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Visuomotor Coupling during Two-Handed Tasks

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Abstract

During many manual tasks, reaching and grasping is a visually-guided action. Two visuomotor coordination steps required when completing a manual task have been classified as Pre-Reach Fixations and Gaze Anchoring. A Pre-Reach Fixation is when someone needs to look at an object before they reach for it and is operationally defined as the difference in time between looking at something and reaching for it (Mennie et al., 2007). Conceptually, Gaze Anchoring is how long someone needs to keep looking at an object in order to grasp it and is operationally defined as the difference in time between looking away from something and grasping it (Rand, 2014). It was theorized that both Pre-Reach Fixations and Gaze Anchoring restrain individuals to coordinate their movements using a particular sequence of eye-hand subtasks. Specifically, these two aspects of visuomotor coupling constrain individuals to complete two-handed task using a sequential turn-taking movement pattern (as opposed to the faster, simultaneous movement pattern). Moreover, when completing a two-handed task that requires simultaneous visually-guided movements, this study showed why it is beneficial to complete an unfamiliar two-handed task with a partner (intermanually) as opposed to completing the same two-handed task individually (bimanually). Eye-tracking and motion-capture data were analyzed to reveal differences among the bimanual and intermanual coordination mode. It was concluded that intermanual out performed bimanual during this previously unpracticed task due to bimanual visuomotor coupling constraints.

Introduction

Some two-handed tasks are faster with a partner compared to completing the same task alone (e.g., Zheng et al., 2005).

A two-handed laparoscopic cutting task with a partner was faster than completing the task alone.



This study analyzed one potential aspects underlying speed difference during two-handed tasks:

- **Bimanual** – two-handed
- **Intermanual** – different people, each using one hand

Bimanual



Bimanual control of steering with the left hand and acceleration with the right hand across two joysticks

Intermanual



Intermanual control of one participant controlling steering with their left hand and another participant controlling acceleration with their right hand

Intermanual is faster than bimanual for an unpracticed task. Between-hand coupling is one factor (Crites & Gorman, 2017).

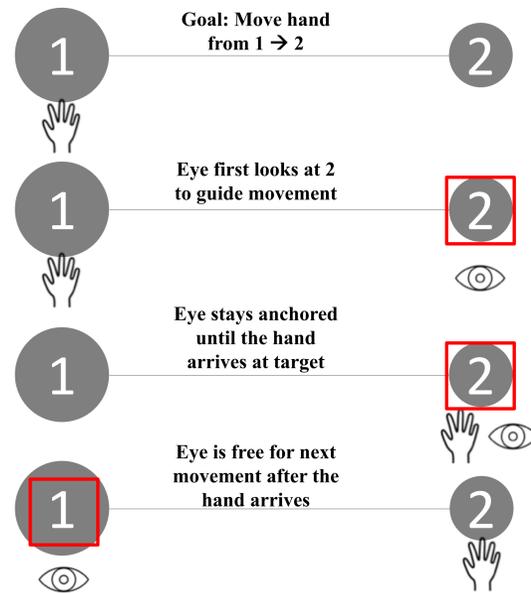
Some have suggested that shared mental models account for the mode effect of speed (Zheng et al., 2007).

However, another (simpler) behavioral aspect inherent to bimanual coordination may limit task performance: **Visuomotor Coupling.**

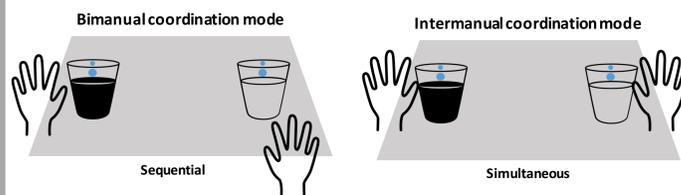
Visuomotor Coupling

Visuomotor coupling refers to the degree in which the eyes and hand move together in space and time.

Guiding fixations and **gaze anchoring** create a sequential process during manual coordination tasks (Mennie et al., 2007; Rand, 2014).



Bimanual visuomotor coupling is the the sequential dependence of visually-guided actions during an individual, two-handed task.

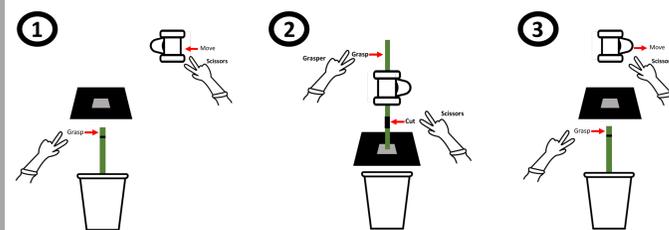


The **intermanual** coordination mode completes subtasks simultaneously due to utilizing two **visuomotor systems**.

The Current Study

A task was constructed investigate whether **visuomotor coupling negatively** impacts **bimanual** performance as measured by **speed**.

