Technical Paper

Annals of Clinical and Medical Case Reports

Fast Object Perception In The Subcortical Pathway

Jianhui Liang, Yuyin Wei and Yan Huang*

[1] Guangdong Provincial Key Laboratory of Brain Connectome and Behavior, CAS Key Laboratory of Brain Connectome and Manipulation, Shenzhen-Hong Kong Institute of Brain Science-Shenzhen Fundamental Research Institutions, the Brain Cognition and Brain Disease Institute (BCBDI), Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences. University of Chinese Academy of Sciences, China

***Corresponding author:**
Yan Huang, the Brain Cognition and Brain Disease Institute (BCBDI), Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences; 1068 Xueyuan Avenue, Nanshan District, Shenzhen, 518055, China,
Email: yan.huang@siat.ac.cn

Author Contributions:
Liang J, Wei Y and Huang Y. All the author are equally contributed to this work.

Received Date: 21 Apr 2023
Accepted date: 05 May 2023
Published Date: 11 May 2023

1. Abstract

The subcortical visual pathway is generally thought to be involved in dangerous information processing, such as fear processing and defensive behavior. A recent study, published in Human Brain Mapping, shows a new function of the subcortical pathway involved in the fast processing of non-emotional object perception. Rapid object processing is a critical function of visual system. Topological perception theory proposes that the initial perception of objects begins with the extraction of topological property (TP). However, the mechanism of rapid TP processing remains unclear. The researchers investigated the subcortical mechanism of TP processing with transcranial magnetic stimulation (TMS). They find that a subcortical magnocellular pathway is responsible for the early processing of TP, and this subcortical processing of TP accelerates object recognition.

2. Keywords:
TMS; Subcortical pathway; Magnocellular pathway; Topological perception; Object

3. Commentary

How does the visual system quickly perceive the presence of an object before we can identify it in detail? Topological perception theory [1, 2] is proposed to address the question of how objects are perceived in the early stages of vision, which holds that the visual system first extracts the topological property (TP) of objects to build up object representation. The TP of an object is a geometric property based on mathematical topology. The TP remains the same during any continuous deformations such as stretching and bending but changes when tearing. Substantial behavioral evidence [1-6] shows that the processing of TP has priority over that of other properties. However, a seemingly paradoxical finding from previous functional magnetic resonance imaging (fMRI) studies [7-8] is that TP perception occurs primarily in the inferior temporal cortex (IT), which is the end of the classical visual pathway. A subcortical pathway hypothesis for TP processing is proposed that TP processing projects directly from the retina to the fast Superior Colliculus (SC)-Pulvinar-Amygdala subcortical pathway and finally to the cortical IT. This hypothesis has been supported by some evidence from humans and mice [9-10, see Figure 1]. Specifically, a human fMRI study [9] found that the processing of 'hole', as a TP, activated the SC and pulvinar more in response to unconscious stimuli than conscious stimuli. In addition, the researchers sought evidence of subcortical neurons in mice [10]. They presented the mice with a looming stimulus that mimicked a dangerous predator from the sky. And they found that when the TP of the looming stimulus changed, the instinctive fear response of mice was significantly reduced, as was the number of neurons activated in the SC. This suggests that the rapid processing of fear signals in subcortical pathways may be related to TP processing. However, these studies did not rule out the effect of cortical processing, so the observed subcortical activation may come from cortical to subcortical feedback signals.

Recent work in Human Brain Mapping by Dr. Huang's group [11], "A subcortical magnocellular pathway is responsible for the fast processing of topological properties of objects: A transcranial magnetic stimulation study", rules out this possibility. Using TMS to block the primary visual cortex at different times, the researchers found that topological processing is processed independently of the classical visual cortical pathway in the early stages, but via a subcortical pathway. Moreover, according to the processing characteristics of Magnocellular (M) and Parvocellular (P) cells, the researchers designed an M stimulus (low-contrast grayscale image) that favored the M-pathway processing and a P stimulus (isoluminant red/green image) that favored the P-pathway processing. They used this M/P pathway separation technique to find that the rapid perception of TP is through the subcortical M pathway. Furthermore, they demonstrated the significance of rapid subcortical processing of TP to facilitate the recognition of other properties of objects.

The finding of the subcortical M pathway involved in rapid object processing extends our traditional understanding of M and P pathways. First, structurally, the M and P pathways are generally thought to correspond to the dorsal and ventral cortical pathways, respectively [12]. This finding extends the M pathway from the cortex to the subcortex. Second, functionally, the M pathway in the dorsal cortex is responsible for processing information like depth and motion [13], while the subcortical

M pathway was found to be responsible for the rapid processing of objects' TP, suggesting a functional separation of the cortical and subcortical M pathways, although both exhibit sensitivity to low contrast.

