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Eye-hand coordination in motor learning

Essence of “keeping your eye on the ball”

Abstract

Motor learning is indispensable to realize skillful behaviors. Under a dynamically changing environment like in tennis, we need to acquire and execute new skilled reaching movements while our gaze is directed toward the ball (foveal vision) and possibly the opponent’s location too (peripheral vision). While previous studies have taken gaze information into consideration for motor learning, conventional theories were restricted to emphasizing the superiority of the reaching to a foveated target over the reaching to a peripheral target. Our current study elucidated that the eye-hand spatial coordination for both foveal and peripheral reaching movements during learning is inherently linked with the internal model of learned reaching skills. Our results highlighted a novel interaction of gaze information with motor learning. By understanding the brain mechanism of this interaction, we will be able to design a novel training method that utilizes different gaze states to enhance sports training and rehabilitation.

Eye-hand coordination

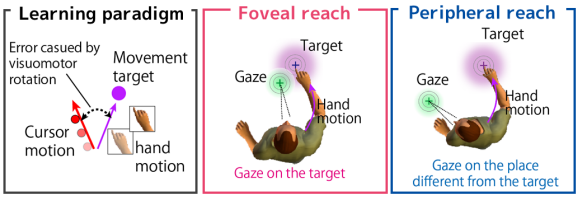
Why should gaze be considered for acquisition and execution of motor skills ?

Conventional theories have focused on the superiority of reaching movements with central vision over peripheral vision.

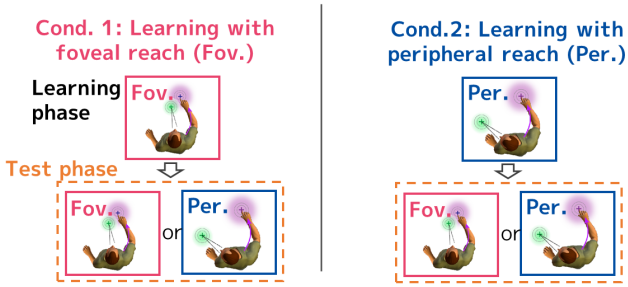
Our study elucidated that the eye-hand spatial relationship, including both foveal and peripheral vision, was inherently related with the motor learning of reaching movements.

Experimental method

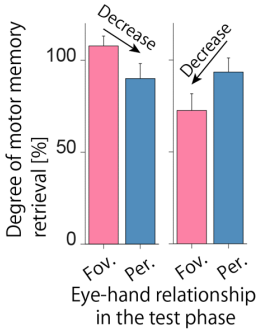
Participants move the cursor to the target. The cursor motion is rotated from hand motion. After repeating trials, hand motion is gradually changed to compensate for visuomotor rotation.



Exp.1: Does the eye-hand relationship have an impact on motor learning?



[Results] In both conditions, the retrieval of motor memory was degraded to about 80 % when the eye-hand relationship for the test phase differed from that of the learning phase.



For better retrieval of motor memory, same eye-hand relationship should be used in both learning and test phases.

Foveal and peripheral reach would be processed differently by the brain.

⇒Is it possible to acquire different motor skills simultaneously by using such distinct representations?

Exp.2: Does foveal and peripheral reach enable us to learn different reaching skills simultaneously?

Learning (480 trials) : Rotational directions (CW & CCW) changed across trials, but were unequally associated with eye-hand relationship.*1

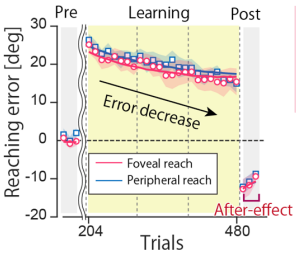
	Trial 1	Trial 2	Trial 3	-----	Trial 480
Eye-hand relationship	Foveal reach	Peripheral reach	Peripheral reach	-----	Foveal reach
Rotational direction	CW	CCW	CCW	-----	CW

An example of learning phase. Two rotational directions appeared with the same frequency and in no particular order.

[Results]

During learning: Error decrease for both rotational directions.
After learning: Clear “after-effect”*2 was observed.

*1 Simultaneous learning of different motor skills is known to be difficult.
*2 After-effect: Estimated in the non-rotational trials after learning. Larger negative value indicates better retrieval of motor memory.



Changing eye-hand relationship enables us to learn different reaching skills simultaneously

Reaching skill consists of gaze status as well as the novel pattern of hand movements

References

[1] N. Abekawa, S. Ito, H. Gomi, “Different learning and generalization for reaching movements in foveal and peripheral vision,” in *Proc. Adv. Mot. Learn. Mot. Control*, 2019.
[2] N. Abekawa, S. Ito, H. Gomi, “Foveal and peripheral vision separate motor memories for reaching movement,” JNNS2020, 2020.

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