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

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2024.4.22

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# Outline

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## Inhibitory Control &linguistics

- **Inhibitory control** (one of the core Executive Functions) involves being able to control one's attention, behavior, thoughts, and emotions to override a strong internal predisposition or external lure, and instead, do what's more appropriate or needed.
- **Bilinguals vs Monolinguals:**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.
- ? Inhibitory control ability:Bilinguals > Monolinguals

## Inhibitory Control &linguistics

- Numerous studies have shown that bilinguals possess enhanced inhibitory control compared to monolinguals (e.g., Bialystok et al., 2005； Martin-Rhee & Bialystok, 2008).
- However, some other studies did not find this bilingual advantage in inhibitory control (e.g., Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2015).
  - Defective 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 Control (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, our study refines the criteria for measuring multilingual users, aiming to explore how linguistic diversity (bilingual/trilingual) and usage balance (balanced/unbalanced) affect the inhibitory control of bilinguals and trilinguals, from a behavioral and neural perspective .

**Behavioral hypotheses:**

1.Balanced trilinguals have better inhibitory control than balanced bilinguals;

2. Balanced bilinguals have better inhibitory control than unbalanced trilinguals (interaction effect).

| EEG Component | Time and Distribution | Relevant Functional Features | Hypothesis |
|---|---|---|---|
| N1 | approximately 100 ms, occipital, parietal, central, and frontal electrode sites | Initial sensory and attentional processing;<br>The better the initial attention processing, the larger the amplitude. | amplitude:(a)>(b)>(d) |
| P2 | 150 and 275 ms;<br>around the centro-frontal and the parieto-occipital areas. | indexes selective attention or change detection;<br>better inhibitory control: earlier and smaller P2(Chung-Fat-Yim et al., 2021) | occurrence time: (a) earlier than (b) earlier than (d)<br>amplitude: a < b < d |
| N2 | 200-350ms;<br>anterior scalp sites. | ①conflict monitoring<br>②signalling for stronger cognitive control<br>better inhibitory control,<br>earlier & higher N2 | occurrence time: (a) earlier than (b) earlier than (d)<br>amplitude: a > b > d |
| P300 | 300-440ms;<br>centro-parietal areas | attentional resource allocation during stimulus categorisation.<br>better inhibitory control:<br>earlier & smaller p300(Markiewicz et al., 2023) | occurrence time: (a) earlier than (b) than (d)<br>amplitude: a < b < d |
| ERN | 80 to 150 milliseconds (ms) after the erroneous response begins;<br>frontal cortex | error detection<br>better inhibitory control:<br>larger ERN amplitude | amplitude:(a)>(b)>(d) |

(a)balanced trilinguals;

(b)balanced bilinguals;

