Phonological encoding and lexical processing of spoken words in dyslexia: linking behaviour and neural responses

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1. Introduction

- Developmental dyslexia, a reading disorder, is associated with phonological processing deficits [1]. This observation has led to the hypothesis that people with dyslexia have poorly specified phonological representations [2].
- Despite phonological deficits, comprehension of everyday speech is mostly unaffected. This raises a key question:

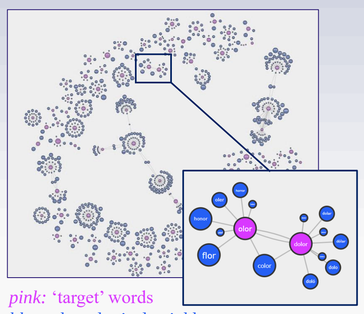
How do people with a phonological deficit process spoken words to achieve normal comprehension?

We investigated the link between phonological skills and neural responses to

(1) Phonological Neighbours (*NP - phonological encoding*)

(2) Written and Spoken Word Frequency (*WF - lexico-semantic encoding)*

- Previous findings on NP and WF effects in dyslexia come from visual word processing and are inconclusive, ranging from no processing differences [3] to differences in localisation [4], atypical word repetition effects [5], and differences in evoked power [6].
- **Can phonological deficits be compensated through neural re-organization of lexical-distributional information?**



pink: 'target' words
blue: phonological neighbours
circle size: word frequency

2. Methods

Participants
14 typical readers (C), 14 diagnosed with dyslexia (D), right-handed, matched in age (12-44, M=26.1) and general IQ (M=119.5)

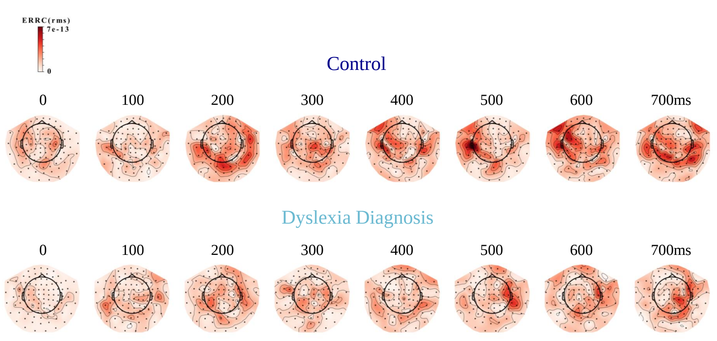
Behavioural Tests of Phonological Skills
(a) Phonological awareness test (PECO: *N/40*)
(b) Nonword reading test (*accuracy/time*100*)
→ Combined into Phonological Composite Score: $\frac{z(a) + z(b)}{2}$

Magnetoencephalography (MEG)
MEG recordings of participants listening to Spanish nouns (N=120) + decision as to whether word was animate or inanimate

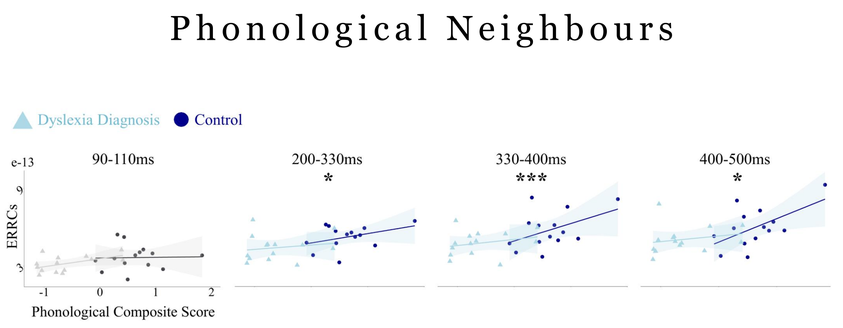
Analysis — Event Related Regression Coefficients (ERRC)
I. Single-subject regression [7] of epoched data (0–700ms) to obtain ERRC of:
(1) Phonological Neighbours (*phonological encoding*)
(2) Written and Spoken Word Frequency (*lexico-semantic encoding*)
II. Correlation of averaged ERRCs with Phonological Composite Score, Group (C vs. D), and Hemisphere in pre-selected time-windows [8]
III. Source localisation (beamformer) of ERRC response in pre-selected ROIs

