The Impact of Language Quantity and Usage Balance on Inhibitory Control: An ERP Study

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Introduction

Inhibitory Functions (Bilinguals vs Monolinguals)

- Numerous studies have shown that bilinguals possess enhanced inhibitory control compared to monolinguals (e.g., Bialystok et al., 2005； Martin-Rhee & Bialystok, 2008).

- Possible explanation： Bilinguals frequently switch between two languages. To smoothly output one language, they must continually suppress conflicting information from the language they are not using now. This constant process of selection and suppression strengthens the brain's executive control functions, especially inhibitory control abilities.

- However, some other studies did not find this bilingual advantage in inhibitory control (e.g., Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2015). This inconsistency may be related to other factors associated with cognitive control abilities, considering that each speaker's linguistic experience is unique

- Other factors： 1. level of language proficiency (Mishra, Hilchey, Singh, & Klein, 2012)
  2. stage of second language acquisition (early bilingual vs. late bilingual, Kalia, Wilbourn, & Ghio, 2014)
  3. the degree of bilingualism (dominant vs. balanced bilingual, Goral, Campanelli, & Spiro, 2015)
  4. pattern of language use, varying experience with frequent language switch (Soveri, Rodriguez-Fornells, & Laine, 2011)
  5. the similarity between a bilingual speakers' two languages (Coderre & van Heuven, 2014, but see Paap et al., 2015a)
  6. multilingualism (Poarch & van Hell, 2012).

Inhibitory Functions (Bilinguals vs Trilinguals)

- Some studies have expanded research from monolinguals and bilinguals to trilinguals and multilinguals, further comparing their inhibitory control.

- Certain findings show no significant difference in inhibitory control between bilinguals and trilinguals. For instance, Poarch and van Hell (2012) used the Simon tasks to measure inhibitory control; monolinguals were slower compared to bilinguals and trilinguals, suggesting that bilinguals and trilinguals performed better in the inhibitory control than monolinguals. This was supported by similar research with younger participants (Poarch & Bialystok, 2015; Vega-Mendoza, West, Sorace, & Bak, 2015).

  Possible explanation: Most researchers consider trilingualism as a variant of bilingualism and they use models of the second language acquisition to characterize the process of acquiring trilingualism (Chevalier, 2015).

- However, other studies suggest differences in inhibitory functions between bilinguals and trilinguals. Madrazo and Bernardo (2018) evaluated Filipino-English bilinguals and Cebuano-Filipino-English trilinguals in the Philippines on language proficiency and performance in the Simon Arrows task. They observed a trilingual advantage in complex cognitive tasks but not in simple tasks requiring only response inhibition.

  Possible explanation: trilingualism, involving more complex language management, may enhance inhibitory control in challenging situations.

Research Gap and Scientific Question

1. Research on executive functions (specifically inhibitory control) is plentiful for monolinguals and bilinguals, but scarce for trilinguals. Moreover, existing studies largely focus on trilinguals from abroad or those who speak Mongolian, Chinese, and English.

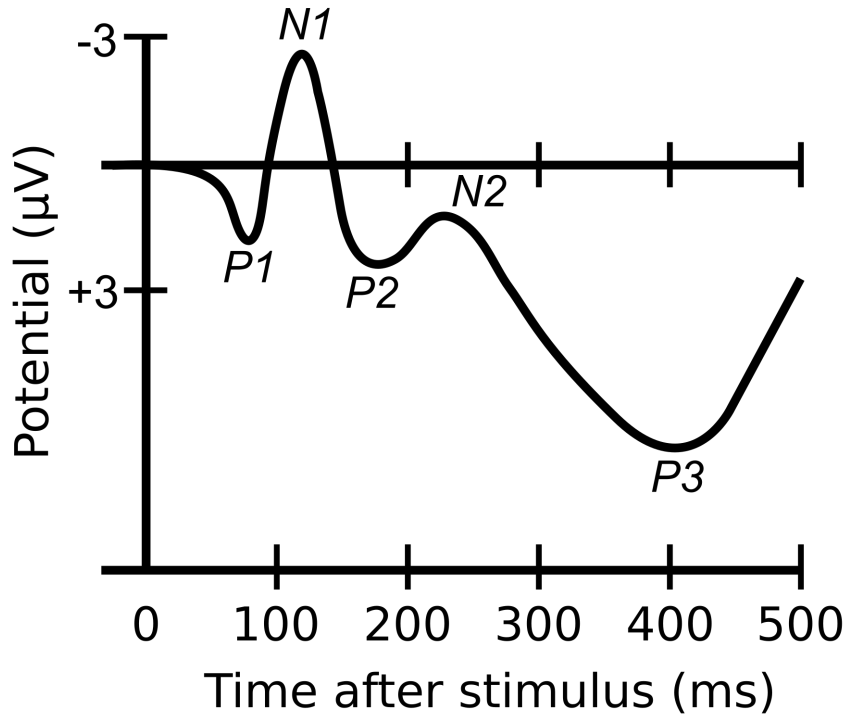
2. Most past studies don't use very precise measures for degree of bilingualism or trilingualism. Specifically, participants categorized as trilinguals may not be proficient in their third language, especially younger participants whose experience with the third language might be very limited. Furthermore, factors related to proficiency, such as age of acquisition, language switching experience, and language balance, are crucial for enhancing the inhibitory control of bilinguals, making it important to categorize trilinguals more finely.