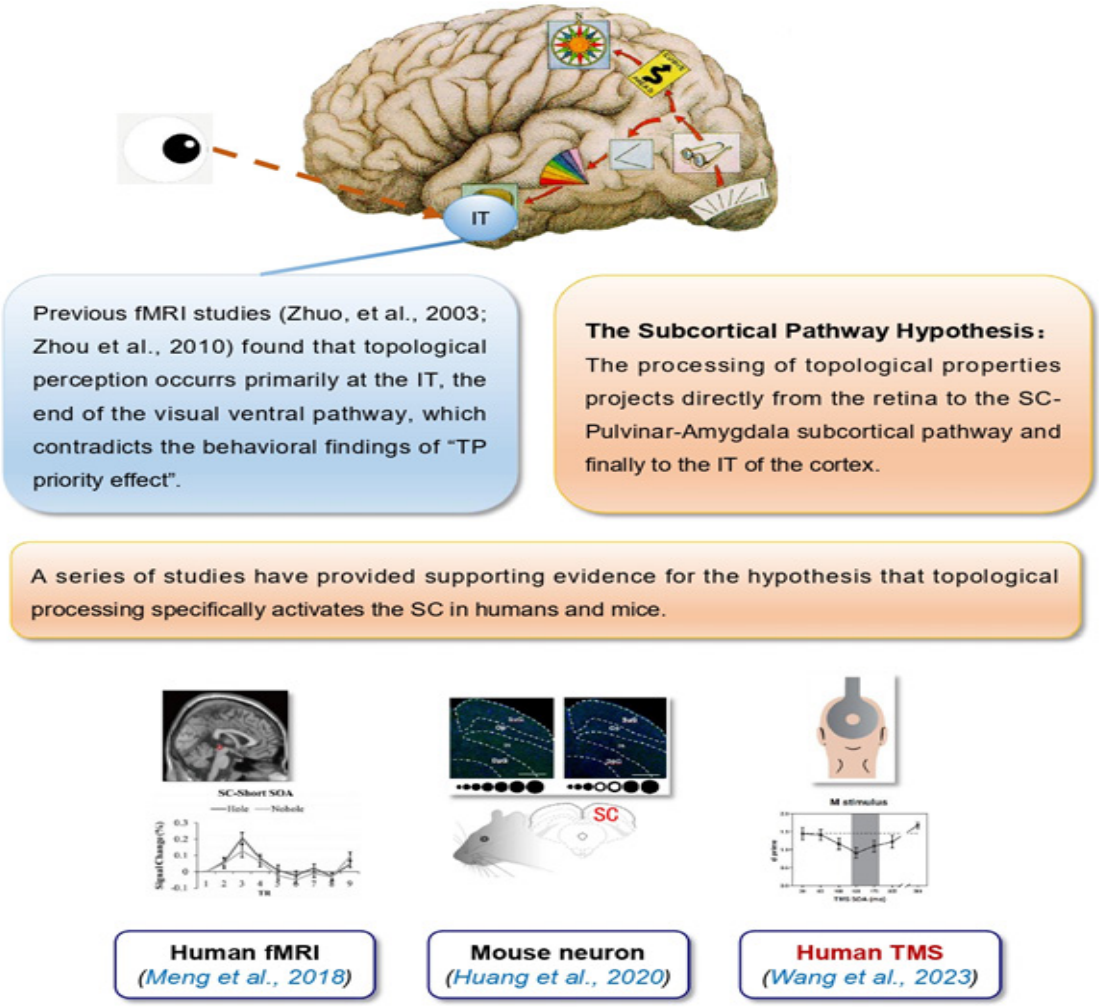

Figure 1: The subcortical pathway hypothesis and its supporting evidence.

This study is an important step forward in exploring the function of human subcortical visual pathways. Subcortical visual pathways are generally considered to be involved in important survival-related information, such as fear processing and defensive behavior. This study provides support for the key role of the subcortical pathway in rapid object recognition, extending the previous understanding of subcortical pathways. Abnormalities in subcortical pathways has been reported in many brain diseases, such as schizophrenia [14], glaucoma [15], and anxiety disorders [16]. This study will help the understanding of the pathogenesis of related brain diseases from a new perspective of the subcortical pathway and provide new research ideas for early screening, objective diagnosis, and intervention strategies.

Future studies could further clarify which subcortical nuclei and subregions are involved in rapid TP processing, and it is also worthwhile to use animals to investigate the neural circuit mechanism of the visual system preferentially processing TP.

4. Acknowledgements

This work was supported by grants from National Science and Technology Innovation 2030- "Brain Science and Brain-Like Intelligence Technology" Major Project (grant number 2022ZD0209500), Guangdong Provincial

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Key Laboratory of Brain Connectome and Behavior (grant number 2017B030301017), and the Chinese Academy Science Key Laboratory of Brain Connectome and Manipulation (grant number 2019DP173024).

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