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Introduction

- The role of specific subregions of the left inferior frontal gyrus (IFG) at different representational levels of language production is unclear
- Functional imaging studies: evidence for level-specific division of anterior and posterior regions for semantic and phonological processing, respectively
- Directly interfering with the neuronal activity of a circumscribed region with transcranial magnetic stimulation (TMS) allows to causally test a potential parcellation
- Word comprehension tasks: evidence for task-specific interference in response to aIFG or pIFG stimulation (Devlin et al. 2003; Hartwigsen et al. 2010)
- Gough et al. (2005): double dissociation of aIFG and pIFG for semantic and phonological word processing in word comprehension
- Here we tested whether this also holds for language production tasks

Methods

Participants

- 24 participants (12 female): native German speakers, right-handed, TMS eligible, mean age: 27.3 years ($SD = 3.9$)

Design

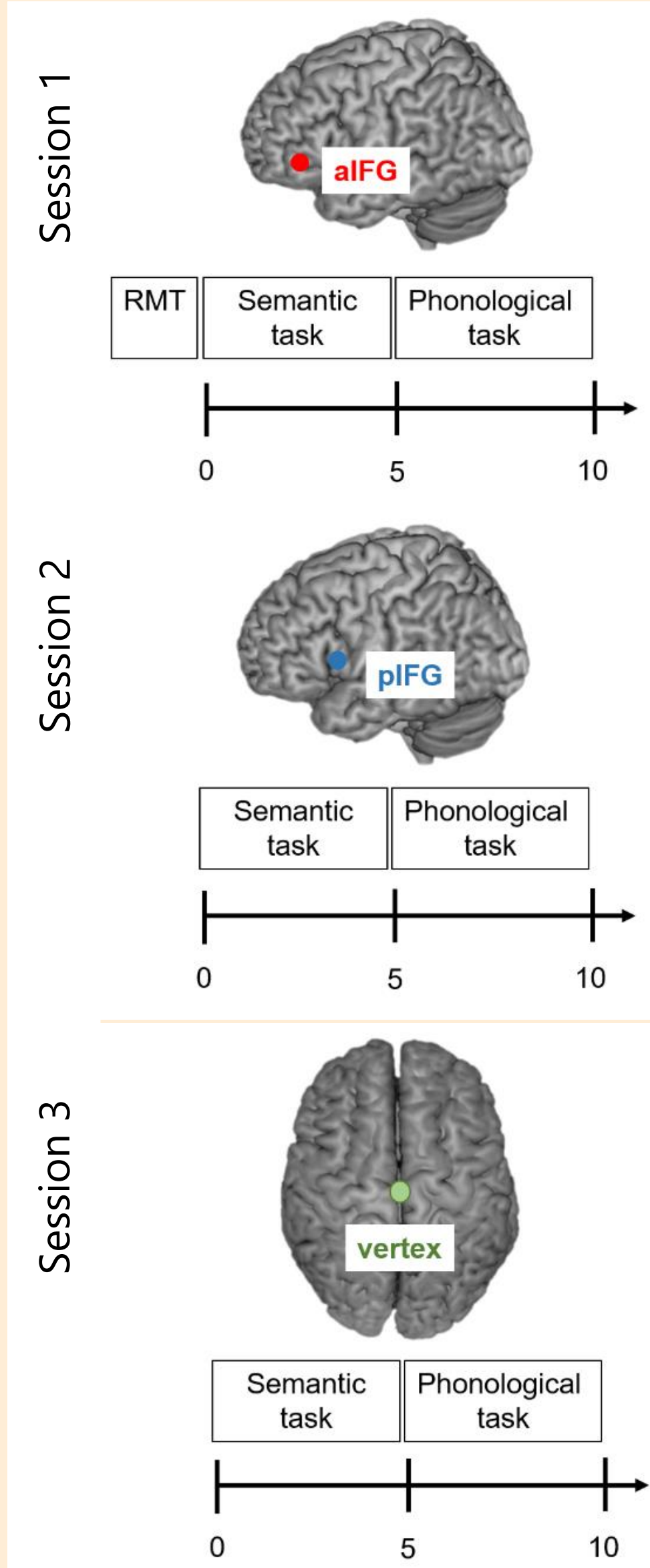
- 2 x 3: Task (semantic vs. phonological) x rTMS site (aIFG vs. pIFG vs. vertex), tested within participants
- 3 experimental sessions, separated by at least one week
- Order of tasks and stimulation sites counterbalanced across participants

Tasks

- Semantic: category member generation task (e.g. visual stimulus "apple", requested response e.g. "pear")
- Phonological: rhyme generation task (e.g. visual stimulus "broom", requested response e.g. "groom")

rTMS

- 5 pulses of 10 Hz rTMS over aIFG, pIFG, or vertex, 500 ms after stimulus onset
- 90% individual resting motor threshold (RMT)
- aIFG: $x, y, z = -52, 34, -6$; pIFG: $x, y, z = -52, 16, 8$ mm
- Mean stimulation intensities: aIFG: $37.3 \pm 7.0\%$; pIFG: $37.5 \pm 7.5\%$; vertex: $39.1 \pm 7.0\%$



