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論 文 内 容 の 要 旨
Synopsis of Thesis

氏 名 Name	Mrinmoy Chakrabarty
論文題名 Title	Short-latency allocentric control of saccadic eye movements (外部座標系に基づくサッカード眼球運動の素早い制御)

論文内容の要旨

〔Purpose〕

It is generally accepted that the oculomotor system uses the retinotopic (gaze-centered) coding of targets to control saccades, but several recent studies have revealed that non-retinotopic representation is also used. This new idea raises a question about whether non-retinotopic coding is still egocentric (head or body-centered) or goes further to be allocentric (environment-centered). Some studies have actually reported that allocentric target coding could be used, but only with a delay longer than 500 ms. In contrast to the literature about saccade control, Uchimura and Kitazawa (2013) have shown that a target location for reaching is represented rapidly (within 300 ms) and automatically in an allocentric coordinate. This finding in reaching led us to hypothesize that allocentric coding plays a crucial role in immediate saccade control as well. In the present study we aimed to test this hypothesis.

〔Methods/Results〕

To test the hypothesis, we employed an immediate double step saccade task toward two sequentially flashed targets with a behaviorally irrelevant, rectangular visual frame in the background which served as the allocentric landmark. A key factor was the position of the background: it was either randomly shifted up, down or remained constant while the second target was presented (83 ms). We examined whether the gaze end point of the second saccade was affected by an unexpected and transient shift of the background that participants were told to ignore. If the brain depends solely on egocentric coordinates (whether retinotopic or non-retinotopic) for guiding saccades, the final saccade should land at the actual second target position regardless of the shift of the background frame. However, if the brain uses allocentric coordinates, the gaze landing position should shift away from the actual target position and toward the direction opposite to that of the frame displacement. Eye gaze positions were measured using a near-infrared eye tracking system while healthy human participants (age: 20-23 years) performed the experimental tasks.

When the background was shifted transiently upward (or downward) during the flash of the second target, the second saccade generally erred the target downward (or upward), which was in the direction opposite to the shift of the background. The effect on the second saccade became significant within 150 ms after the frame was presented for decoding and was built up for 200 ms thereafter. When the second saccade was not adjusted, a small corrective saccade followed within 300 ms. The effect scaled linearly with the shift size up to 3 degrees for a non-corrective (direct) second saccade and up to 6 degrees for a corrective saccade. Thus, the final gaze landing position was significantly shifted as expected from the allocentric hypothesis, even when the saccade latency was smaller than 200 ms.

〔Conclusion〕

We found that the saccade endpoint was shifted from the actual target position toward the direction expected from allocentric coding, when a large frame in the background was transiently shifted during the period of target presentation. The effect occurred within 150 ms. From the results, we conclude that an allocentric location of a target is rapidly represented by the brain and used for controlling saccades.

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論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

外界から情報を取り入れるために1秒に3回程度行われている急速な眼球運動（サッカード）の制御に関しては、標的の網膜上の位置（網膜座標）に基づいて制御されていると考えられてきた。しかし、頭部中心座標系や外界中心の座標が使われている可能性も指摘されるようになった。そこで本研究では、外界中心の座標に基づく標的位置の表象が即時性のサッカード制御に重要な役割を果たしているという仮説を立て、検証する実験を行った。参加者には次々に提示される2個の標的にできるだけ早く目を向け、標的以外の背景は無視するように指示をした。標的の背後には、四角い大きな枠を提示して、枠を一過性に上または下に動かして、枠の動きがサッカードに与える効果を調べた。その結果、枠を一過性に上方（または下方）にシフトした場合、サッカードの終点は、下方（または上方）にシフトすることがわかった。さらに、サッカードへの影響は、枠提示後150ms以内に有意となった。本結果は、標的の位置が外界中心の座標系で迅速に表現されて、サッカード制御に使われることを示している。本論文は、サッカード制御に関する従来の定説を覆す新しい知見を示しているため、博士（医学）の学位授与に値する。