Cognitive Load and Language Dominance: Bilingual performance in a Dual –Task Paradigm

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Objective

- To explore whether individuals perform better in their dominant language even under higher cognitive load.

What is Language Dominance?

- The dominance of a language has been referred to as the language which is stronger in a bilingual's mind, where a bilingual is referred to as someone who is proficient in two languages (Chow, 2015).

Language Activation

- Focused on the **Language Activation Model** (Pavlenko)
- **Activation:** Refers to words waiting to be retrieved for recognition and production
- **Bilingual Mind Interaction:** Dual language activation complicates word retrieval (Pavlenko, 2012)

Bilingual Interactive Activation (BIA) Model (Dijkstra & van Heuven, 2002):

- **BIA Model:** Word presented visually activates the word in the language it was written
- **BIA+ Model:** Adds phonology and orthography retrieval, enhances activation of one language while suppressing the other

Caution in Language Activation:

- Need to control influences that may affect language activation measurement

Relevance to Study:

- BIA+ framework explains the suppression and activation of languages in bilingual individuals
- Important for understanding language dominance and cross-language processing

Cognitive Load Framework

A popular theoretical framework in learning and instruction research (Choi et al., 2014)

Key Assumptions:

- Working memory has **limited capacity**
- Efficient resource use **enhances learning**

Cognitive Load Effects:

- Split attention, poor text-image format, etc.

Measurement Methods:

- **Subjective:** Self-rating scales (prone to bias)
- **Objective:**
    - Secondary task performance
    - **Eye-tracking**, **pupillometry**
    - Behavioural data (Korbach et al., 2018)

Visual Identity Matching

Importance of images

- Experiments designed – picture naming, word-picture matching, visual paradigm, and translation equivalence

Line drawings vs. photographs

- Line drawings - schematic, simple, and prototypical representations of concepts
- Photographs - realistic depiction that includes colour and surface features like texture, along with information about volume, brightness, and shade

Better contextual cues à Language production, comprehension, vocabulary and linguistic structures

Dual Task Paradigm

- Used to assess **attentional resource demands** in cognitive processes (de Bruin & McGarrigle, 2024)
- Participants complete **two tasks simultaneously**
- Example: **Picture naming (primary)** + **Tone response (secondary)**

- **Key Assumption:**
  - Assumes a **shared pool of attentional resources**
- **Interpretation:**
  - If the primary task demands more attention, **secondary task RT increases**
  - Secondary task performance is a **measure of cognitive load**

Dual Task Paradigm (Cont.)

Evidence from Research:

- **Piai & Roelofs (2013):**
  - Primary: Picture-word matching with distractors
  - Secondary: Responding to pitch tones
  - Result: Increased difficulty → **slower secondary task response**

Implications:

- Slower RT may reflect **task prioritization or increased cognitive load**
- Helps assess **working memory and cognitive capacity**

Dual task paradigm is effective in **language production research** to study **resource allocation**

Digit Span Recall

- First described by **Kahneman & Beatty (1966)**
- Measures **short-term memory** using number sequences

- **Associated Processes Studied:**
  - **Rehearsal** (Kahneman & Wright, 1971)
  - **Grouping** (Kahneman et al., 1968)
  - **Long-term recall** (Beatty & Kahneman, 1966)
- **Pupil Dilation Insight:**
  - **0.5 mm dilation plateau** at 7-digit point (Peavler, 1974)
  - Confirms **working memory load** (Granholm et al., 1996; Klingner et al., 2011)

Digit Span Recall (Cont.)

Language & Dyslexia Studies:

- Used by **Helland & Asbjørnsen (2004)** for dyslexic vs control comparison
- Assessed **language comprehension & math skills**

Cognitive Load Assessment:

- Common in **n-back tasks**
- Used in **3-back designs** to evaluate **working memory load**

N – back Task

- A **working memory task** that varies **cognitive load** (von Janczewski et al., 2021)

Task Design:

- Sequential stimuli (e.g., **numbers/letters**) shown with **fixed pauses**
- Participants respond to stimulus shown **‘n’ steps back**

N-Back Level	Sample Sequence	Correct Response	Cognitive Load
0-back	7 – 4 – 9 – 5 – 2	Say **target number shown** (e.g., “5”)	**Low (Baseline)**
1-back	3 – 6 – 8 – 2 – 7	Say number **1 step before** (e.g., for “2” → “8”)	**Mild Load**
2-back	5 – 1 – 9 – 3 – 6	Say number **2 steps before** (e.g., for “3” → “1”)	**Moderate Load**
3-back	2 – 8 – 4 – 7 – 3	Say number **3 steps before** (e.g., for “7” → “2”)	**High Load**

Participants

- B.Tech till PhD students of IIT Guwahati
- Age: 18 – 30 years
- Bengali bilinguals and Hindi bilinguals

Tools

- Google form
- Language background questionnaire adapted from LEAP-Q and Language History Questionnaire-3(LHQ3)
- E-prime 3.0
- Tobii Pro Fusion 250 Hz
- Tobii Pro Lab
- E-prime Extension for Tobii Pro 3.2
- Python
- Likert Scale

Experiment 1

Groups: Bengali – English bilinguals & Hindi – English bilinguals

No. of Bengali participants: 32

No. of Hindi participants: 90

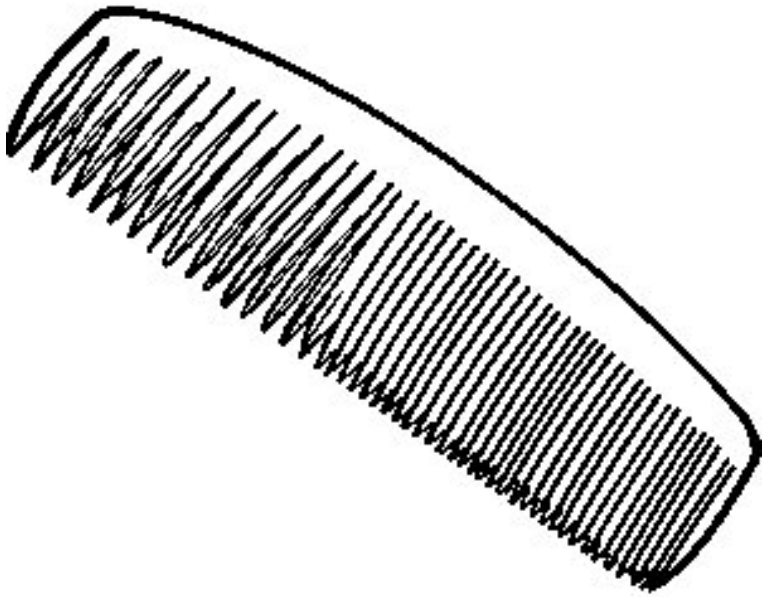
Database: The International Picture Naming Project