3. Results

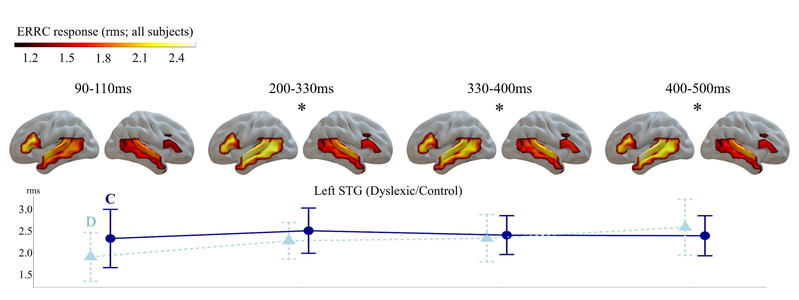
I. Sensor (ERRC)

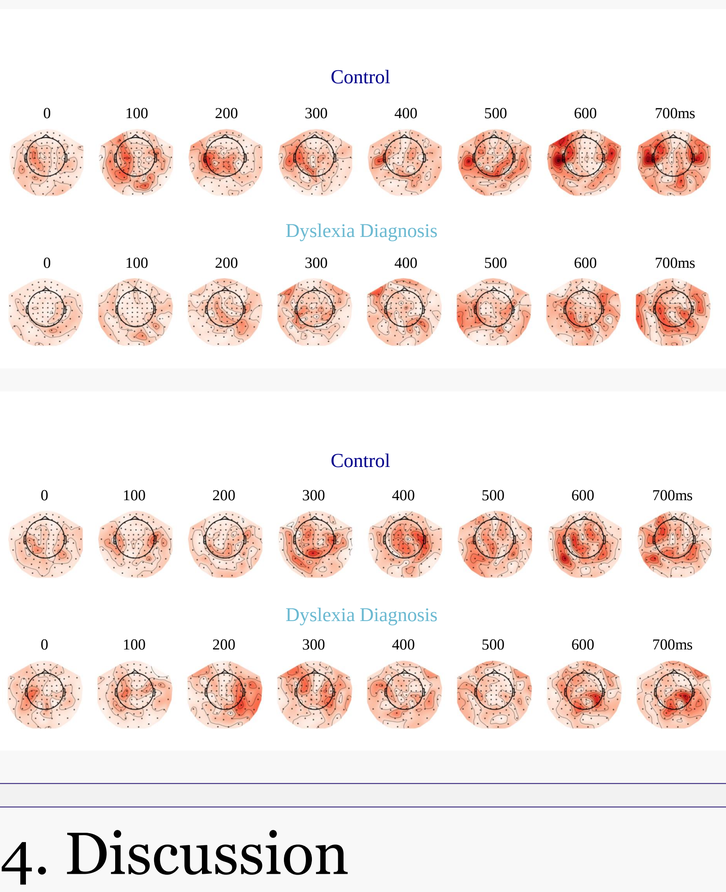


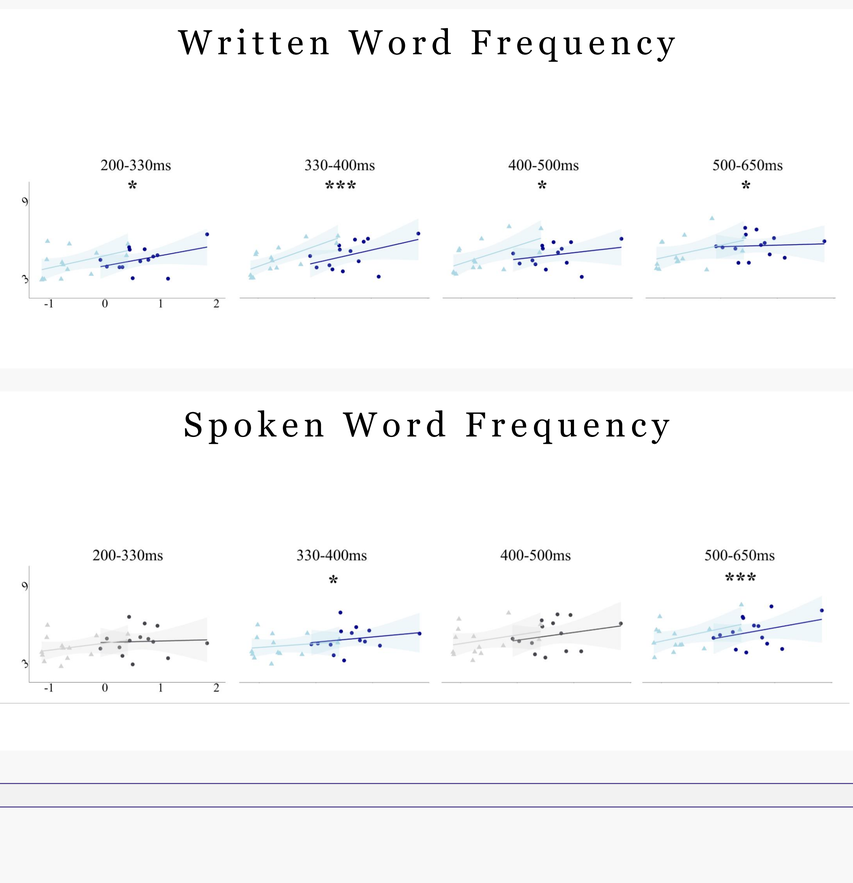
II. Correlation ERRC – Behaviour

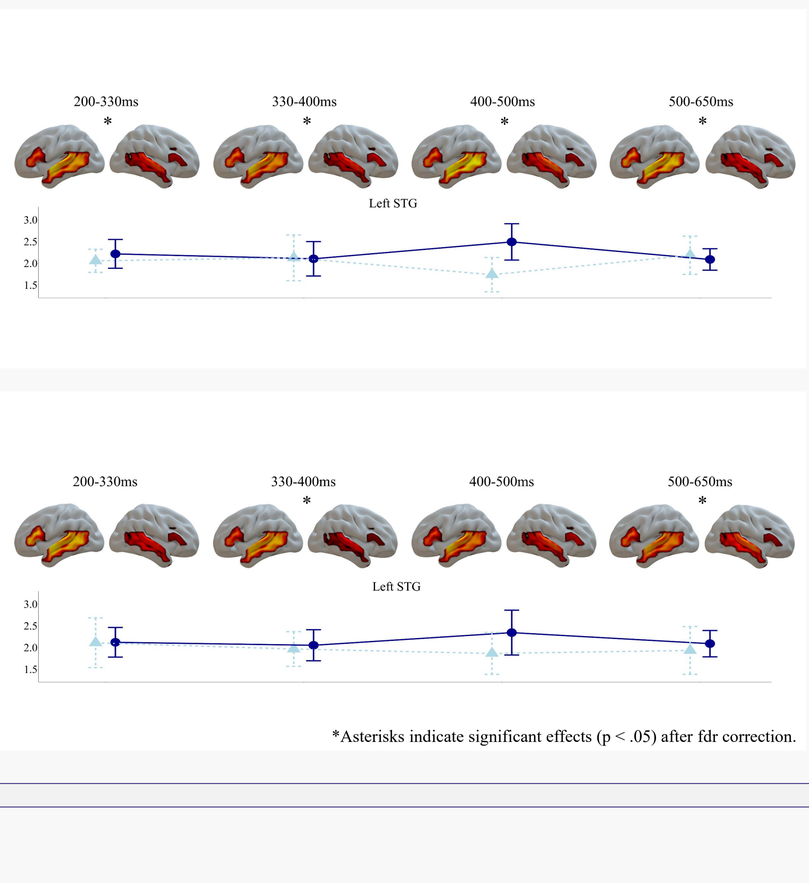


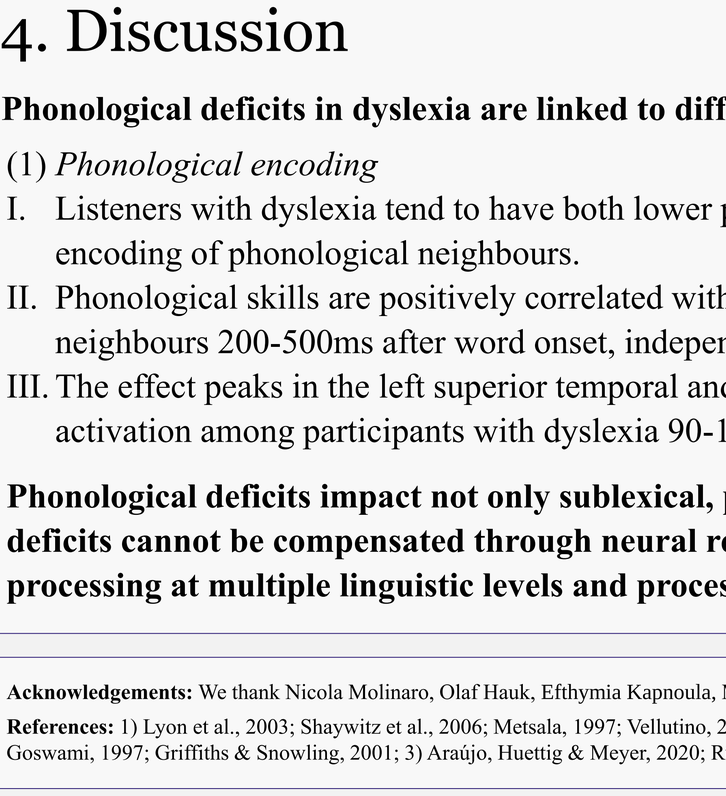
III. Source Localisation of ERRC

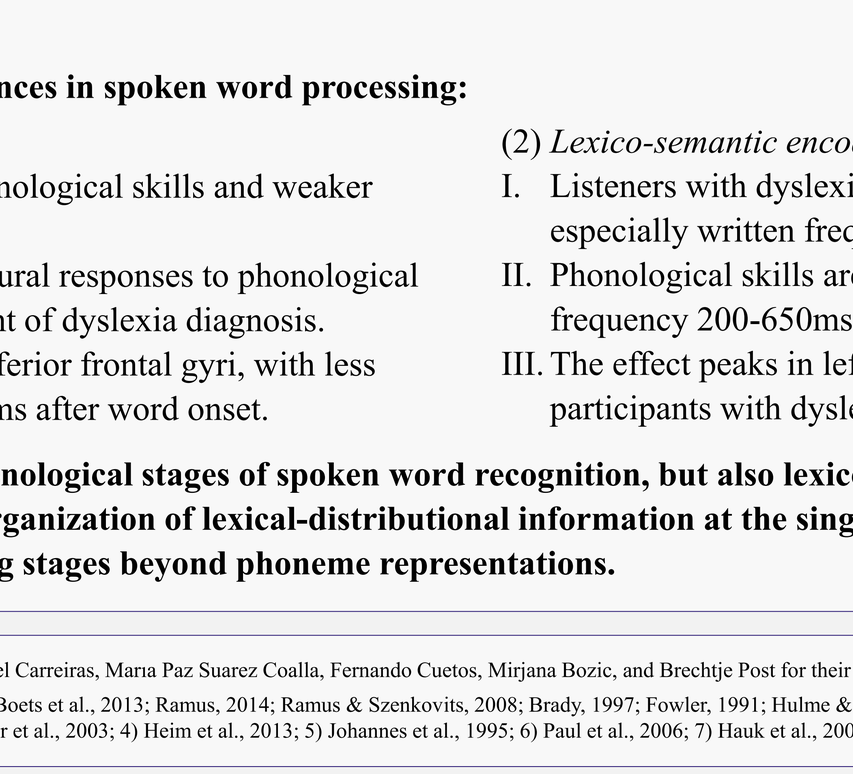


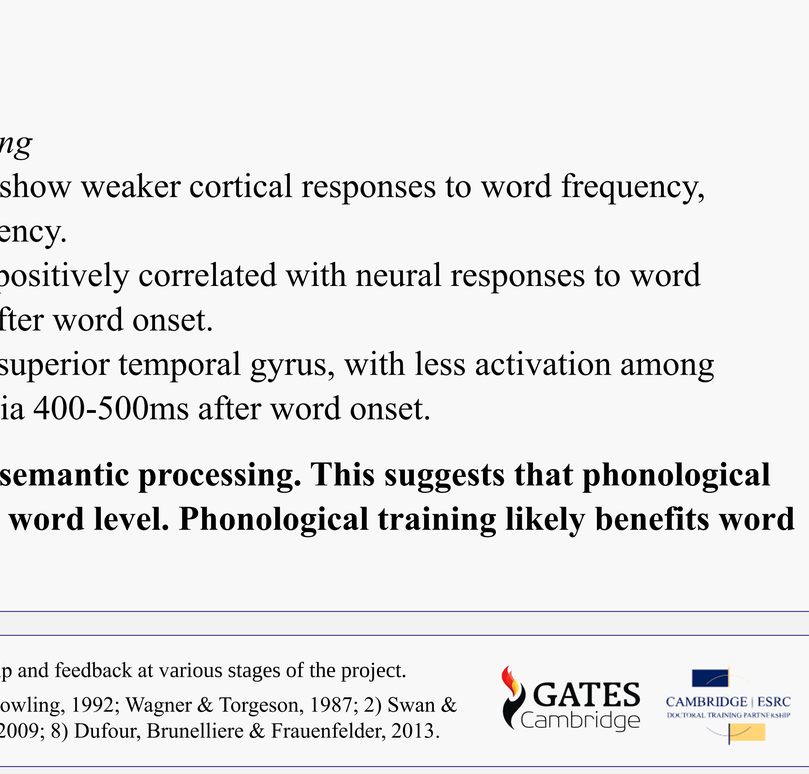












*Asterisks indicate significant effects ($p < .05$) after fdr correction.

4. Discussion

Phonological deficits in dyslexia are linked to differences in spoken word processing:

(1) *Phonological encoding*
