Investigating the Neural Time Course of Stroop Interference in Bilinguals: An ERP Study

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INTRODUCTION

Stroop ERP Literature:

Two components related to conflict processes are reliably identified in the Stroop task:

- **Incongruent Negativity (N_{inc}):** increased negativity in the incongruent condition from approximately 350-550 ms, indicating more effortful processing compared to congruent or control conditions. Reflects conflict detection processes (Coderre et al., submitted; West, 2003).
- **Late Positivity Component (LPC):** increased positivity in the incongruent condition from approximately 600-900 ms. May be involved in conflict resolution processes (West, 2003; Coderre et al., submitted).

Stimulus onset asynchrony (SOA) manipulation in the Stroop task affects the latencies of these components (Coderre et al., submitted; Appelbaum et al., 2009):

- **Negative SOAs:** word appears before colour → N_{inc} and LPC are shifted forward because semantic access to the word gets a head-start, so conflict detection and resolution can proceed faster.
- **Positive SOAs:** word appears after colour → N_{inc} latency not affected because conflict detection processes are reliant on the speed of lexical access. No LPC occurs in long positive SOAs (200ms or longer) because a response is already in preparation so no resolution is needed.

Bilingual Literature:

Bilinguals experience less Stroop interference than monolinguals. The **bilingual advantage hypothesis** suggests that this is because *non-selective access* of the bilingual lexicon creates between-language competition, requiring constant cognitive control over both languages which enhances executive control abilities (Bialystok, 2001).

Conversely, bilinguals are slower at tasks of picture naming and lexical decision than monolinguals. The **weaker links hypothesis** claims that relative to monolinguals, bilinguals use each language less often, leading to weaker language ties between words and concepts (Gollan et al. 2005). Similarly, the **temporal delay assumption** of the BIA+ model states that bilinguals experience slower lexical access in their L2 compared to their L1 because of lower proficiency (Dijkstra & van Heuven, 2002).

How does bilingualism affect Stroop-related ERP components?

More effortful cognitive processing is reflected by a higher negative N_{inc} amplitude (Wang et al., 2010). If bilinguals have more effective control mechanisms, they should show a reduced (i.e. less negative) amplitude compared to monolinguals.

➢ **Bilingual advantage hypothesis → reduced N_{inc} amplitude in bilinguals vs. monolinguals**

Being a conflict detection component, the N_{inc} is sensitive to the speed of lexical access because conflict cannot be registered without full lexico-semantic access. If bilinguals have delayed lexical access they should have a delayed N_{inc} onset latency in their L1 compared to monolinguals, and in their L2 compared to L1.

➢ **Weaker links hypothesis/temporal delay assumption → delayed N_{inc} onset latency with decreasing proficiency**

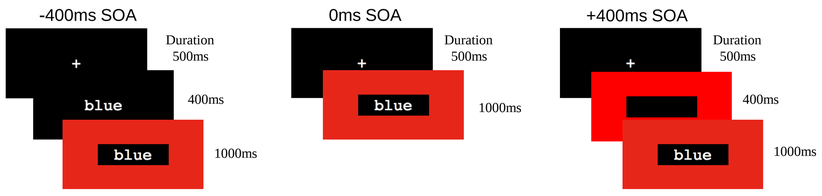
METHOD

Materials and Design:

Experiment 1: 31 English monolinguals, 18 female, mean age 22 yrs., performed the English SOA Stroop task in one session of EEG recording (Coderre et al., submitted).

Experiment 2: 19 Chinese-English bilinguals, 15 female, mean age 23 yrs., average self-rated English proficiency 7.5 on a 10-point scale, performed Chinese (L1) and English (L2) versions of the Stroop SOA task on two separate sessions (counterbalanced) with EEG recording

- Blocked SOA: -400ms, 0ms, +400ms. In each block, 72 congruent, incongruent and control ('%%%%') trials presented randomly using colours red, green, blue; English words 'red', 'green' and 'blue'; Chinese characters 红, 绿, and 蓝.