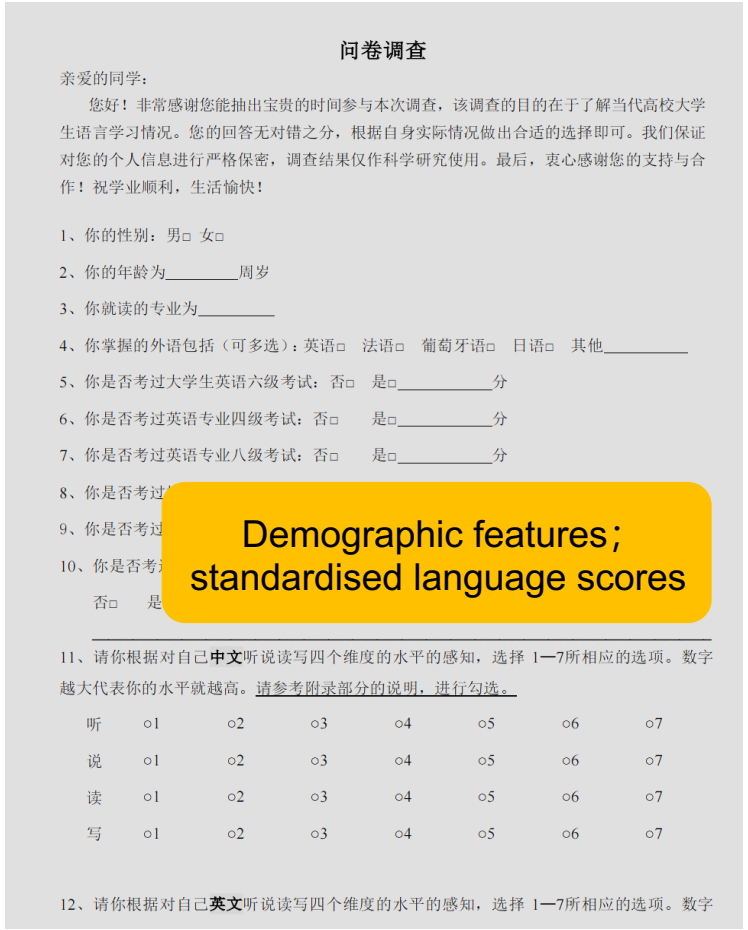
(c) unbalanced bilinguals

(d)unbalanced trilinguals

## Neural Level

Participant

Recruitment  trilingual and bilingual students in our class, screened according to conventional standars and questionaire: standardised language scores and **Language 7-point self-assessment scale(**revised from Common European Framework of Reference for Languages)



问卷调查

亲爱的同学：

您好！非常感谢您能抽出宝贵的时间参与本次调查，该调查的目的在于了解当代高校大学生语言学习情况。您的回答无对错之分，根据自身实际情况做出合适的选择即可。我们保证对您的个人信息进行严格保密，调查结果仅作科学研究使用。最后，衷心感谢您的支持与合作！祝学业顺利，生活愉快！

1、你的性别：男□ 女□

2、你的年龄为_____周岁

3、你就读的专业为_____

4、你掌握的外语包括（可多选）：英语□ 法语□ 葡萄牙语□ 日语□ 其他_____

5、你是否考过大学生英语六级考试：否□ 是□_____分

6、你是否考过英语专业四级考试：否□ 是□_____分

7、你是否考过英语专业八级考试：否□ 是□_____分

8、你是否考过

9、你是否考过

10、你是否考

否□ 是

Demographic features；standardised language scores