Tools: E-prime 3

Pre-Processing

- 2 levels of pre-processing
- Familiarity testing of the images and words
- Relevant for the study
- Reliable for the study
- Likert scale Rating between 1-5
- Images and words with Highest rate of familiarity

Images Used in the Experiment



Task 1

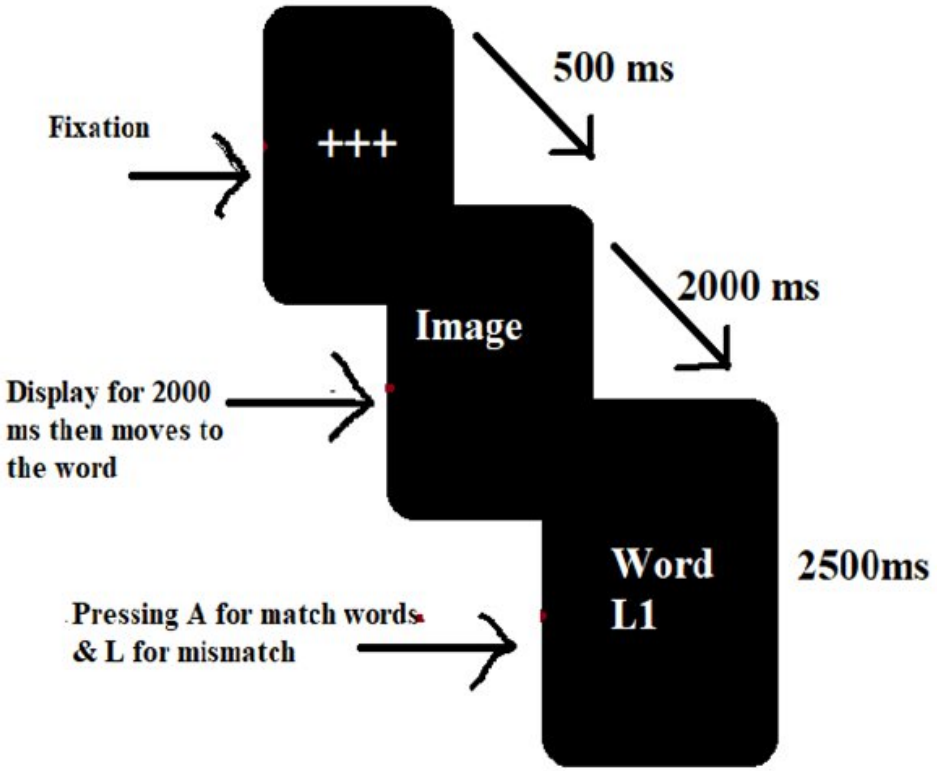


Fig.1: Design of Task 1

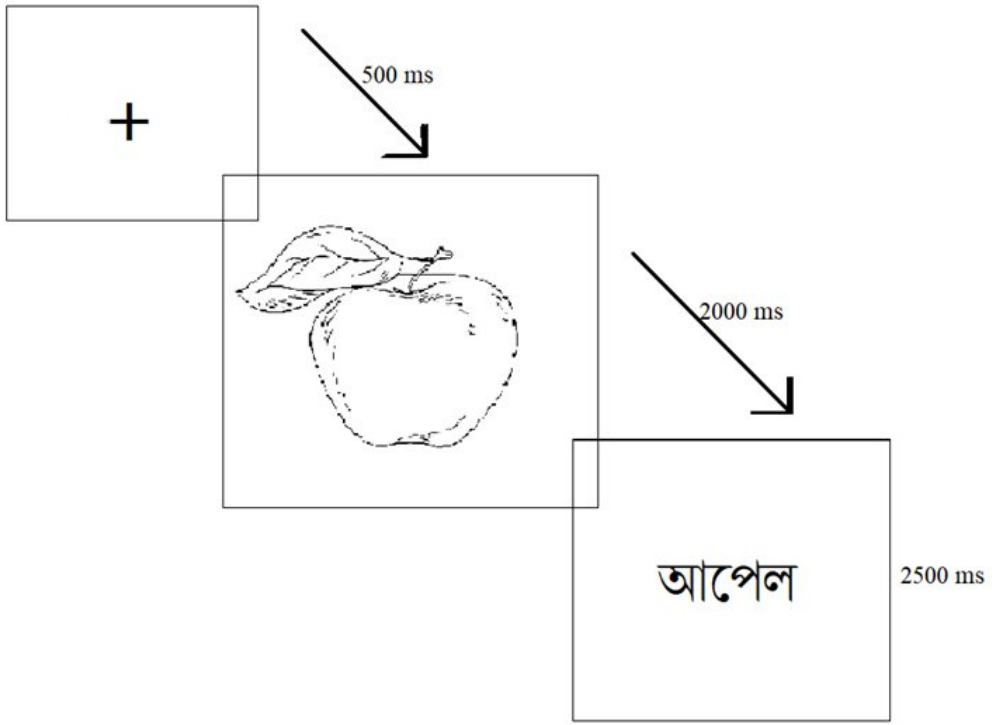