3. Therefore, this study refines the criteria for measuring multilingual users, aiming to explore how linguistic diversity (bilingual/trilingual) and usage balance (balanced/unbalanced) affect the inhibitory function of bilinguals and trilinguals, from a behavioral and neural perspective .

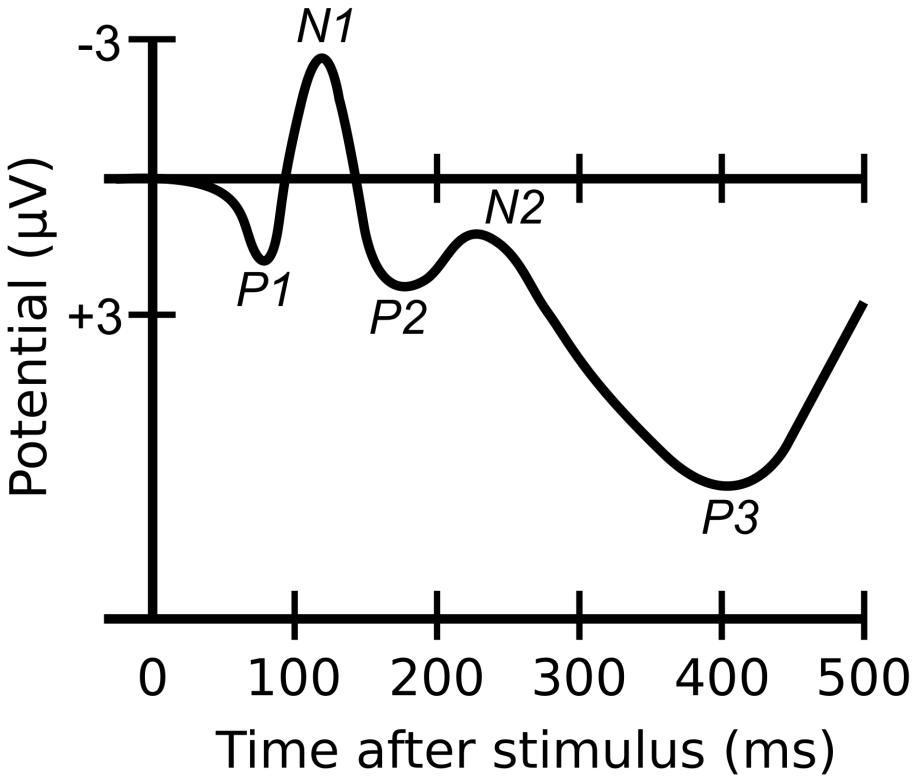
4. behavioral hypotheses: (a) Balanced trilinguals have better inhibitory control than balanced bilinguals; (b) Balanced bilinguals have better inhibitory control than unbalanced trilinguals (interaction effect).