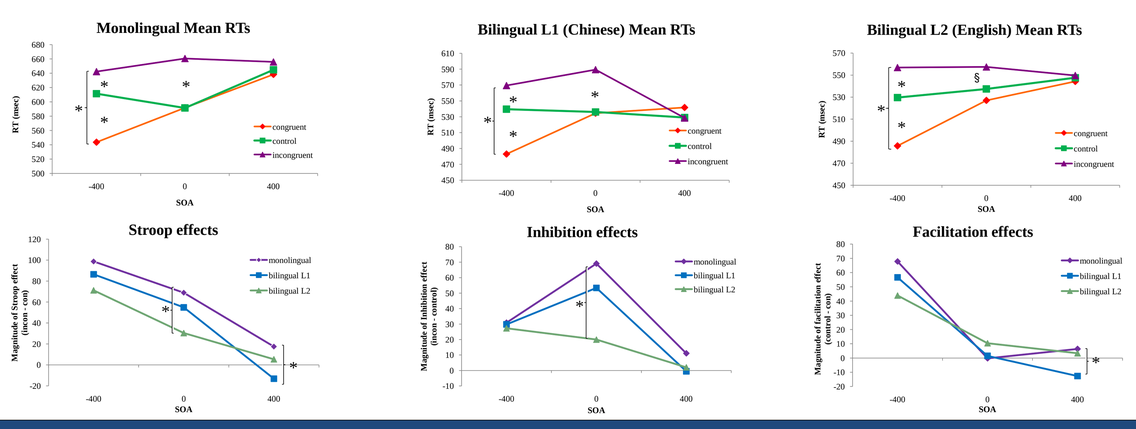


- EGI 128-channel EEG system, sample rate 250 Hz, recorded with NetStation version 4.3.
- 0.5-40 Hz bandpass filter. Eye blinks and other artifacts were removed using independent component analysis (ICA). Incorrect responses and outliers removed before averaging. Average of 6% of the data rejected due to artifacts, errors or outliers.
- Running *t*-tests: successive 24ms bins, 12ms shifts, significance threshold 5 consecutive windows (p<0.05).

RESULTS

Behavioural Results:

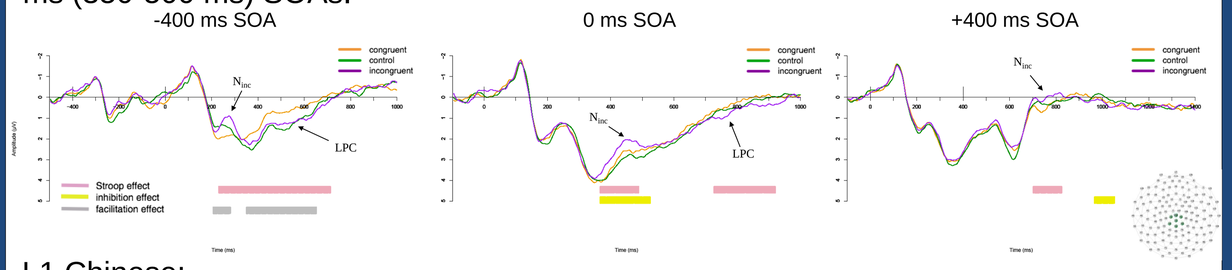
* = $p < 0.05$; § = trend



ERP Results

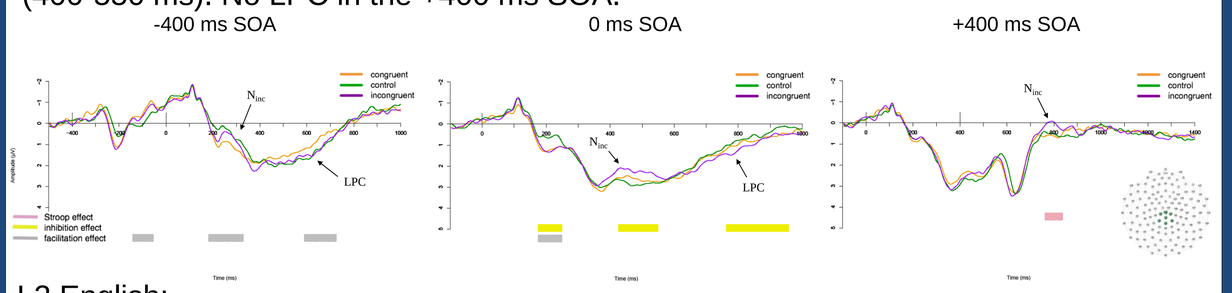
Monolinguals (Coderre et al., submitted):

- Significantly earlier N_{inc} in the -400 ms SOA (200-350 ms) than the 0 ms SOA (350-500 ms). Significantly earlier LPC in the -400 ms SOA (550-850 ms) than the 0 ms SOA (800-950 ms).
- No significant latency shift in the N_{inc} between +400 ms (350-450 ms after word) and 0 ms (350-500 ms) SOAs.