Fig 2: Experimental Design of Task 1

Task 2

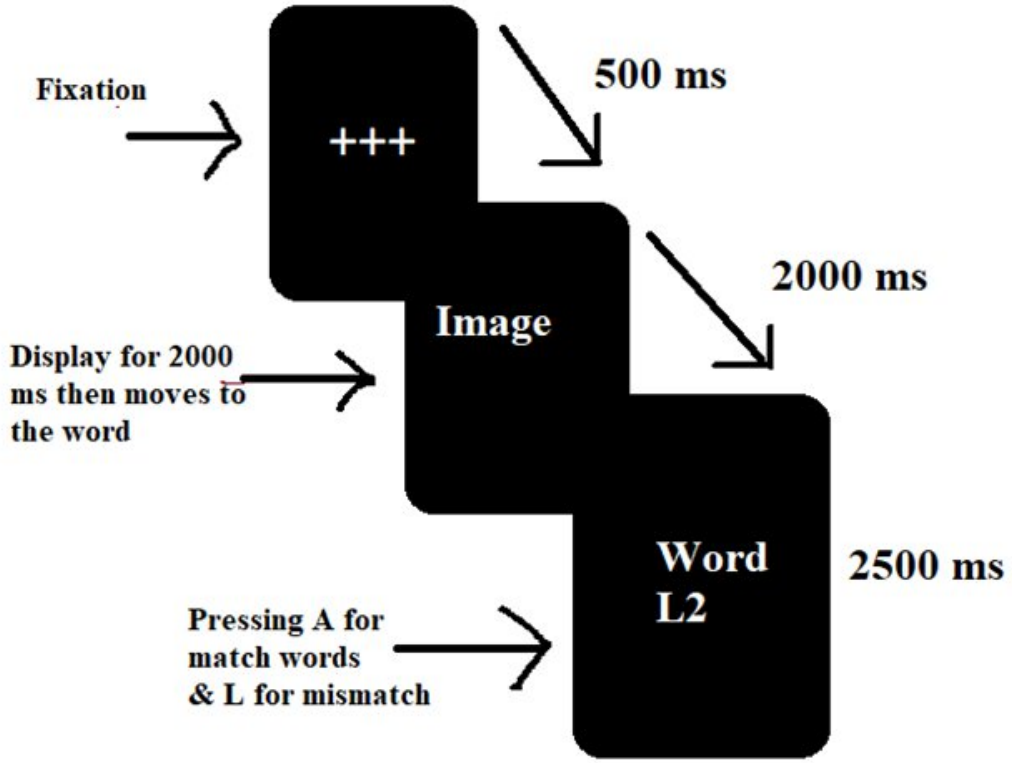


Fig.3: Design of Task 2

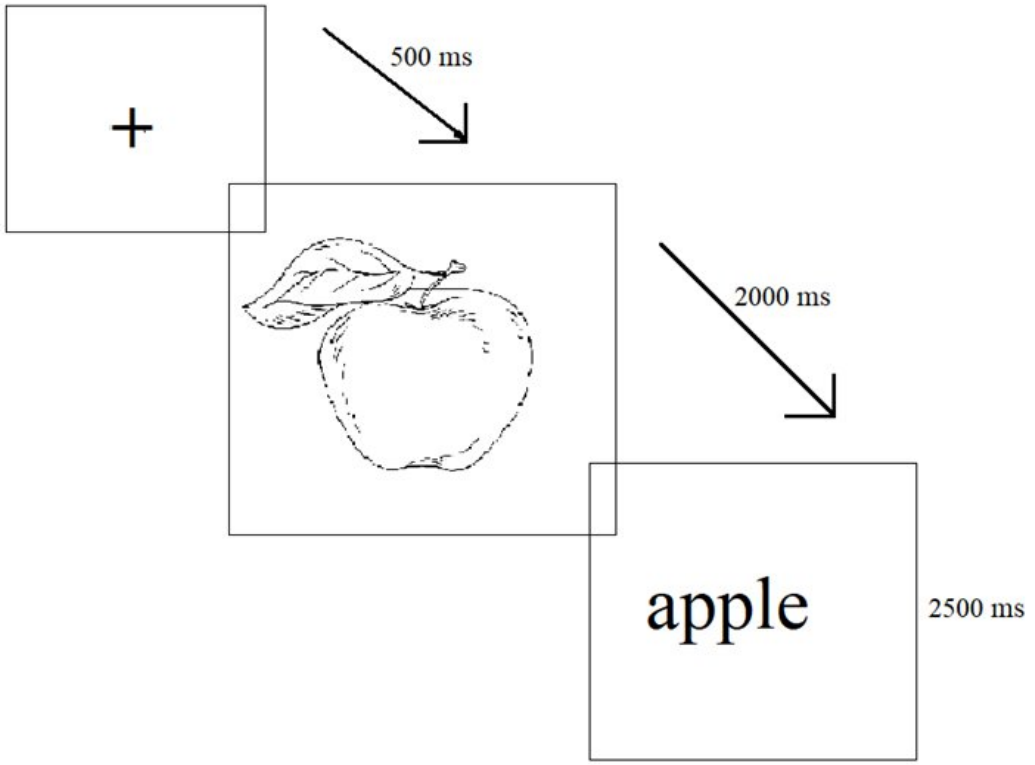


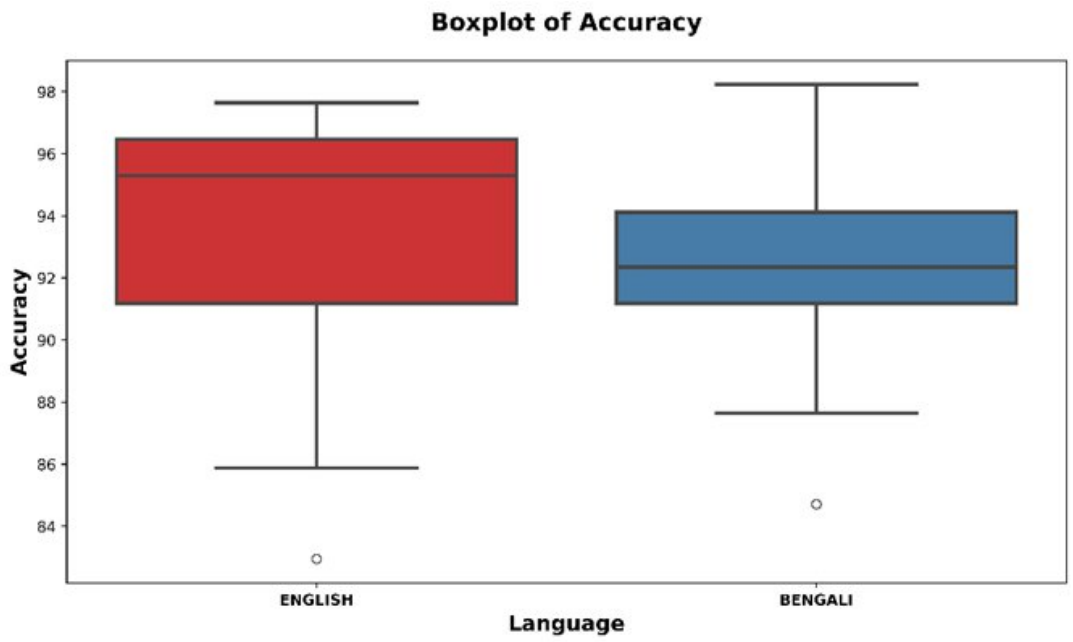
Fig 4: Experimental Design of Task 2

Results:

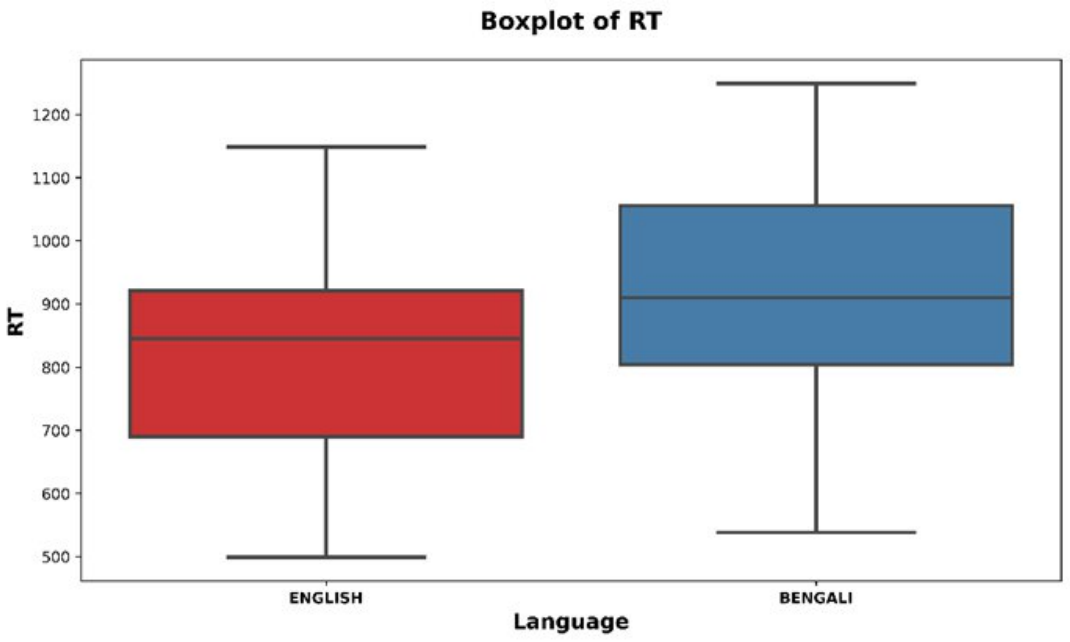
Descriptive Statistics

Bengali – English Bilinguals

	Mean	**Median**	**SD**