Task Overview

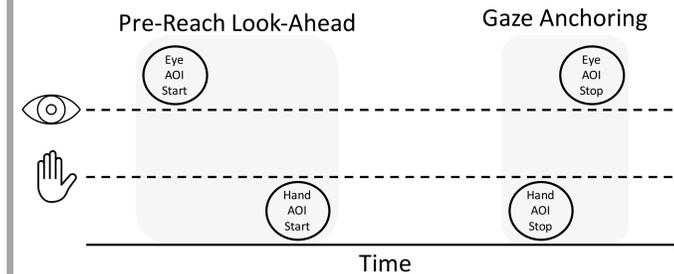


Participants completed a novel two-handed simulated cutting task both individually (bimanually) and as a team (intermanually).

Nearly all two-handed motions during this task were designed to exploit visuomotor coupling.

Measuring Visuomotor Coupling

The measurement of **visuomotor coupling** consists of both “Pre-Reach” and “Gaze Anchoring”



Pre-Reach is the difference in time between looking at something and starting a manual action.

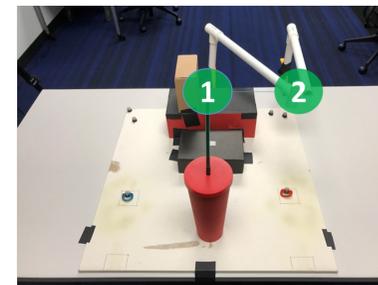
Gaze Anchoring is the difference in time between looking away from something and completing a manual action.

Exploiting Bimanual Visuomotor Coupling

During **bimanual performance**, each subtask was typically completed **sequentially**.

Hypothetical gaze pathway example of a participant completing the task using the bimanual coordination mode.

Green = Participant controlling the grasper and the scissors.

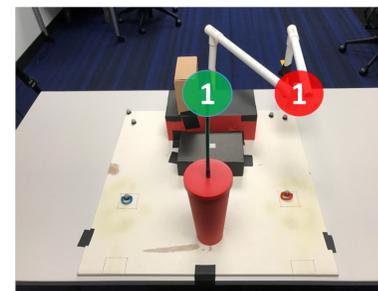


However, during **intermanual performance**, each subtask was typically completed **simultaneously**.

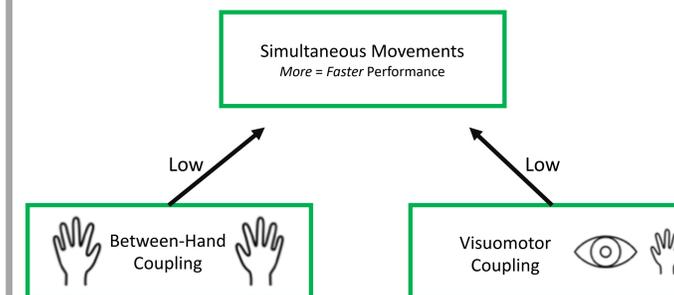
Hypothetical gaze pathway example of participants completing the task using the intermanual coordination mode.

Green = Participant controlling the grasper.

Red = Participant controlling the scissors.

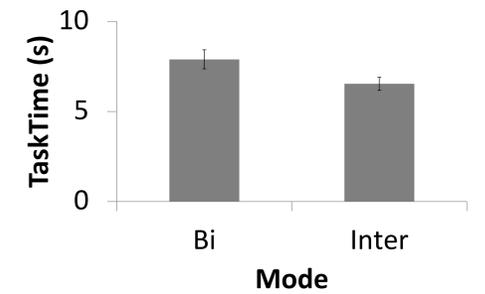


Visuomotor coupling and **between-hand coupling** both seem to contribute to **speed** during two-handed task performance.

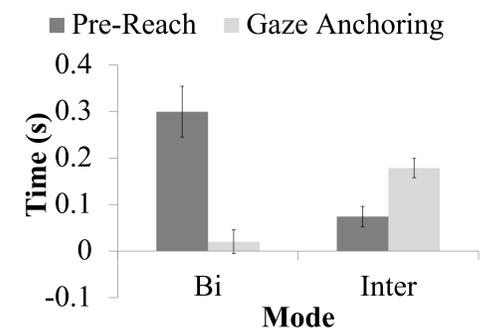


Results

Speed. As predicted, participants were significantly slower when using the Bi Mode ($M = 7.70$; $SD = 1.14$) compared to the Inter Mode ($M = 6.07$; $SD = .98$).



Visuomotor coupling. As predicted, **Pre-Reach** was significantly longer using the Bi Mode ($M = 0.30$, $SD = 0.18$) when compared to the Inter Mode ($M = 0.07$, $SD = 0.07$).



However, **Gaze Anchoring** was significantly longer using the Inter Mode ($M = 0.18$, $SD = 0.07$) when compared to the Bi Mode ($M = 0.02$, $SD = 0.08$).

Correlations between **Speed** and measures of **Visuomotor Coupling** were analyzed as a function of mode.

TaskTime	Bi		Inter	
	Pre-Reach	Gaze	Pre-Reach	Gaze
	0.77**	0.57	0.61*	0.68*

$N = 12$; * $p < .05$, ** $p < .01$

Conclusions

- Intermanual is faster than bimanual (for an unpracticed task).
- Visuomotor coupling is an explanatory variable of speed.
- Intermanual sacrifices speed during Gaze Anchoring.
- Future research should experimentally manipulate previous practice when comparing these two coordination modes.

References

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