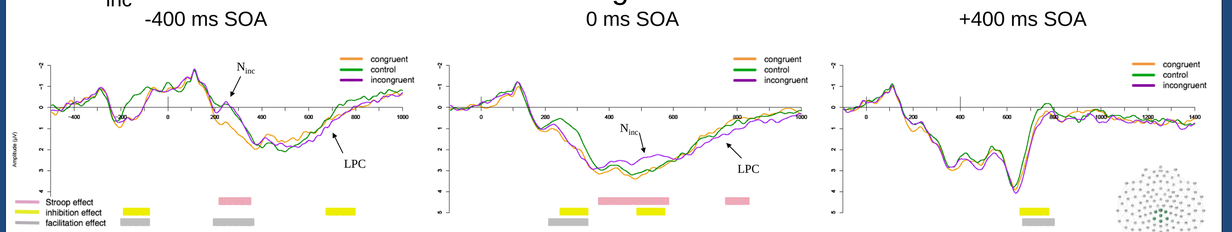
L1 Chinese:

- Significantly earlier N_{inc} in the -400 ms SOA (200-350 ms) than the 0 ms SOA (400-550 ms). Significantly earlier LPC in the -400 ms SOA (600-750 ms) than the 0 ms SOA (750-950 ms).
- Significantly earlier N_{inc} in the +400 ms SOA (350-450 ms after word) than 0 ms SOA (400-550 ms). No LPC in the +400 ms SOA.



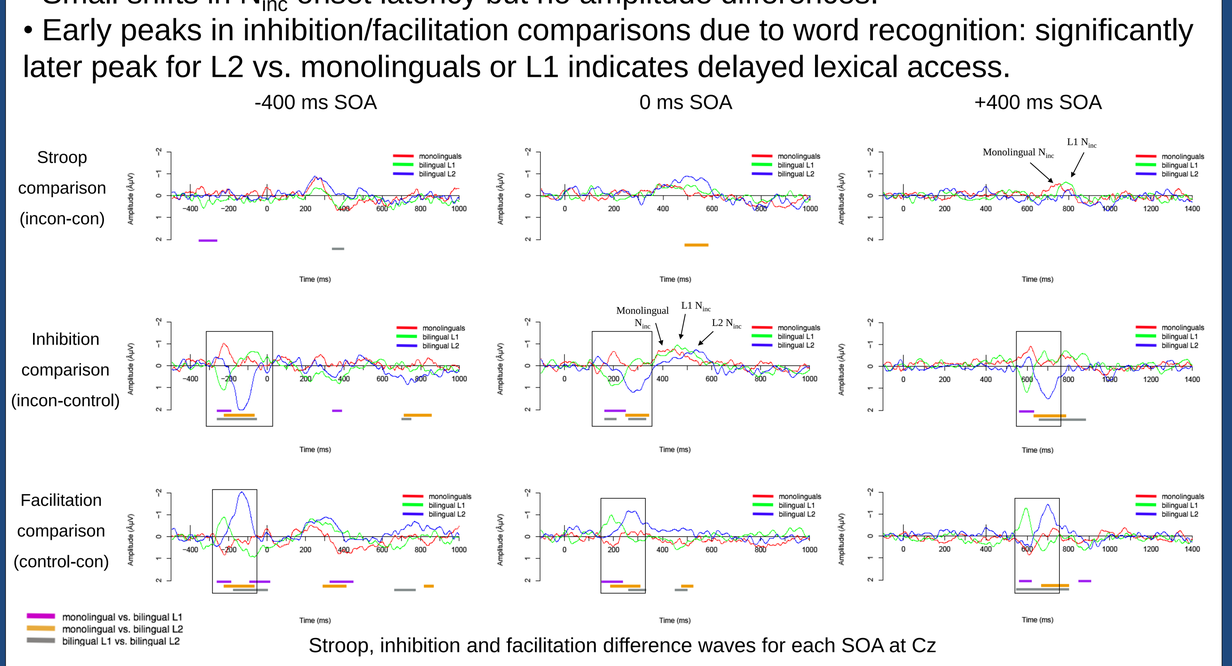
L2 English:

- Significantly earlier N_{inc} in the -400 ms SOA (200-350 ms) than the 0 ms SOA (350-500 ms). Significantly earlier LPC in the -400 ms SOA (650-800 ms) than the 0 ms SOA (750-850 ms).
- No N_{inc} or LPC in the +400 ms SOA but large control differences.



Difference Wave Comparisons:

- Small shifts in N_{inc} onset latency but no amplitude differences.
- Early peaks in inhibition/facilitation comparisons due to word recognition: significantly later peak for L2 vs. monolinguals or L1 indicates delayed lexical access.



Stroop, inhibition and facilitation difference waves for each SOA at Cz

CONCLUSIONS

- Bilinguals show the same Stroop ERP components in both L1 and L2 as monolinguals, and these components are affected the same way by SOA manipulation.
- Significantly later word processing peak for L2 but no differences between monolinguals and L1 → **support for the temporal delay assumption**.
- Shifts in N_{inc} onset latency between groups → **support for weaker links hypothesis.**
- No differences in N_{inc} amplitude between groups→ ***no* support for bilingual advantage hypothesis.**
- Differences in speed of lexical access explains the observed N_{inc} latency shifts and indicates that conflict detection processes in the Stroop task are highly dependent on linguistic processes.

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