Accuracy_Bengali	92.31	92.35	3.17
Accuracy_English	93.57	95.29	3.76
RT_Bengali	911.33	910.02	191.95
RT_English	815.75	844.96	178.38



Boxplot of Accuracy of English –Bengali



Boxplot of Response time of English –Bengali

Normality Testing:

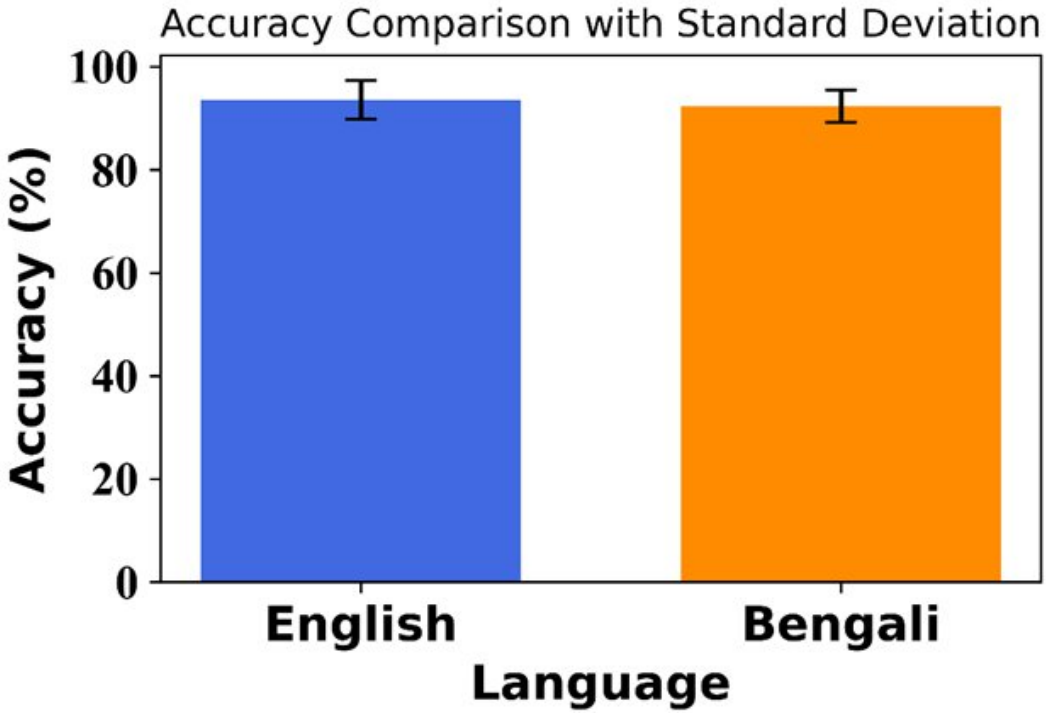
- Shapiro-Wilk test was used to assess normality for both **Response Time (RT)** and **accuracy**.