EEG Components

- **P2:**
  - **Time:** a positive going electrical potential that peaks at about **200 milliseconds** (varying between about **150 and 275 ms**) after the onset of some external stimulus.
  - **Distribution position：** around the **centro-frontal and the parieto-occipital areas of the scalp.**
  - **Relevant Functional Features：**
    - indexes **selective attention** or **change detection**.
    - Subjects who have better inhibitory control: P2 appears **earlier** and have a **smaller amplitude**(Chung-Fat-Yim et al., 2021)
  - **Hn1：**
    - **P2 occurrence time**: balanced trilinguals (a) earlier than balanced bilinguals (b)； balanced bilinguals (c) earlier than unbalanced trilinguals (d)
    - **P2 amplitude**: a < b; c < d

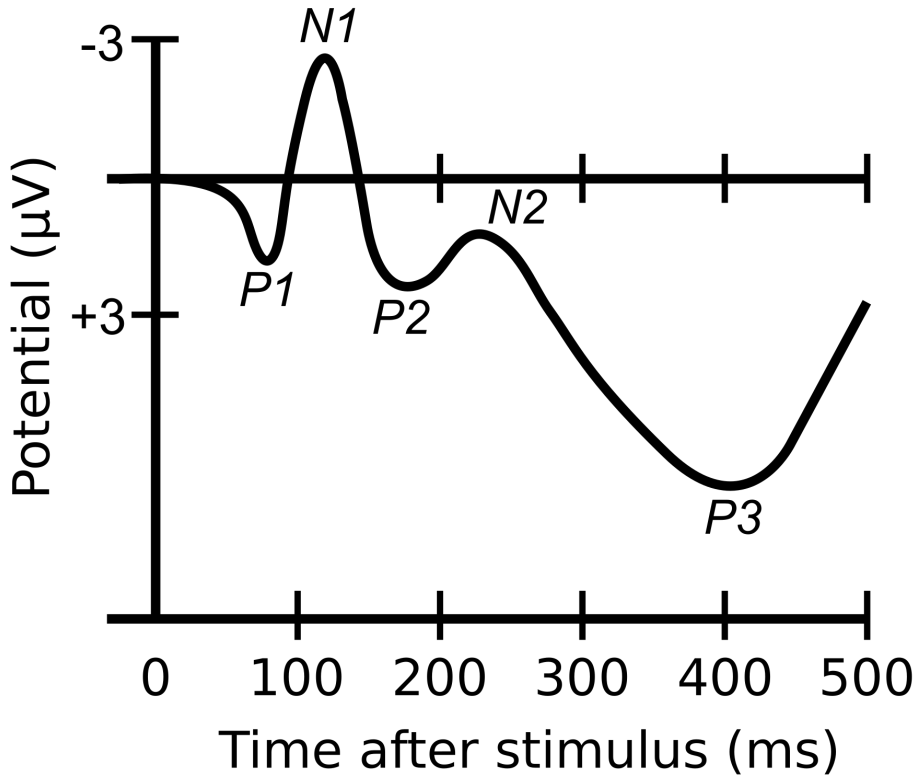


- **N2:**
  - **TIME：** a negative-going wave that peaks 200-350ms post-stimulus.
  - **Distribution position：** primarily over anterior scalp sites.
  - **Relevant Functional Features：**
    - **①conflict monitoring**
    - **②signalling for stronger cognitive control**
    - Subjects with better inhibitory control，N2 appears **earlier** & **higher amplitude** (Markiewicz et al., 2023)
  - **Hn1：**
    - **N2 occurrence time：** balanced trilinguals (a) earlier than balanced bilinguals (b)； balanced bilinguals (c) earlier than unbalanced trilinguals (d)
    - **N2 amplitude：** a > b ; c > d



P300:

- **TIME:** 300-440ms
- **Distribution position:**centro-parietal distribution
- **Relevant Functional Features：**
  - It is associated with **attentional resource allocation** during **stimulus categorisation**.
  - Subjects with better inhibitory control: P300 appears **earlier** & **smaller amplitude** (Markiewicz et al., 2023)
- **Hn3：**
- **P300 occurrence time:** balanced trilinguals (a) earlier than balanced bilinguals (b)； balanced bilinguals (c) earlier than unbalanced trilingual (d)
  - **P300 amplitude**： a < b; c < d



Research Design

Participant

- **Conventional standards:**students who is studying at the University of Macau; no neurological diseases, major mental health problems or audio-visual impairments
- **Language level:**