11、请你根据对自己**中文**听说读写四个维度的水平的感知，选择 1—7所相应的选项。数字越大代表你的水平就越高。请参考附录部分的说明，进行勾选。

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 听 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 说 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 读 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 写 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |

12、请你根据对自己**英文**听说读写四个维度的水平的感知，选择 1—7所相应的选项。数字

越大代表你的水平就越高。请参考附录部分的说明，进行勾选。

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 听 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 说 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 读 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 写 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |

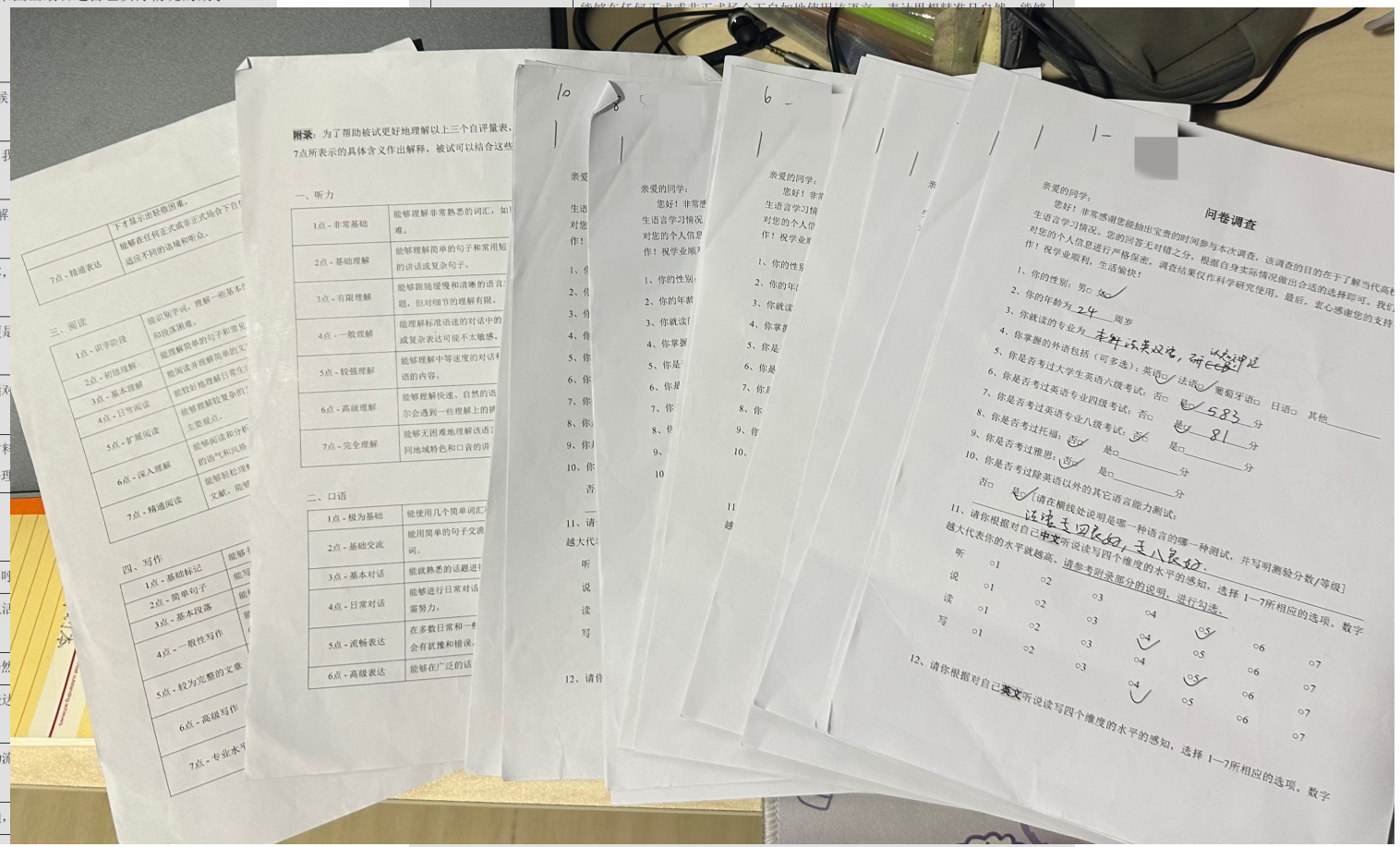
13、请你根据对自己**第二外语**听说读写四个维度的水平的感知，选择 1—7所相应的选项。数字越大代表你的水平就越高。请参考附录部分的说明，进行勾选。