RT (Response Time):

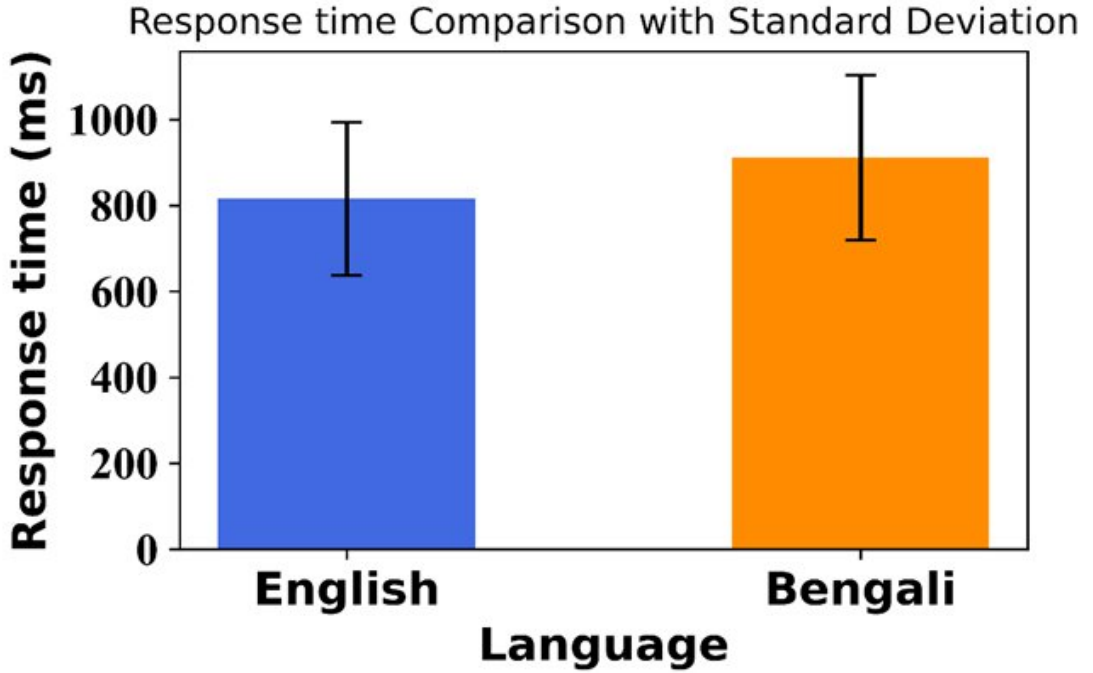
- Both **L1 and L2 RT data** were normally distributed.
- → A **t-test** was conducted to compare the means between the two groups.

Accuracy:

- **L1 accuracy** data was normally distributed.
- **L2 accuracy** data **did not** follow a normal distribution.



Bar graph of Accuracy of English and Bengali



Bar graph of Response Time of English and Bengali

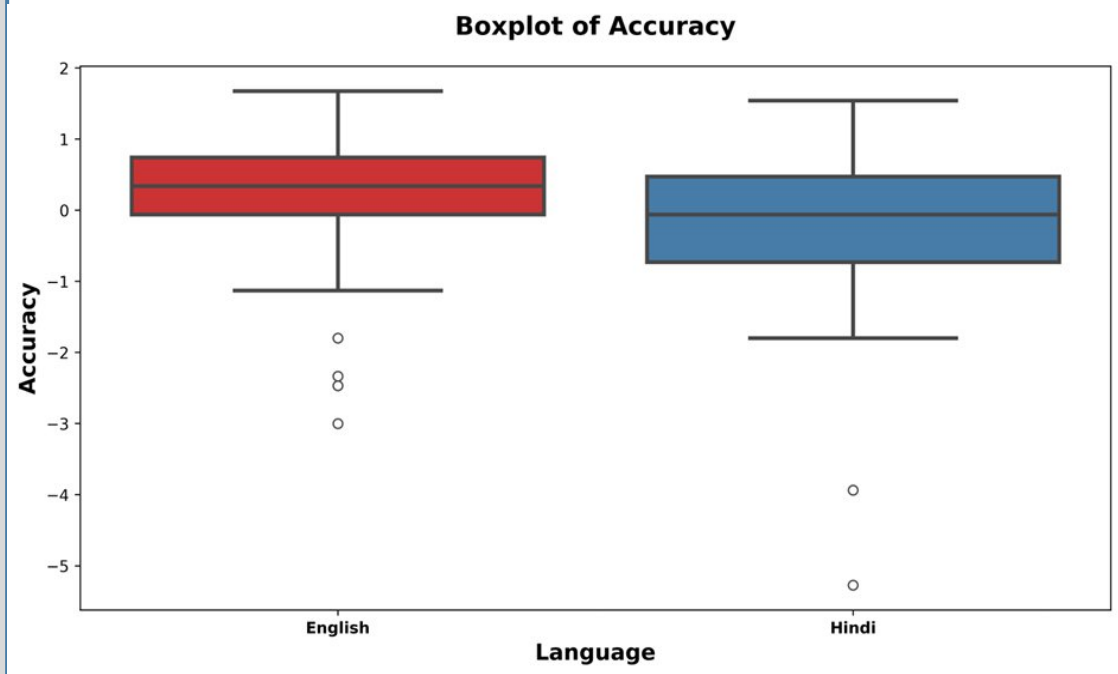
Measure	Statistical Test	p-value	Interpretation
Response Time (RT)	Independent t-test	0.048	Statistically significant difference ($p < 0.05$); L2 English has a significantly faster RT than L1 Bengali.
Accuracy	Mann–Whitney U Test	0.037	Statistically significant difference ($p < 0.05$); L2 English has significantly better accuracy than L1 Bengali.