Results

Semantic task:

- Relative to rTMS over the vertex, naming latencies increased in response to rTMS over the aIFG ($\beta = 19.15, SE = 8.96, z = 2.1, p = .033$), but not in response to rTMS over the pIFG ($p > .808$).
- Naming latencies were prolonged under aIFG stimulation relative to pIFG stimulation ($\beta = 20.90, SE = 6.32, z = 3.3, p < .001$)

Phonological task:

- Relative to rTMS over the vertex, naming latencies significantly decreased in response to rTMS over the pIFG ($\beta = -64.03, SE = 7.10, z = -9.0, p < .0001$), but not in response to rTMS over the aIFG ($p > .184$).
- Relative to aIFG stimulation, naming latencies were selectively facilitated under pIFG stimulation ($\beta = 54.63, SE = 6.51, z = 8.4, p < .0001$).

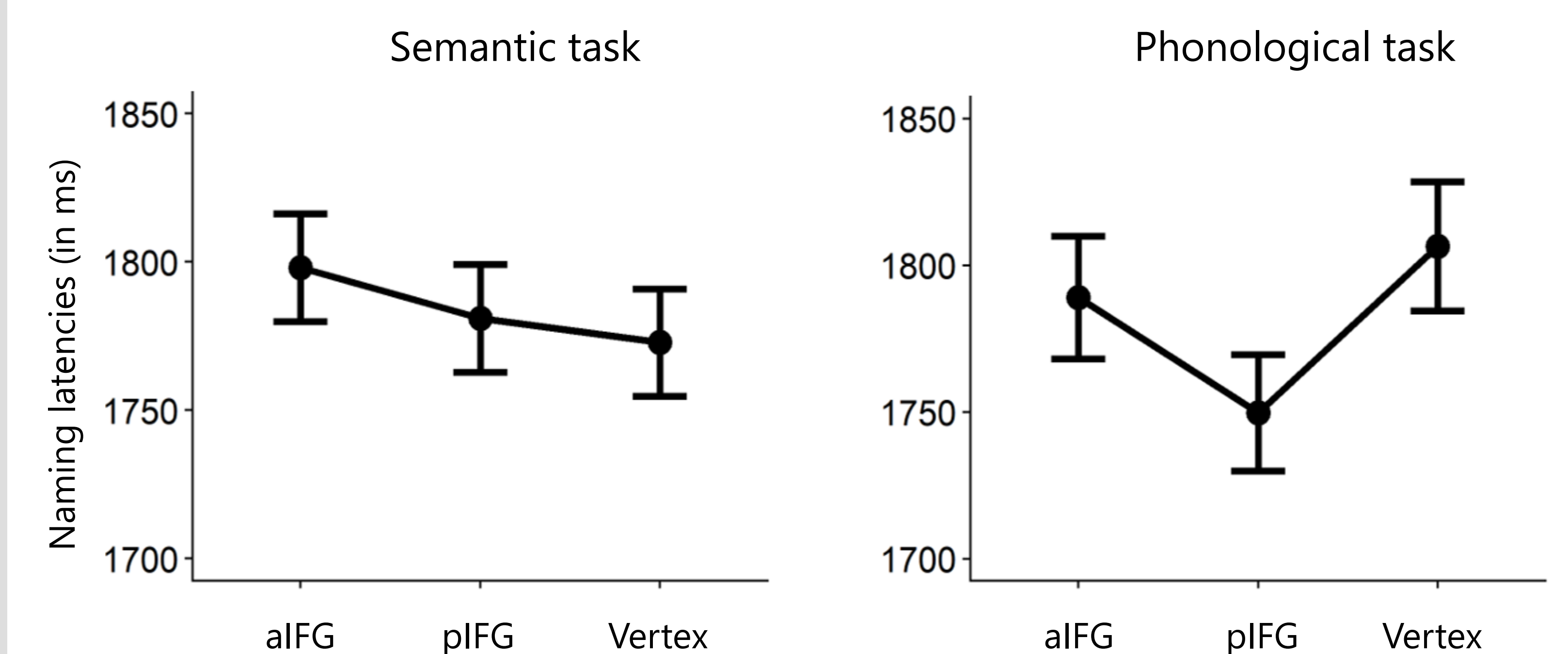


Figure 1. Raw naming latencies ($\pm SEM$) broken down by task and stimulation site.

Table 1. Mean naming latencies (Response Times [RT] in ms) and error rates (ER, in %), broken down by task (semantic vs. phonological) and stimulation site (aIFG vs. pIFG vs. vertex). Standard error of the mean (SEM) in brackets.

