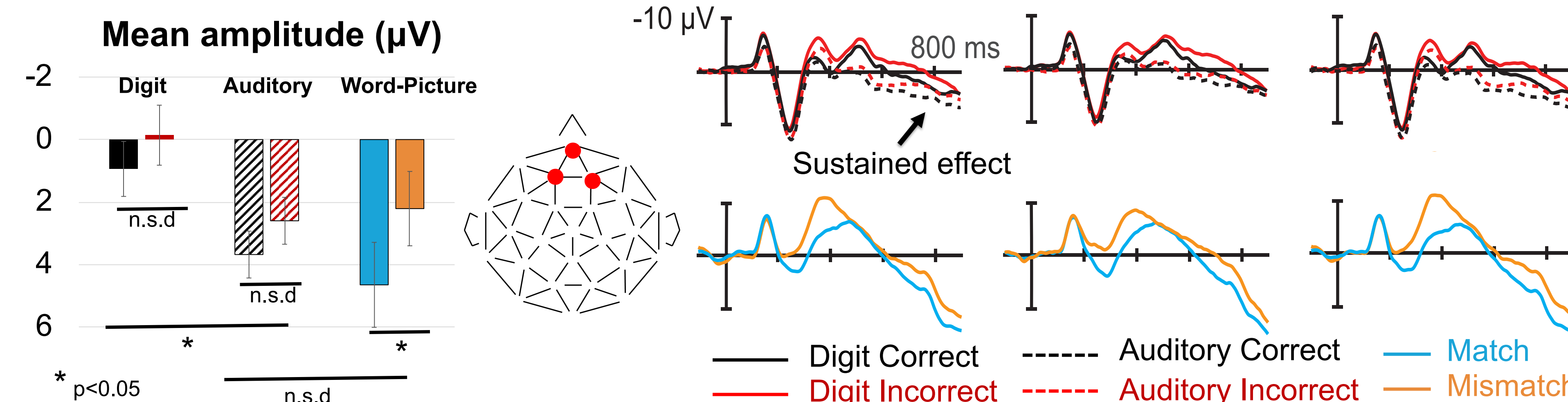
TASK COMPARISON: N400 EFFECT

Multiplication Verification Tasks

Digit Correct — Digit Incorrect — Auditory Correct — Auditory Incorrect

Word-Picture Verification Task

Match — Mismatch

Effect (incorrect – correct) Latency (ms)

Effect (incorrect - correct) Mean amplitude (µV)

Digit — Auditory — Word-Picture

TASK COMPARISON: ANTERIOR EFFECT

Mean amplitude (µV)

Digit — Auditory — Word-Picture

* p<0.05

Sustained effect

Digit Correct — Digit Incorrect — Auditory Correct — Auditory Incorrect — Match — Mismatch

BEHAVIORAL RESULTS

Accuracy (%)

Response Times (ms)