Results:

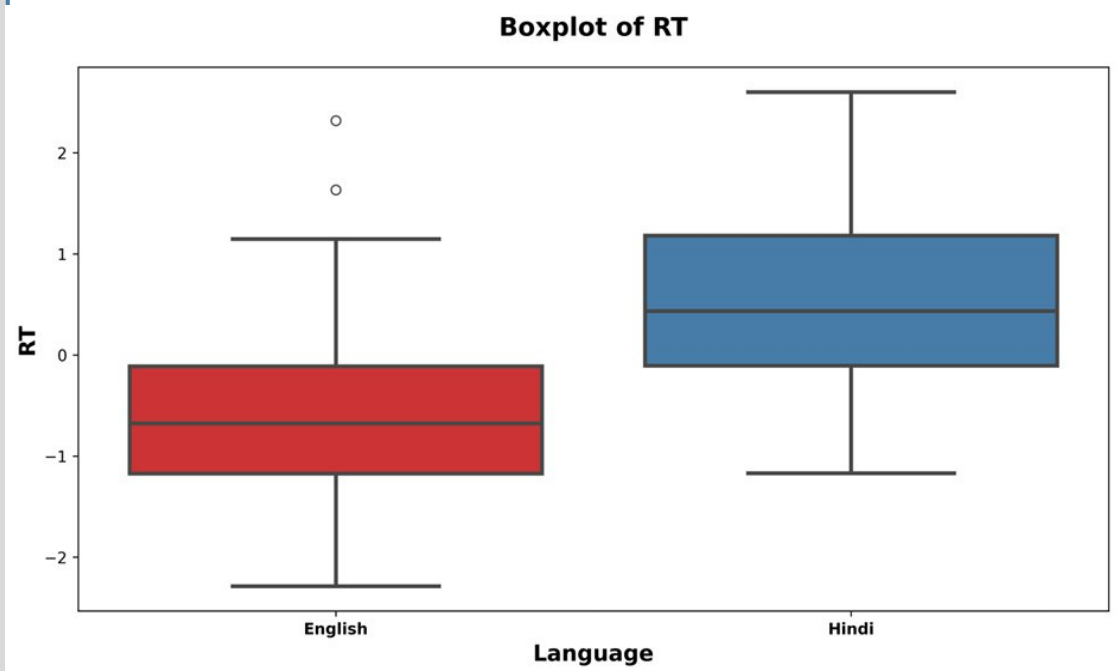
Descriptive Statistics

Hindi – English Bilinguals

	Mean	**Median**	**SD**
Accuracy_Hindi	91.18	91.77	4.77
Accuracy_English	92.89	93.53	3.87
RT_Hindi	835.07	814.75	161.84
RT_English	632.06	607.5	152.79



Boxplot of Accuracy of English –Hindi



Boxplot of RT of English –Hindi

Measure	Statistical Test	p-value	Interpretation
Response Time (RT)	Mann–Whitney U Test	< 0.005	Highly significant ($p < 0.05$); L2 English shows significantly faster RT than L1 Hindi.
Accuracy	Mann–Whitney U Test	0.004	Highly significant ($p < 0.05$); L2 English shows significantly better accuracy than L1 Hindi.

Experiment 2

- **Groups:** Hindi – English bilinguals
- **No. of Hindi participants:** 37
- **Database:** The International Picture Naming Project
- **Tools:** E-prime 3, Tobii Pro Fusion 250 Hz, Tobii Pro Lab, E-prime Extension for Tobii Pro 3.2

