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Exploring the Differences in Mental Rotation of Letters and Faces

Comparing Reaction time and Contralateral Delay Activity (CDA)

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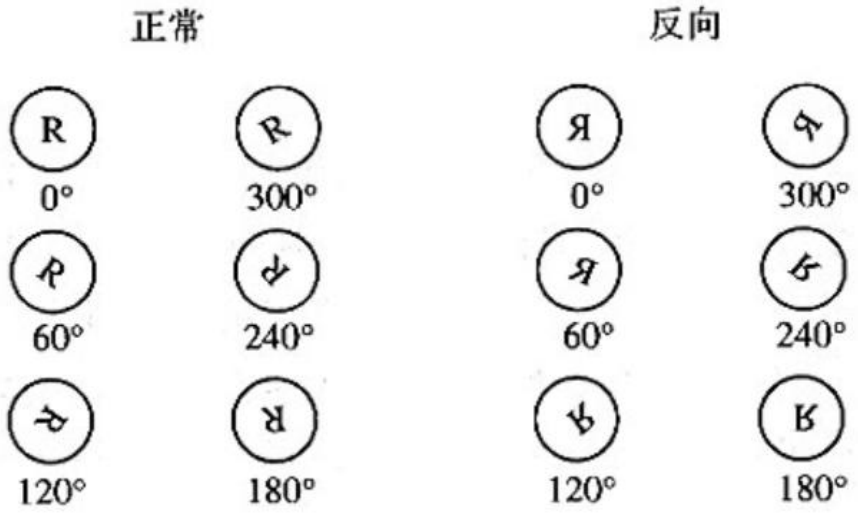
Mental rotation paradigm (Cooper & Shepard, 1973)



Mental Rotation (Upright/Inverted): Mental rotation involves rotating an object's image in the mind to match or compare orientations, highlighting spatial cognition and visual processing skills.

Result: The greater the degree of deviation of the sample from the orthostatic position, the more mental rotation is required and the longer it takes. Reverse R's response times were consistently larger than normal.

Neural study Mental rotation:

This study used EEG to explore contralateral delay activity (CDA) as one of the visual working memory (VWM) load indicators. Existing research has proven that it has higher sensitivity than traditional reaction time and can distinguish the two processes of image rotation (rotation angle and mirror image flip).

What is Contralateral Delay Activity (CDA)?

CDA is a crucial indicator of the load on visual working memory, manifesting as delayed activity in the brain's contralateral regions. It is considered a sensitive marker for assessing an individual's capacity to maintain and process visual information (Vogel & Machizawa, 2004).

Research purpose:

Exploring differences in the brain's processing of letters and faces. Whether or not processing mechanisms are different during mental rotation

- RT: Used to assess the time it takes for an individual to respond to a stimulus.
- CDA: When studying letter and face rotation tasks, CDA can be used to measure the amount of information carried by visual working memory during rotation.

Current research:

1. Association of CDA with Task Types: Studies have shown that different types of visual working memory tasks activate different regions of the brain.
For example, spatial tasks tend to activate more parietal and frontal areas, while face or object memory tasks rely more on the temporal lobes (Xu & Chun, 2005).

2. SPATIAL PROCESSING AND LETTER ROTATION: Letter rotation tasks rely heavily on spatial processing abilities, a process that takes place in the parietal and frontal regions of the brain (Corballis, 1997). These regions are thought to be critical for processing spatial information and performing mental rotation tasks.

3. Special Mechanisms for Face Recognition: Face rotation tasks involve more specialized visual processing mechanisms, mainly relying on face recognition-related brain regions such as the inferior temporal lobes and the fusiform gyrus (Haxby et al., 2000). These areas are specialized for processing face information, including identification and emotional interpretation.

4. Uniqueness of Face Processing: Face processing is believed to have a unique visual processing pathway, distinct from the pathways for objects or letters. It involves more activity in the temporal lobes, especially the inferior temporal lobes and the fusiform gyrus, crucial for processing face information (Kanwisher et al., 1997).

Hypothesis:

We hypothesize that under the different combinations of independent variables – material type (letters/faces), orientation (upright/mirror), and rotation angle (every 30° increment) – there will be significant differences in reaction time (RT) and visual working memory load (CDA).

1. **The impact of material type on CDA and RT**: We anticipate that the CDA for face rotation tasks will be lower than that for letter rotation tasks, as face recognition may activate specialized processing mechanisms in the brain, thereby reducing the load on visual working memory. Conversely, the RT for face rotation tasks may be higher than for letter rotations, due to the additional cognitive processing required to recognize rotated faces, despite the existence of specialized pathways for face processing.

2. **The impact of orientation (upright/mirror):** It is anticipated that recognizing mirrored stimuli, especially mirrored faces, will require longer reaction times because processing the asymmetrical features of mirrored faces necessitates additional cognitive resources. Simultaneously, mirrored stimuli might also affect CDA. Previous research has shown that CDA maintains a high amplitude for rotations of mirrored images, indicating that the rotation of mirrored pictures imposes a significant working memory load on individuals. For mirrored faces, we predict that the CDA for mirrored faces will be lower than that for mirrored images of the letter R.

3. **The impact of rotation angle**: We further predict that regardless of the material type and orientation, reaction times will increase with the increase in rotation angle, reflecting increasing difficulty of rotational tasks. For RT, the increase in rotation angle may lead to more significant changes in face rotation tasks, indicating an increased sensitivity to rotation in face recognition.

4. **Dissociation Effect**

We believe that different types of visual tasks, such as face rotation versus letter rotation, exhibit differences in cognitive processing. These differences are manifested through various psychological measurement indicators, such as reaction time (RT) and visual working memory load (CDA).