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 听 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 说 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 读 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |
| 写 | ○1 | ○2 | ○3 | ○4 | ○5 | ○6 | ○7 |

**Language 7-point self-assessment scale**

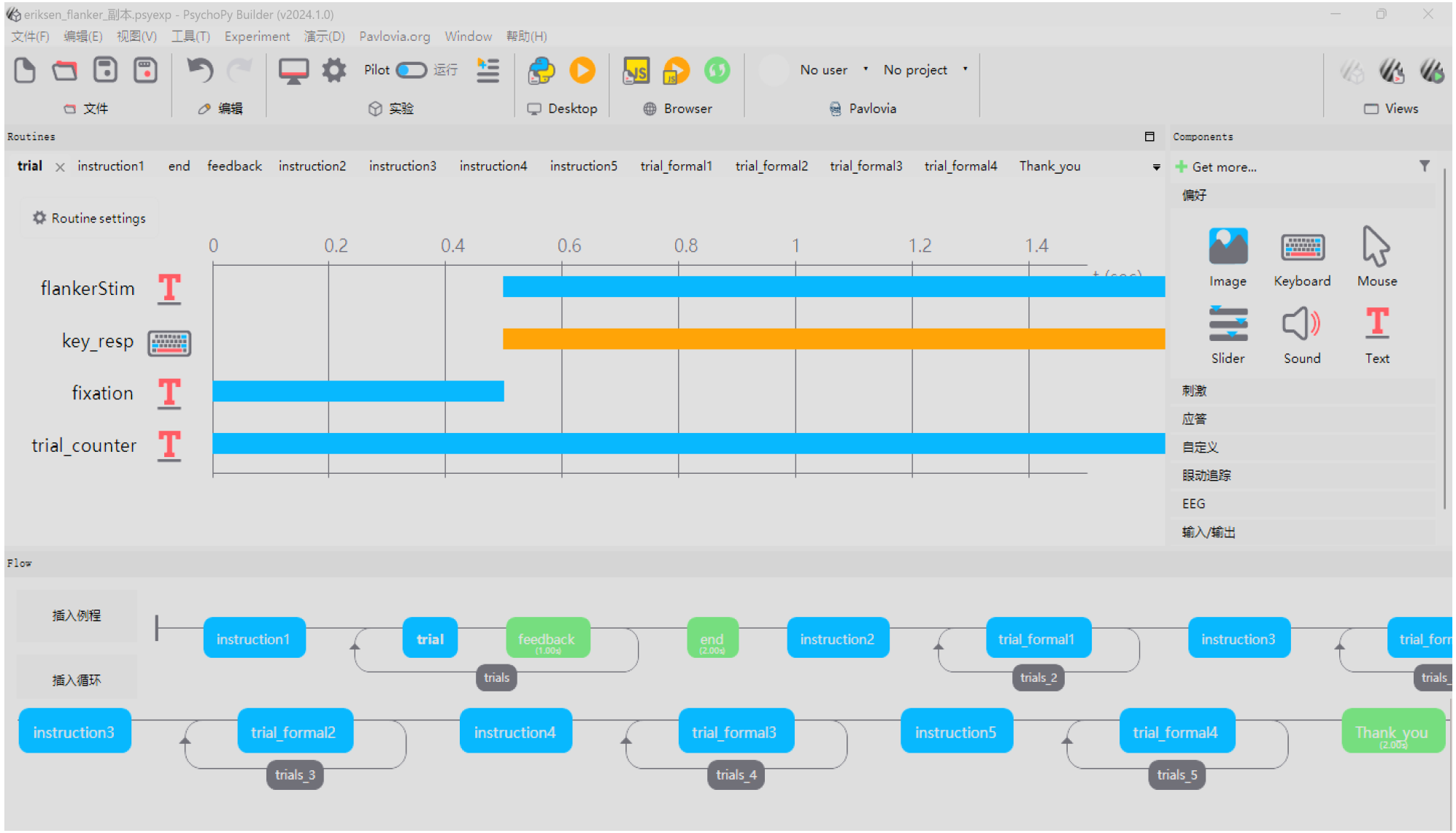
Participant

Recruitment  trilingual and bilingual students in our class, screened according to conventional standars and questionaire: standardised language scores and **Language 7-point self-assessment scale(**revised from Common European Framework of Reference for Languages)