1. Initial Screening: Oral report bi- and trilinguals(fisrt language:Chinese; second language:Englsih;third language:Portuguese)

2. Usage Balance scale screening:

Usage Balance: defined as the balance in proficiency of the different languages mastered by the subjects

1) Proficiency Measure:

Scale: Dörnyei's (2010) CLASSIFICATION OF PROFICIENCY LEVEL AND REQUIREMENTS SCALE

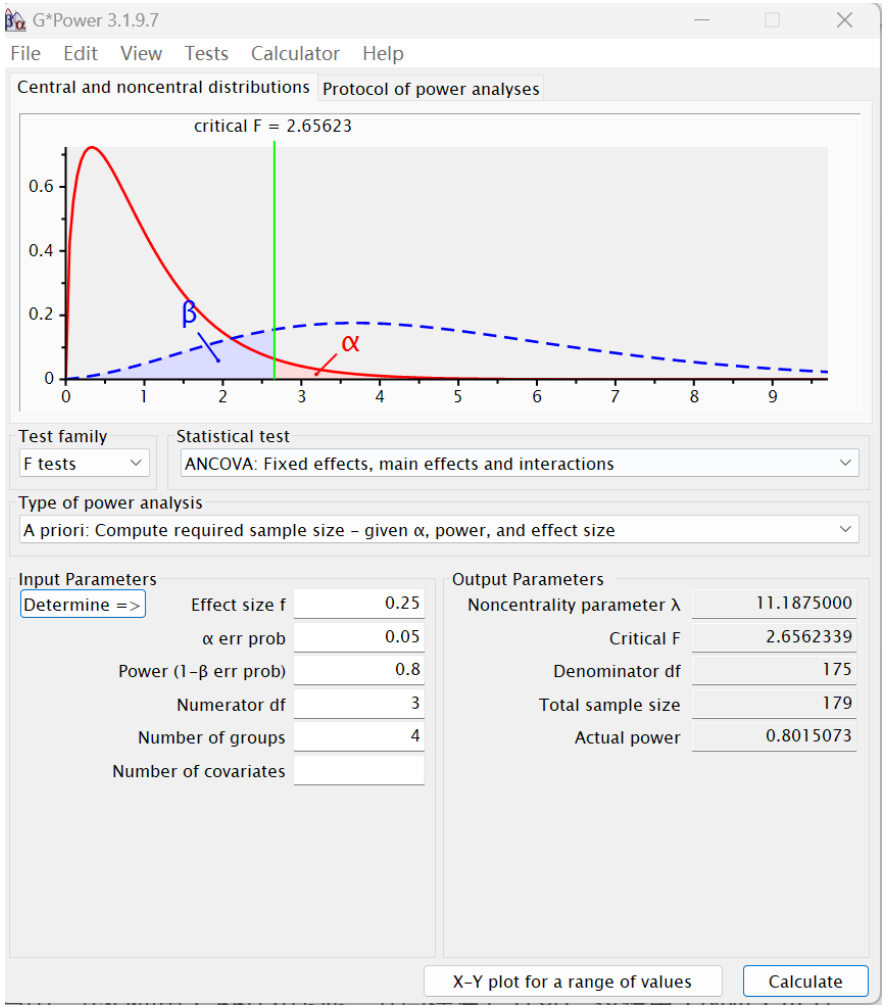
Scores: standardized language tests (e.g., Grade 6, TOEFL, IELTS, or other language tests,through questionnaire, served as an objective reference.

2)Balance measure:

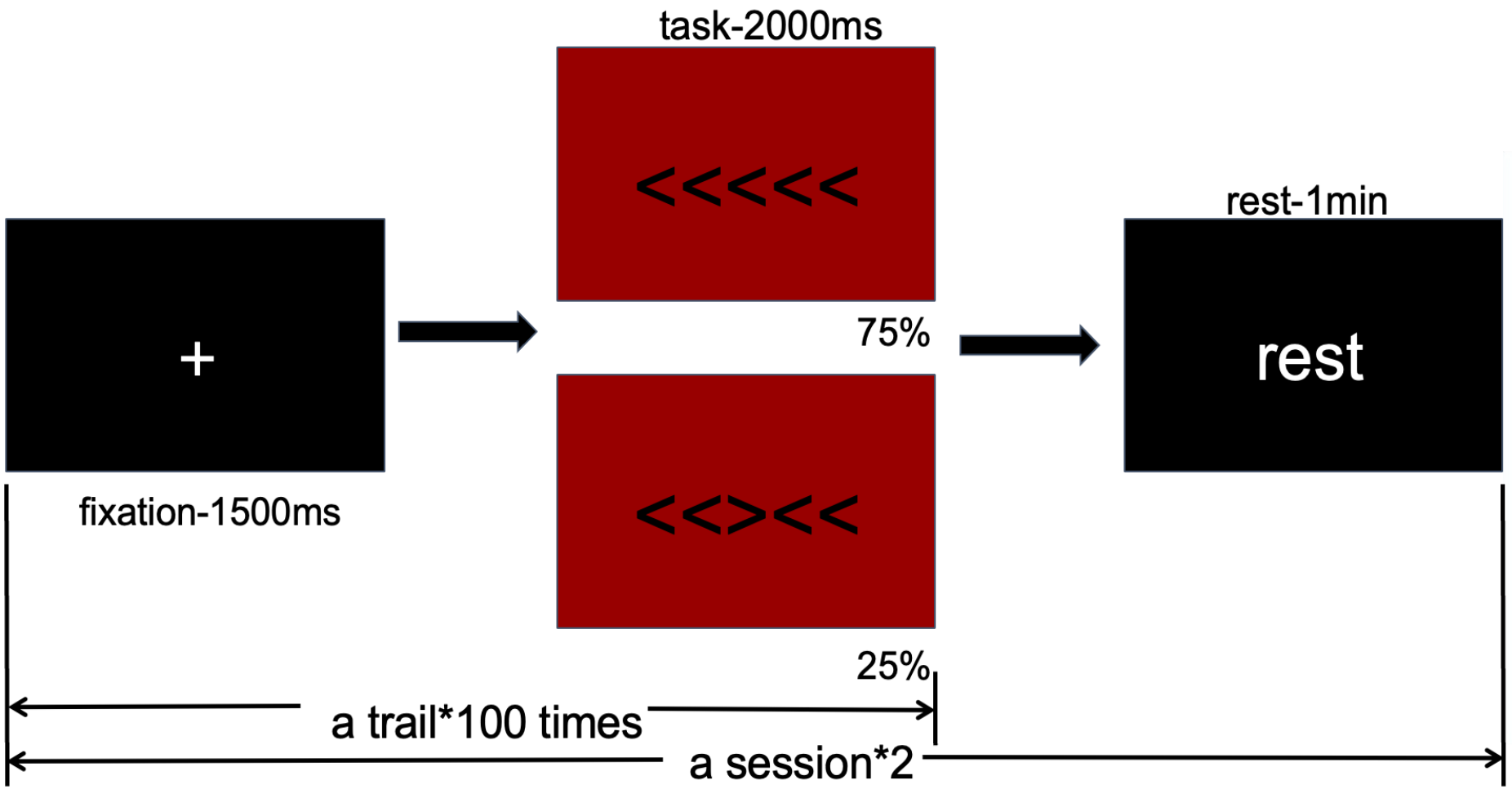
bilinguals:T-test; trilinguals:F-test

Participant

- **Subject category**
  - Balanced bilinguals
  - unbalanced bilinguals
  - balanced trilinguals
  - unbalanced trilinguals
- **Number：**
  - According to the G power:179
  - According to the feasiblity:8



Eriksen Flanker Task



EEG

■ Behavioural analysis:

①compute the conflict performance(reaction time and accuracy rate difference between inconsistent condition and consistent condition)

②test the difference of conflict performance among different language types and balanced types:

2 (language type: trilingual, bilingual) x 2 (balanced type: balanced, unbalanced) analysis of variance (ANOVA) (two-tailed,Significance level:0.05)

■ EEG data analysis:

ERP data were processed by tools such as EEGLAB, Fieldtrip and visual inspection.

A nonparametric cluster-based permutation test is used to assess differences in the magnitude and timing of ERP components (P2,N2,P300) in the 0-1 s time window after stimulus appearance:

- Compare consistent and inconsistent conditions to check for the presence of expected interference effects.
- Compare the differences in ERP components between the consistent and inconsistent conditions across groups.

Thank You!