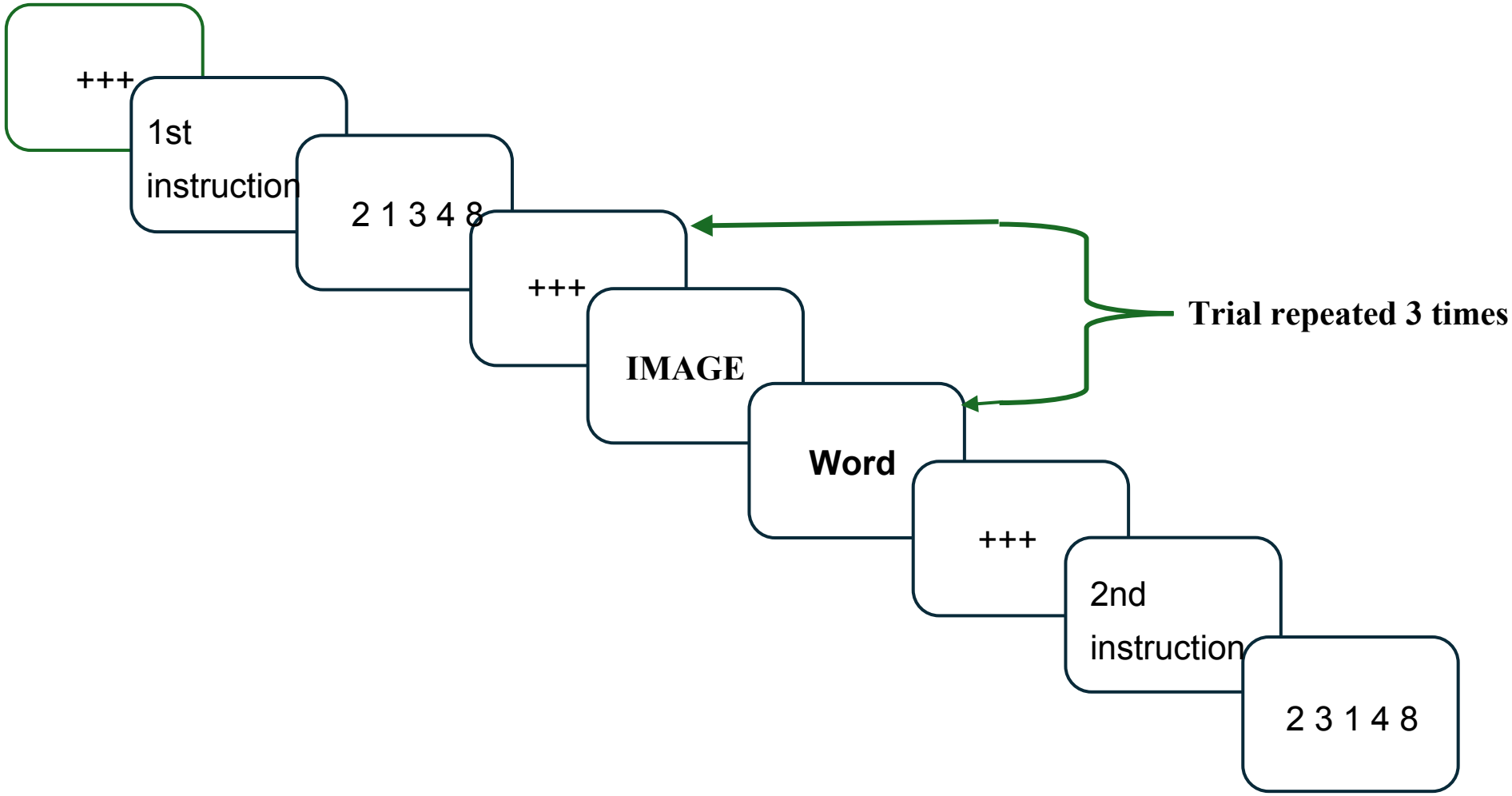
Design and Setup

Primary Task:

- **Picture-Word Matching**
- Used the **same stimuli** as in Experiment 1

Secondary Task:

- **Digit Span Recall (3-back task)**
- After every **3 trials** of the primary task, a digit sequence appeared.
- Participants had to identify if the current sequence matched the previous one.
- Each sequence: **Single digits**, **maximum length of 5 digits**


+++
1st instruction
2 1 3 4 8
+++
IMAGE
Word
+++
2nd instruction
2 3 1 4 8
Trial repeated 3 times

Results:

Descriptive Statistics

Hindi – English Bilinguals

	Mean	**Median**	**SD**
Accuracy_Hindi	91	91.3	2.88
Accuracy_English	94.11	95.24	4.99
RT_Hindi	1208.85	1172.66	259.5
RT_English	875.16	875.95	167.15

Normality Testing:

- Conducted using **Shapiro-Wilk test** for both **Response Time (RT)** and **accuracy**.
- Purpose: To check if data is **normally distributed** across L1 and L2 groups.

Response Time (RT):

- RT data for **both L1 and L2** followed a **normal distribution**.
- → **t-test** was used to compare the means of the two groups.

Accuracy:

- Accuracy data for **both L1 and L2 did not** follow a normal distribution.
- → **Mann-Whitney U test** was used for comparison.

Task	Measure	Statistical Test	p-value	Statistical Significance	Interpretation
Primary Task	Response Time (RT)	Independent t-test	< 0.005	**Highly significant** ($p < 0.05$)	L2 (English) showed significantly better RT despite cognitive load.
	Accuracy	Mann–Whitney U Test	< 0.005	**Highly significant** ($p < 0.05$)	L2 (English) showed significantly higher accuracy in the primary task.
Secondary Task	Response Time (RT)	Mann–Whitney U Test	0.065	Not significant ($p > 0.05$)	No statistically significant difference, although L2 performance was slightly better.
	Accuracy	Mann–Whitney U Test	0.316	Not significant ($p > 0.05$)	No significant difference in accuracy between L1 and L2.