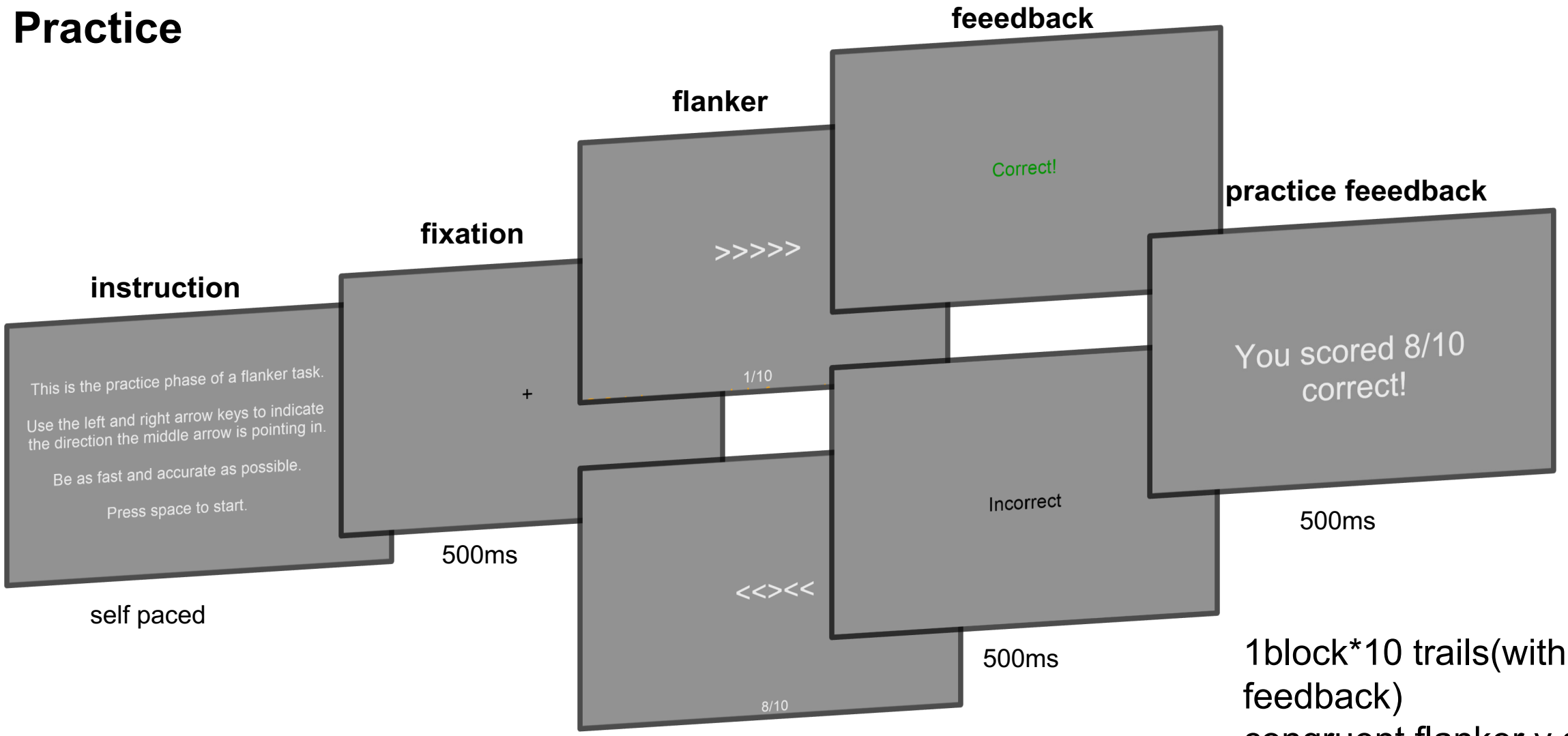

# Method

# Flanker task-psychopy



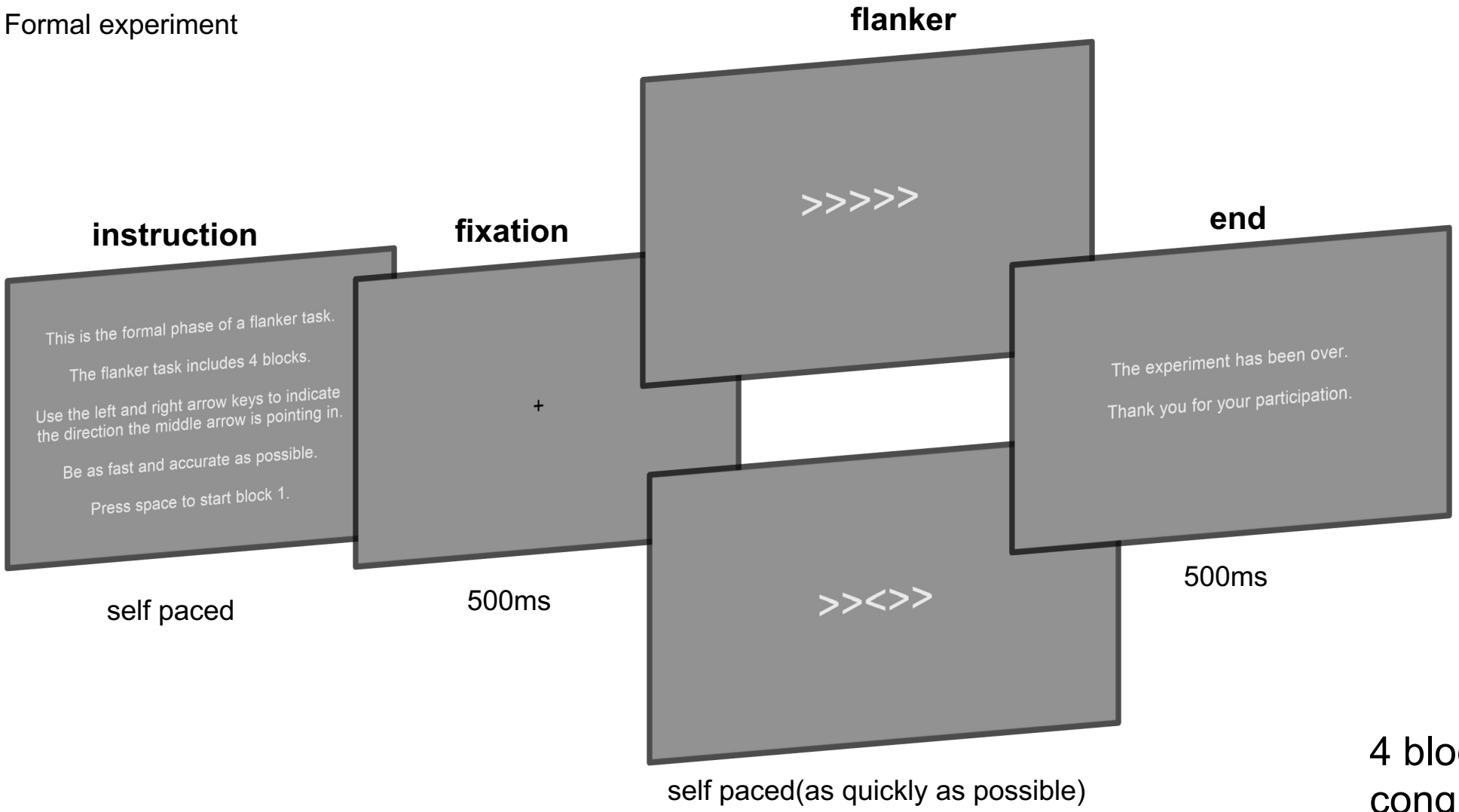

## Method

# Practice




1block*10 trails(with feedback)
congruent flanker v.s. incongruent flanker:3:1

Formal experiment




4 block*30 trails
congruent flanker v.s.
incongruent flanker:3:1

# Data Anlaysis & Results

## ■ Self-report analysis:

1. Standardization  Z score
2. Compare the differences to dvide balanced and unbalanced groups in bilinguals and trilinguals deparetely
3. T-test

- **Final participants' category**
  - 2 Balanced bilinguals
  - 3 unbalanced bilinguals
  - 2 balanced trilinguals
  - 3 unbalanced trilinguals

| | |
|---|---|
| 3 | b |
| 2 | a |
| 2 | a |
| 2 | b |
| 2 | a |
| 3 | a |
| 2 | b |
| 3 | a |
| 3 | b |
| 3 | a |