Digit — Auditory

Correct — Incorrect   * p<0.05
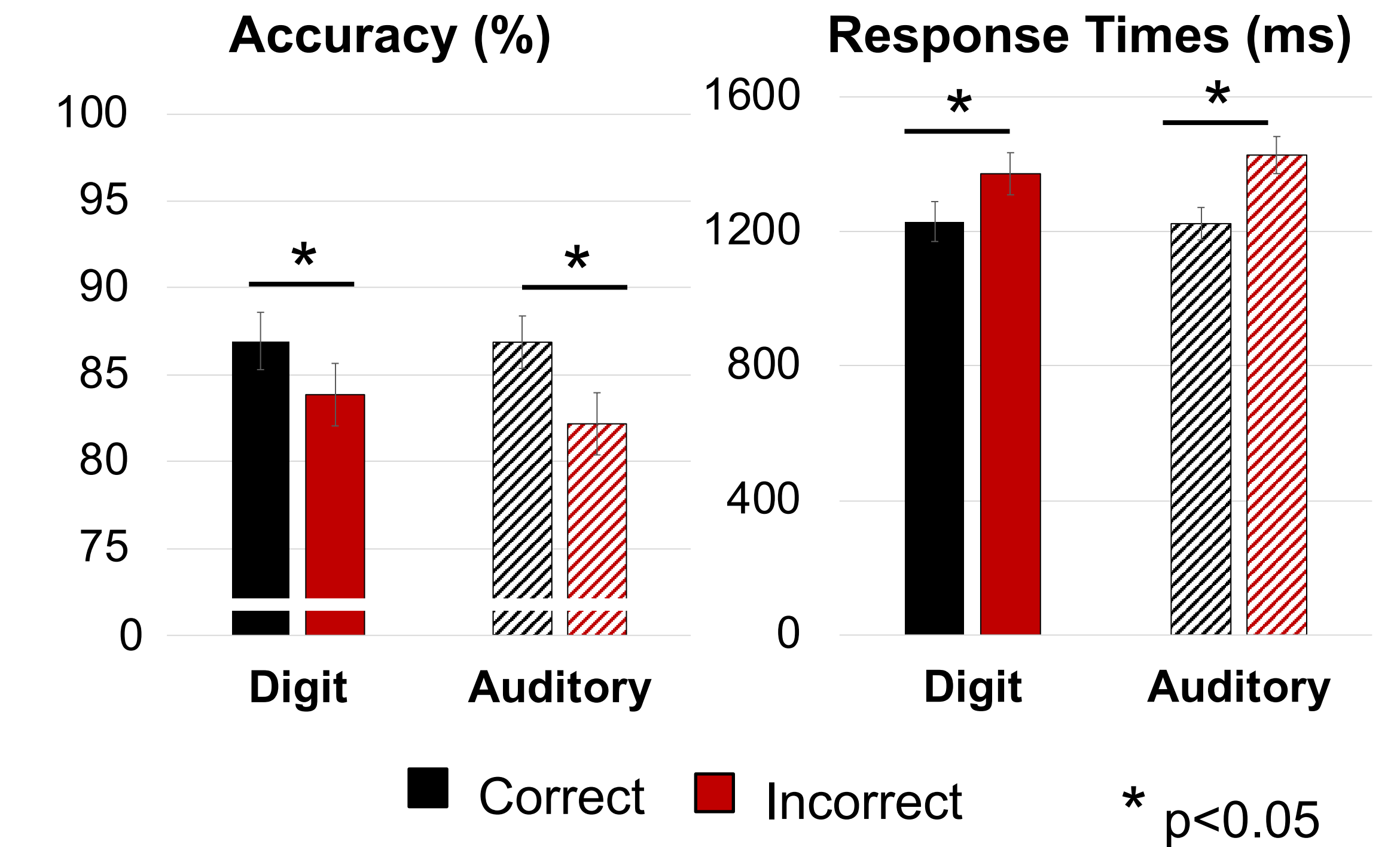
CONCLUSION

- Children showed an N400 effect at the solution, with more negative amplitude for incorrect than correct problems. This was true when the digit solutions were preceded both by digit and spoken word operands.

- There were no differences in performance (accuracy and response times) across the two math tasks, indicating that operand format did not influence multiplication fact verification.

- Children also showed an N400 effect in the word-picture verification task, with more negative amplitude for mismatch than match trials.

- The timing of the N400 was similar across the three tasks, but the amplitude was larger in the word-picture task.

- A later frontal positivity was observed for multiplication trials with auditory operands and for the word-picture trials, but not for digit trials.

- Overall, the results indicate that 1) verifying math facts and word-picture (mis)matches engage similar semantic level processes, 2) retrieving multiplication facts from memory occurred similarly regardless of operand format, and 3) spoken number words engage language-like processes similar to the language task.

REFERENCES

1. Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual review of psychology, 62*, 621-647.
2. Grenier, A. E., Cerda, V. R., Dickson, D. S., Obinyan, B. O., Momson, J. P., & Wicha, N. Y. Y. (2018). Children engage semantic processes to verify arithmetic facts: Evidence from the N400. *Journal of Cognitive Neuroscience, Supplement.*
3. Jasinski, E. C., & Coch, D. (2012). ERPs across arithmetic operations in a delayed answer verification task. *Psychophysiology, 49*(7), 943-958.
4. Dickson, D. S., Cerda, V. R., Beavers, R. N., Ruiz, A., Castañeda, R., & Wicha, N. Y. (2018). When 2× 4 is meaningful: the N400 and P300 reveal operand format effects in multiplication verification. *Psychophysiology*, e13212.

ACKNOWLEDGEMENTS