I. Listeners with dyslexia tend to have both lower phonological skills and weaker encoding of phonological neighbours.
II. Phonological skills are positively correlated with neural responses to phonological neighbours 200-500ms after word onset, independent of dyslexia diagnosis.
III. The effect peaks in the left superior temporal and inferior frontal gyri, with less activation among participants with dyslexia 90-110ms after word onset.

(2) *Lexico-semantic encoding*
I. Listeners with dyslexia show weaker cortical responses to word frequency, especially written frequency.
II. Phonological skills are positively correlated with neural responses to word frequency 200-650ms after word onset.
III. The effect peaks in left superior temporal gyrus, with less activation among participants with dyslexia 400-500ms after word onset.

Phonological deficits impact not only sublexical, phonological stages of spoken word recognition, but also lexico-semantic processing. This suggests that phonological deficits cannot be compensated through neural re-organization of lexical-distributional information at the single word level. Phonological training likely benefits word processing at multiple linguistic levels and processing stages beyond phoneme representations.

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References: 1) Lyon et al., 2003; Shaywitz et al., 2006; Metsala, 1997; Vellutino, 2004; Boets et al., 2013; Ramus, 2014; Ramus & Szenkovits, 2008; Brady, 1997; Fowler, 1991; Hulme & Snowling, 1992; Wagner & Torgeson, 1987; 2) Swan & Goswami, 1997; Griffiths & Snowling, 2001; 3) Araújo, Huettig & Meyer, 2020; Rüsseler et al., 2003; 4) Heim et al., 2013; 5) Johannes et al., 1995; 6) Paul et al., 2006; 7) Hauk et al., 2006, 2009; 8) Dufour, Brunelliere & Frauenfelder, 2013.