**Assumptions**

Normality Test (Shapiro-Wilk)

| | W | p |
|---|---|---|
| ▲1 | 0.840 | 0.164 |

*Note.* A low p-value suggests a violation of the assumption of normality

Homogeneity of Variances Test (Levene's)

| | F | df | df2 | p |
|---|---|---|---|---|
| ▲1 | 2.72 | 1 | 3 | 0.198 |

*Note.* A low p-value suggests a violation of the assumption of equal variances

[3]

Independent Samples T-Test

| | | Statistic | df | p |
|---|---|---|---|---|
| ▲1 | Student's t | −4.19 | 3.00 | 0.025 |

*Note.* $H_a\ \mu_b \neq \mu_a$

Independent Samples T-Test

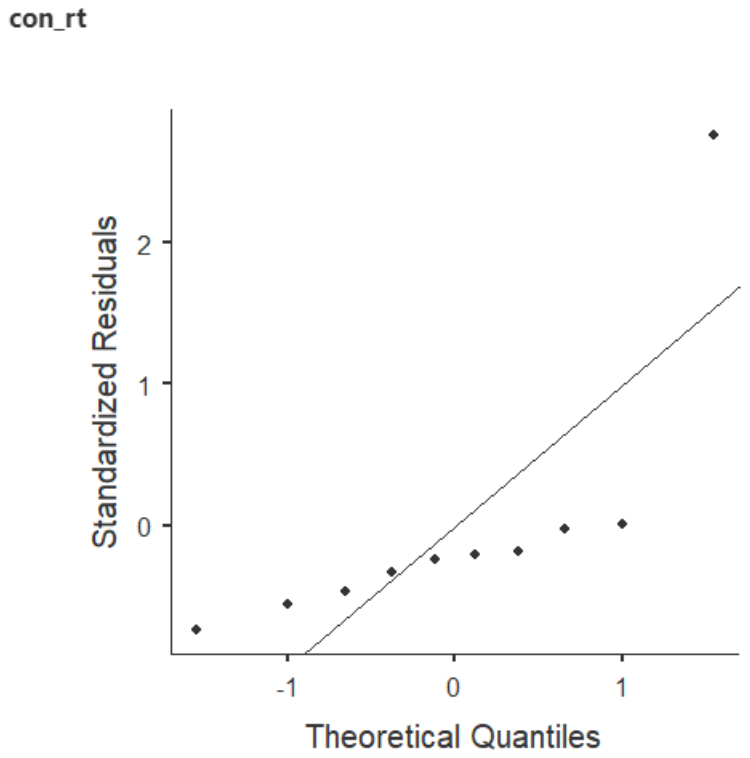
| | | Statistic | df | p |
|---|---|---|---|---|
| ▲2 | Student's t | −4.383 | 3.00 | 0.022 |
| ▲1 | Student's t | 0.979 | 3.00 | 0.400 |
| ▲3 | Student's t | −2.697 | 3.00 | 0.074 |