Pupillometry

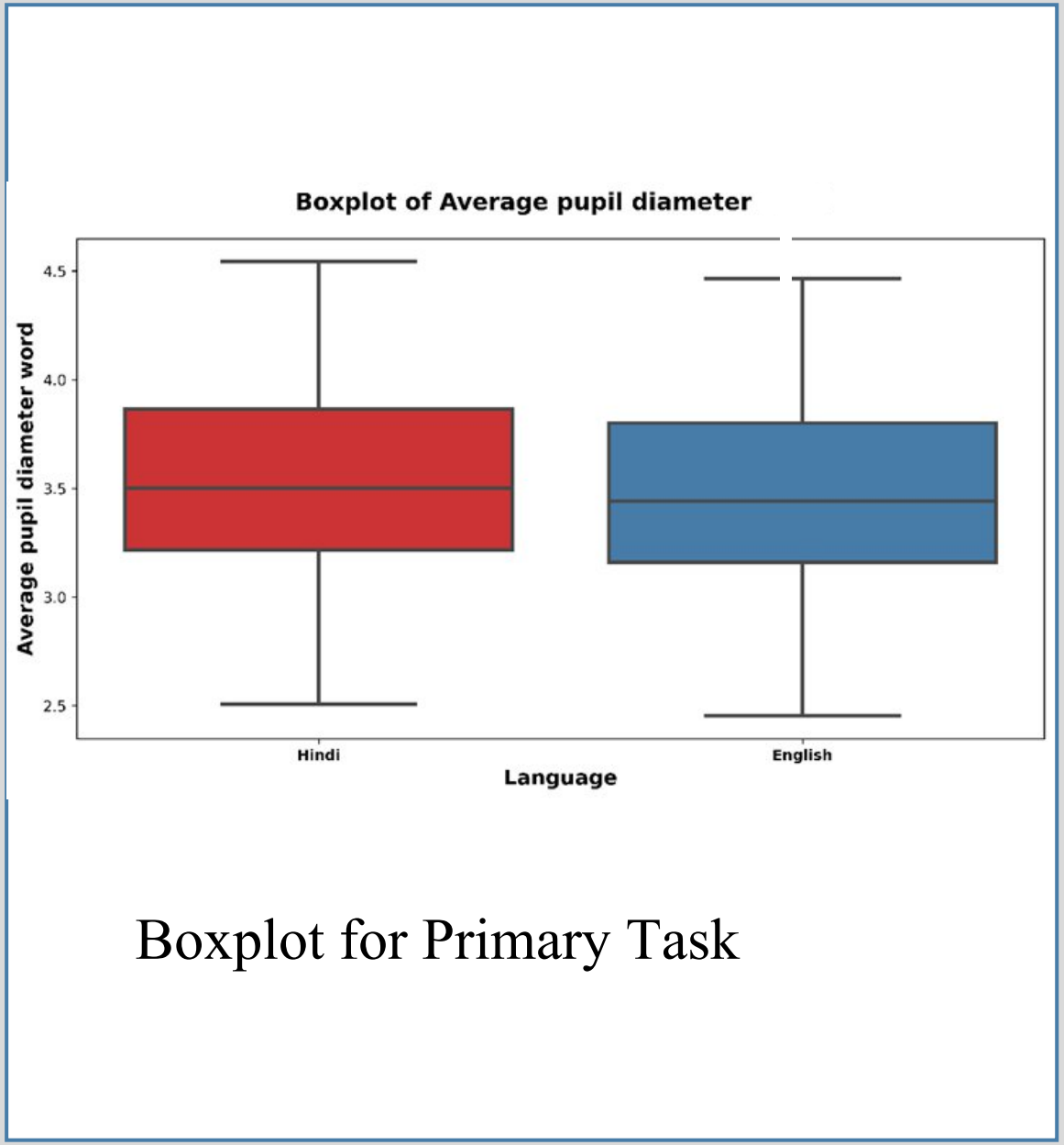
Primary Task

- Average pupil size for L1: 3.54 mm
- Average pupil size for L2: 3.47 mm

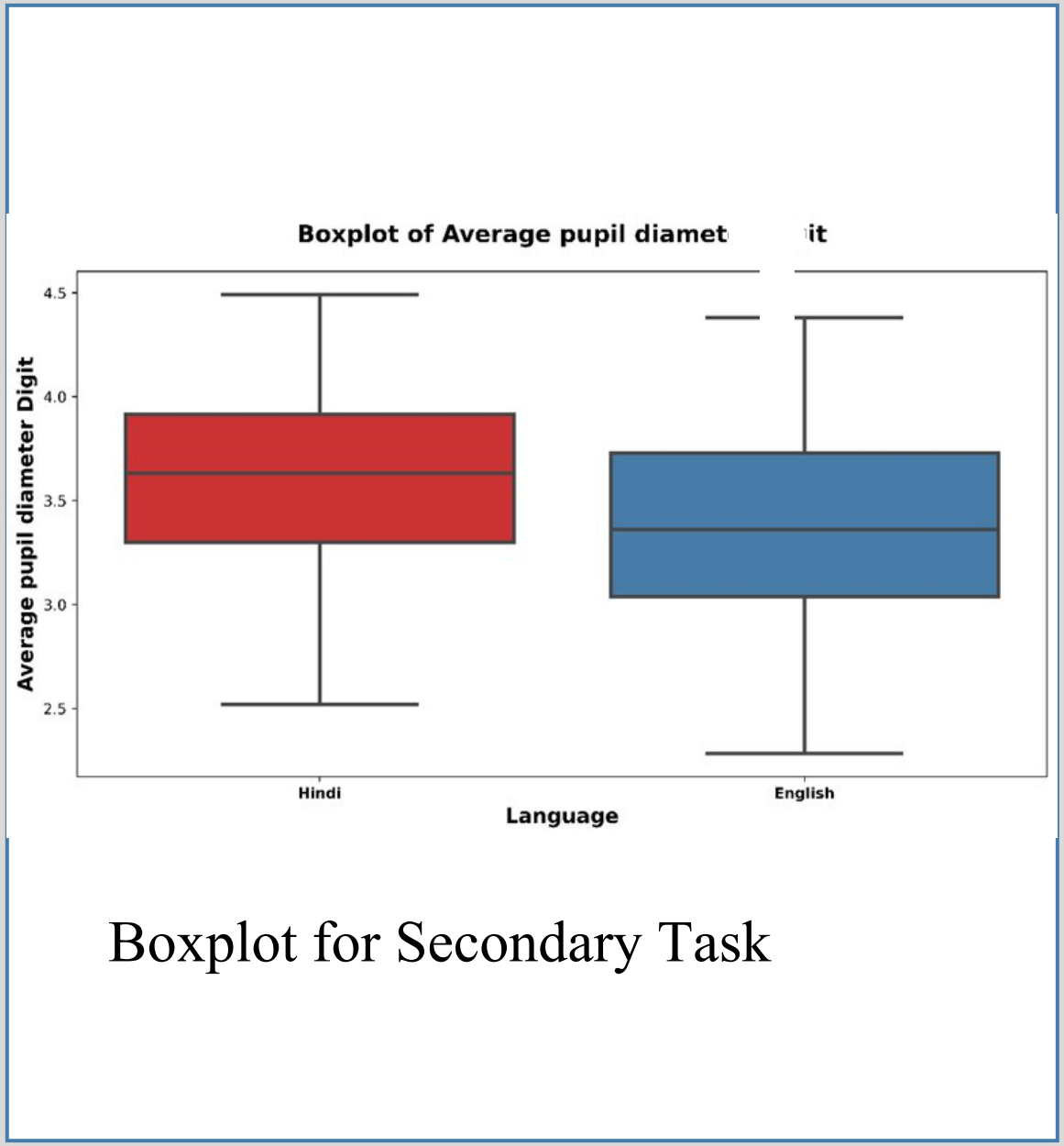
Secondary Task

- Average pupil size for L1 block: 3.59 mm
- Average pupil size for L2 block: 3.39 mm

Primary Task	Independent t-test	0.554	Not significant ($p > 0.05$)	No statistically significant difference in cognitive load.
Secondary Task	Independent t-test	0.088	Not significant ($p > 0.05$), but close	Suggests a possible trend; cognitive load appears higher, though not significant.



Boxplot for Primary Task



Boxplot for Secondary Task

Discussions

Investigated **language dominance in bilinguals** through **task-based experiments** using a Picture-Word Matching task combined with various cognitive loads.

Explored the **interaction between language dominance and cognitive load** in bilinguals.

Limitations and Ongoing work

- Experiment to be conducted on Bengali – English bilinguals
- Self rating analysis (ongoing)
- **Sample size** in Experiments 2 needs to be **increased**.
- **3-back task** showed minimal load difference → consider using **n = 4 or 5** and **mixed n-back tasks** for clearer effects.

Different participants used in Experiments 1 and 2:

- Future studies should include **same participants** for better comparison of cognitive effort.

Thank You!