	Semantic task		Phonological task	
	RT	ER	RT	ER
aIFG	1798 (18)	10.6 (0.9)	1789 (21)	19.4 (1.1)
pIFG	1781 (18)	10.8 (0.9)	1750 (20)	19.2 (1.1)
Vertex	1773 (18)	11.6 (0.9)	1807 (22)	19.2 (1.1)

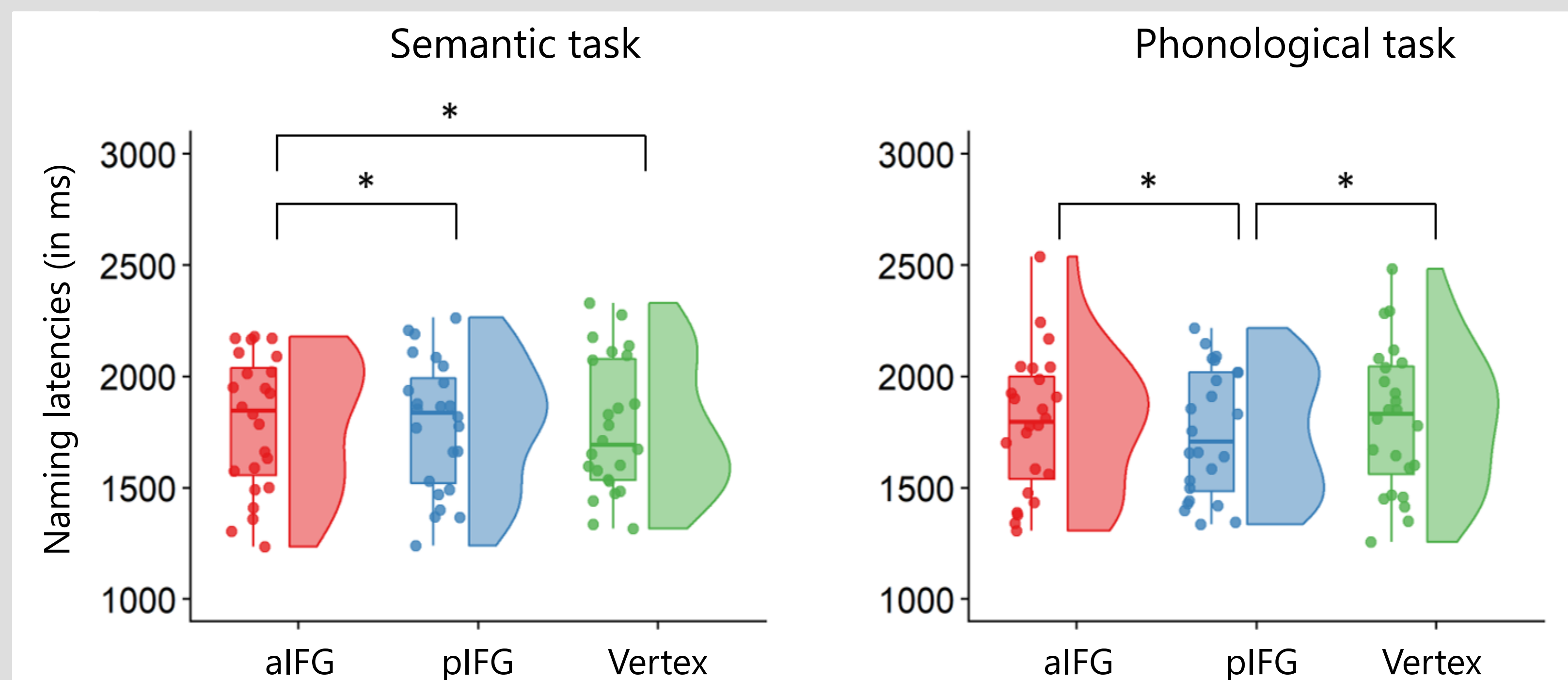


Figure 2. Raincloud plots of naming latencies, broken down by task and stimulation site, aggregated by participants. * $p < .05$

Discussion

Functional-anatomical double dissociation in left IFG

- Naming latencies selectively increased during rTMS over the left aIFG in the semantic task, and selectively decreased during rTMS over the left pIFG in the phonological task
- Causal evidence for a locally specific division of labor for semantic and phonological contents within the left IFG in language production

Reconciling semantic effects with previous results

- Previous studies found no semantically specific role of aIFG (i.e. BA45; Heim et al., 2008, 2009)
- Here, aIFG was located in anterior-ventral regions of BA45 and 47, which have been implicated in semantic and executively demanding tasks (Binder et al., 2009; Katzev et al., 2013; Vigneau et al., 2006)

(Unexpected) Facilitation from rTMS in pIFG

- rTMS-induced activity might be synchronized with the ongoing relevant signal, providing an "optimum" level of noise for a specific task (Miniussi et al., 2013) \rightarrow "paradoxical" improvement
- Intensity and time point of stimulation may affect behavioural outcome (Silvanto & Cattaneo, 2017) \rightarrow at mean naming latencies of 1,800 ms, rTMS may have preceded phonological processing

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