*Note.* $H_a\ \mu_b \neq \mu_a$

## Behavioural analysis:

Descriptives

| | con_acc | con_rt | incon_acc | incon_rt | acc | RT |
|---|---|---|---|---|---|---|
| N | 10 | 10 | 10 | 10 | 10 | 10 |
| Missing | 0 | 0 | 0 | 0 | 0 | 0 |
| Mean | 0.982 | 0.403 | 0.837 | 0.492 | 0.951 | 0.420 |
| Median | 0.994 | 0.380 | 0.875 | 0.436 | 0.971 | 0.392 |
| Standard deviation | 0.0229 | 0.102 | 0.144 | 0.181 | 0.0501 | 0.118 |
| Minimum | 0.947 | 0.327 | 0.541 | 0.363 | 0.850 | 0.334 |
| Maximum | 1.00 | 0.685 | 1.00 | 0.995 | 1.00 | 0.747 |




Outliar

## ■ Behavioural analysis:

Flanker task ——congruency

Independent Samples T-Test

| | | Statistic | df | p | | Effect Size |
|---|---|---|---|---|---|---|
| acc | Student's t | 3.40[a] | 16.0 | 0.004 | Cohen's d | 1.60 |
| rt | Student's t | −3.98 | 16.0 | 0.001 | Cohen's d | −1.88 |

*Note.* $H_a$ $\mu_1 \neq \mu_2$

[a] Levene's test is significant ($p < .05$), suggesting a violation of the assumption of equal variances

Group Descriptives

| | Group | N | Mean | Median | SD | SE |
|---|---|---|---|---|---|---|
| acc | 1 | 9 | 0.980 | 0.989 | 0.0233 | 0.00777 |
| | 2 | 9 | 0.819 | 0.875 | 0.1399 | 0.0466 |
| rt | 1 | 9 | 0.371 | 0.378 | 0.0251 | 0.00836 |
| | 2 | 9 | 0.437 | 0.434 | 0.0426 | 0.0142 |

## ■ Behavioural analysis:

Repeated measures ANOVA-Accuracy

### Repeated Measures ANOVA

Within Subjects Effects

| | Sum of Squares | df | Mean Square | F | p | $\eta^2_p$ |
|---|---|---|---|---|---|---|
| consist | 0.08451 | 1 | 0.08451 | 8.231 | 0.035 | 0.62 |
| consist ✻ language | 0.00156 | 1 | 0.00156 | 0.152 | 0.713 | 0.029 |
| consist ✻ balance | 0.00311 | 1 | 0.00311 | 0.303 | 0.606 | 0.057 |
| consist ✻ language ✻ balance | 0.00117 | 1 | 0.00117 | 0.114 | 0.750 | 0.022 |
| Residual | 0.05134 | 5 | 0.01027 | | | |

*Note.* Type 3 Sums of Squares

[3]

Between Subjects Effects

| | Sum of Squares | df | Mean Square | F | p | $\eta^2_p$ |
|---|---|---|---|---|---|---|
| language | 0.00167 | 1 | 0.00167 | 0.0998 | 0.765 | 0.020 |
| balance | 0.01095 | 1 | 0.01095 | 0.6530 | 0.456 | 0.116 |
| language ✻ balance | 0.00213 | 1 | 0.00213 | 0.1273 | 0.736 | 0.025 |
| Residual | 0.08385 | 5 | 0.01677 | | | |

*Note.* Type 3 Sums of Squares

### Post Hoc Tests

Post Hoc Comparisons - consist

| Comparison | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| consist | | consist | Mean Difference | SE | df | t | p | $p_{bonferroni}$ |
| con | - | incon | 0.151 | 0.0527 | 5.00 | 2.87 | 0.035 | 0.035 |

[4]

With accuracy as the dependent variable, the main effect of consistency was significant, $F(1, 5) = 8.23$, $p = .035$, $\eta^2_p = 0.622$, but the main effect of language and balance was not significant.

Post hoc analysis found that there is significant difference between consistent condition and inconsistent condition ($t(5) = 2.87$, $p = .035$).

