



|              |                                                                                                        |
|--------------|--------------------------------------------------------------------------------------------------------|
| Title        | Neural basis of correct and inverted judgments in a crossed-hands tactile temporal order judgment task |
| Author(s)    | Moharramipour, Ali                                                                                     |
| Citation     | 大阪大学, 2022, 博士論文                                                                                       |
| Version Type | VoR                                                                                                    |
| URL          | <a href="https://doi.org/10.18910/88182">https://doi.org/10.18910/88182</a>                            |
| rights       |                                                                                                        |
| Note         |                                                                                                        |

*The University of Osaka Institutional Knowledge Archive : OUKA*

<https://ir.library.osaka-u.ac.jp/>

The University of Osaka

## Abstract of Thesis

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Name (Ali Moharramipour)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                         |
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Neural basis of correct and inverted judgments in a crossed-hands tactile temporal order judgment task<br>(腕交差触覚時間順序判断課題における正・逆判断の神経基盤) |
| <p>If we are asked to judge the temporal order of two successive tactile stimuli delivered to each hand, we often make inverted judgments when we cross our hands. This phenomenon, termed the crossing effect, indicates that our brain utilizes not only the somatosensory information but the posture-related spatial information in the perception of touch and its temporal order. In the present thesis, we examined the neural basis associated with the crossing of the hands and making an inverted judgment.</p> <p>We first paid attention to the fact that the degree of reversal (i.e., making inverted judgments due to the crossing of the hands) varies significantly across individuals. The brain regions responsible for the inter-individual variability should play a major role in the crossing effect. We then turned to the intra-individual variability. Each individual makes inverted judgments in some of the trials and not the others. To study the trial-by-trial variability, we examined the time-frequency dynamics of the interactions between those regions associated with the crossing effect.</p> <p>In the first part, by analyzing the structural MRI image of different individuals, we discovered that the participants with a thinner, larger, and more convoluted cerebral cortex in ten anatomical regions, including the right pars-orbitalis, right and left postcentral gyri, left precuneus, left superior parietal lobule, right middle temporal gyrus, left superior temporal gyrus, right cuneus, left supramarginal gyrus, and right rostral middle frontal gyrus had a smaller degree of reversal. We hypothesize that a better cortical elaboration (development) in those ten regions should contribute to better integrating the somatosensory and spatial postural information and a superior top-down inhibitory control.</p> <p>In the second part, we analyzed magnetoencephalographic data to derive the dynamic network connectivity across the regions found in the first part. We discovered that there were two distinct modes in the brain network connectivity, one in the low alpha band (5-10 Hz) and the other in the low beta band (12-18 Hz). When the hands were uncrossed, the brain mainly utilized the low alpha mode, and the low alpha connectivity was dominated by one of the hemispheres contralateral to the hand being stimulated first. On the contrary, when the hands were crossed, the low beta mode was profoundly recruited as well, and the connectivity involved both hemispheres. Most importantly, the low beta mode connectivity was less recruited in the trials with inverted judgments and the participants with a larger degree of judgment reversal.</p> <p>Our study suggests that the brain network involving the ten brain regions is responsible for ordering the tactile signals represented in both somatotopic and spatial coordinates. Furthermore, the network utilizes the low alpha band by default, but the low alpha mode yields inverted judgments when the hands are crossed. The recruitment of the low beta mode is a major contributor to making a correct judgment.</p> <p><b>Keywords:</b> tactile temporal order judgment (TOJ), judgment reversal, structural MRI, cortical characteristics, magnetoencephalography, functional connectivity, touch</p> |                                                                                                                                         |

論文審査の結果の要旨及び担当者

| 氏 名 ( Ali Moharramipour ) |     |     |         |
|---------------------------|-----|-----|---------|
|                           | (職) | 氏 名 |         |
| 論文審査担当者                   | 主 査 | 教 授 | 北 澤 茂   |
|                           | 副 査 | 教 授 | 西 本 伸 志 |
|                           | 副 査 | 教 授 | 藤 田 一 郎 |
|                           | 副 査 | 教 授 | 八 木 健   |

論文審査の結果の要旨

右手と左手に1回ずつ刺激を加えてその時間順序を判断する課題において、手を平行に置くと刺激時間差100 msでは正解率がほぼ100%となる。しかし、腕を交差すると判断に誤りが生じる。この腕交差による主観的時間順序の逆転現象の神経基盤の解明には多くの研究者が取り組み、時間情報と空間情報の相互作用が幅広い脳領域を巻き込んで生じていることが明らかとなっている。しかし、逆転の量に、確率0.1程度から1近くまで、大きな個人差がある理由は謎として残されてきた。本論文の目的は、腕交差時間順序逆転現象の個人差の原因を明らかにすることである。

前半では、大脳皮質の解剖学的構造の個人差を調べ、左半球を中心とする10個の領域が「薄く広く折りたたまれているほど、逆転しない」ことを示すことに成功した。この成果はCerebral Cortex Communications誌に掲載された。さらに後半では、これらの領域を含む18個の領域に注目して、脳の領域間通信のダイナミクスの個人差を追求した。その結果、1) 時間順序判断にはピーク周波数6 Hzの低い通信モードと、ピーク周波数16 Hzの高い通信モードの2つが存在すること、2) 腕非交差では低い通信モードだけを使い、交差すると高い通信モードもリクルートすること、3) 腕交差時に低いモードも使う人は逆転するが、高いモードだけを使う人は正解すること、を見出した。つまり、エネルギーの低い通信モードでは腕交差の空間配置の違いを補正しきれず誤り、高い通信モードを使って初めて正解することが示唆された。「薄く広く折りたたまれている」皮質は、16 Hzの高い周波数での領域間長距離通信を実現するエネルギーを供給するうえで有利なのであろう。

本研究は、腕交差時間順序判断の個人差の原因を追究して、脳における時間・空間情報処理の通信モードとその切替の原理を提示した独創的な研究として、高く評価できる。以上の理由により、学位を授与するに値するものと考える。