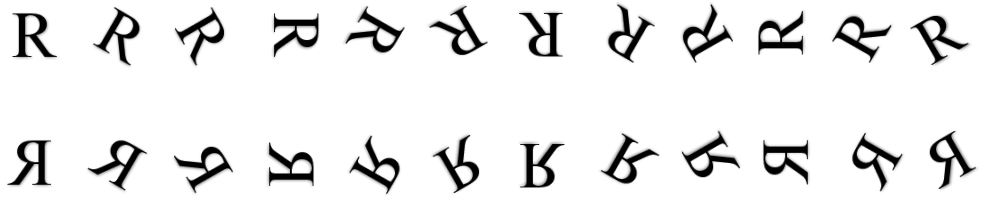
- RT is typically used to measure the time required to complete a task, reflecting processing speed. If the RT for face rotation tasks is longer, this may imply that the recognition and processing of rotated faces require more time, possibly due to more complex visual and cognitive transformations involved in recognizing faces after rotation.

- CDA reflects the ability to maintain information in visual working memory, closely related to the visual working memory demand of the task. If the CDA amplitude caused by letter rotation tasks is greater than that for face rotation tasks, it may indicate that although face recognition is more efficient in visual working memory, letter rotation tasks demand more from visual working memory.

Therefore, we predict that face and letter rotation tasks may activate different processing mechanisms in the brain. Face recognition utilizes specialized facial processing pathways, which may make the recognition of rotated faces somewhat more efficient than the recognition of rotated letters, despite the additional time required to process the physical changes introduced by face rotation.

A. Alphabet

- Similar with classic paradigm of Cooper's.
- Apply some alphabets from different languages but are mirror-symmetric with each other.
- E.g. R—Я , N—И
- Including 12 revolve levels to capture more subtle changes.

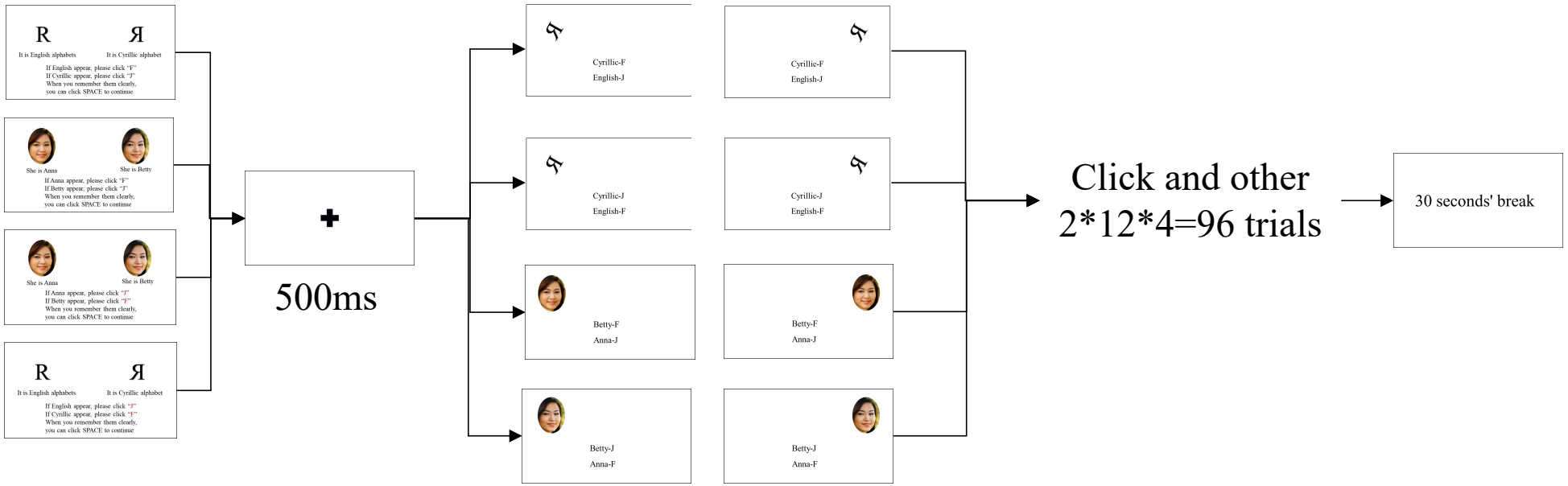


- B. Face
- Similar faces generated from a generative adversarial network (GAN) (Karras et al., 2018), pretrained on the CelebA-HQ data set (Liu et al., 2015), but could be distinguished (De La Torre-Ortiz et al., 2023)
- Do same revolve as alphabets.

Background
Hypothesis
Design

A. Task

- The Alphabets are used as target in Part1 and Part4
- The faces are used as target in Part2 and Part3, to balance sequential effect
- For every part, participants will be taught two alphabets are from different languages or there are two people firstly.
- And then in paradigm, alphabets/faces will be shown until participant do a judge that alphabet/face they are showed is from certain language/certain person by click keyboard.
- For CDA, the target will be showed in left and right equally and randomly.
- In part1/part4 and part2/part3, the keys are exchanged to control the influence of the dominant hand



A. Reaction time

Since the images showed, to the shoot that participant do a judgement

B. CDA（Contralateral Delay Activity）

- The electrodes used for CDA analysis include P7, P8, PO3, PO4, PO7, and PO8, as well as two electrodes placed on the mastoids.
- The method involves subtracting the ipsilateral amplitude from the contralateral amplitude, where the contralateral and ipsilateral amplitudes are defined relative to the position of the target on the screen.
- eg. When target is in left, the left hemisphere of the brain is ipsilateral, while the right one is contralateral.

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The End
Thanks for listening