- RT

With response time as the dependent variable, repeated measures ANOVA showed significant main effect of consistency, $F(1, 5) = 173.68$, $p < .001$, $\eta^2_p = 0.972$, and significant interaction effect of consistency and balance, $F(1, 5) = 9.81$, $p = .026$, $\eta^2_p = 0.662$, but the main effect of language and balance was not significant.

Post hoc analysis found that there is no significant difference in the balance group and the unbalanced group in the consistent condition, but in the inconsistent condition, the balanced group was significantly higher than the unbalanced group ($t(5) = 2.59$, $p = .049$).

## Repeated Measures ANOVA

Within Subjects Effects

| | Sum of Squares | df | Mean Square | F | p | $\eta^2_p$ |
|---|---|---|---|---|---|---|
| consist | 0.01899 | 1 | 0.01899 | 173.680 | < .001 | 0.972 |
| consist ✻ language | 2.23e−5 | 1 | 2.23e−5 | 0.204 | 0.670 | 0.039 |
| consist ✻ balance | 0.00107 | 1 | 0.00107 | 9.809 | 0.026 | 0.662 |
| consist ✻ language ✻ balance | 1.19e−5 | 1 | 1.19e−5 | 0.108 | 0.755 | 0.021 |
| Residual | 5.47e−4 | 5 | 1.09e−4 | | | |

*Note.* Type 3 Sums of Squares

[3]

Between Subjects Effects

| | Sum of Squares | df | Mean Square | F | p | $\eta^2_p$ |
|---|---|---|---|---|---|---|
| language | 1.19e−5 | 1 | 1.19e−5 | 0.00763 | 0.934 | 0.002 |
| balance | 0.00861 | 1 | 0.00861 | 5.54062 | 0.065 | 0.526 |
| language ✻ balance | 0.00156 | 1 | 0.00156 | 1.00250 | 0.363 | 0.167 |
| Residual | 0.00777 | 5 | 0.00155 | | | |

*Note.* Type 3 Sums of Squares

## Post Hoc Tests

Post Hoc Comparisons - consist

| Comparison | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| consist | | consist | Mean Difference | SE | df | t | p | $p_{bonferroni}$ |
| con | - | incon | −0.0717 | 0.00544 | 5.00 | −13.2 | < .001 | < .001 |

Post Hoc Comparisons - consist ✻ balance

| Comparison | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| consist | balance | | consist | balance | Mean Difference | SE | df | t | p | $p_{bonferroni}$ |
| con | banlaced | - | con | unbalanced | 0.0313 | 0.01625 | 5.00 | 1.92 | 0.113 | 0.675 |
| | | - | incon | banlaced | −0.0887 | 0.00905 | 5.00 | −9.80 | < .001 | 0.001 |
| | | - | incon | unbalanced | −0.0234 | 0.01946 | 5.00 | −1.20 | 0.283 | 1.000 |
| | unbalanced | - | incon | banlaced | −0.1200 | 0.02285 | 5.00 | −5.25 | 0.003 | 0.020 |
| | | - | incon | unbalanced | −0.0547 | 0.00604 | 5.00 | −9.06 | < .001 | 0.002 |
| incon | banlaced | - | incon | unbalanced | 0.0653 | 0.02524 | 5.00 | 2.59 | 0.049 | 0.293 |

# Summary

- There is no significant difference in inhibitory control between bilinguals and trilinguals (consistent with previous studies, like Poarch and van Hell in 2012). Moreover, under conflict conditions, participants with unbalanced language proficiency exhibit better inhibitory functions compared to those with balanced language proficiency.

- Inconsistent with initial hypotheses:
  [1] Balanced trilinguals have better inhibitory control than balanced bilinguals;
  [2] Balanced bilinguals have better inhibitory control than unbalanced trilinguals.

- Possible reasons: sample size & experimental design.

## Specific Defects

- Insufficient sample size: between-subjects design(4 groups, 2-3per/group).
- Use a non-semantic flanker task (left and right arrows).
- Self-report scales cannot represent participants' actual language proficiency.
- No maximum reaction time setting in PsychoPy.

## Future Work

- Increase the sample size.
- Use a semantically related flanker task.
- Employ more precise tasks of language ability such as Oxford Online Placement Test.
- Establish a time threshold: taking too long to respond is automatically counted as incorrect.

**Wang Rao:**
**Propose research idea, Design questionnaire and experiment**

**Gao Wenyue:**
**Organize the literature, Collect experimental data**

**Zhu Jiajia:**
**Data analysis, Make a PowerPoint presentation**

# Thank You!