Effect of movement speed on multi-sensory integration during multi-digit rotation task

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Introduction

- Speed-accuracy trade-off (SAT) denotes the negative relation between response speed and response accuracy.
- The neural mechanism of the SAT proposed the influence of sensory processing (Ho, T., et al., 2012).
- Multi-sensory integration is a efficient way to improve motor performance under sensory processing (Brayanov, J. B., & Smith, M. A., 2010).
- Purpose: ***compare the efficiency of the multi-sensory integration during multi-digit rotation actions with different movement speed.***

Methods

Subjects

- Eight males (age 30.3 ± 2.7 years, height 167.5 ± 6.5 cm, weight 69.4 ± 15.7 kg).

Equipment

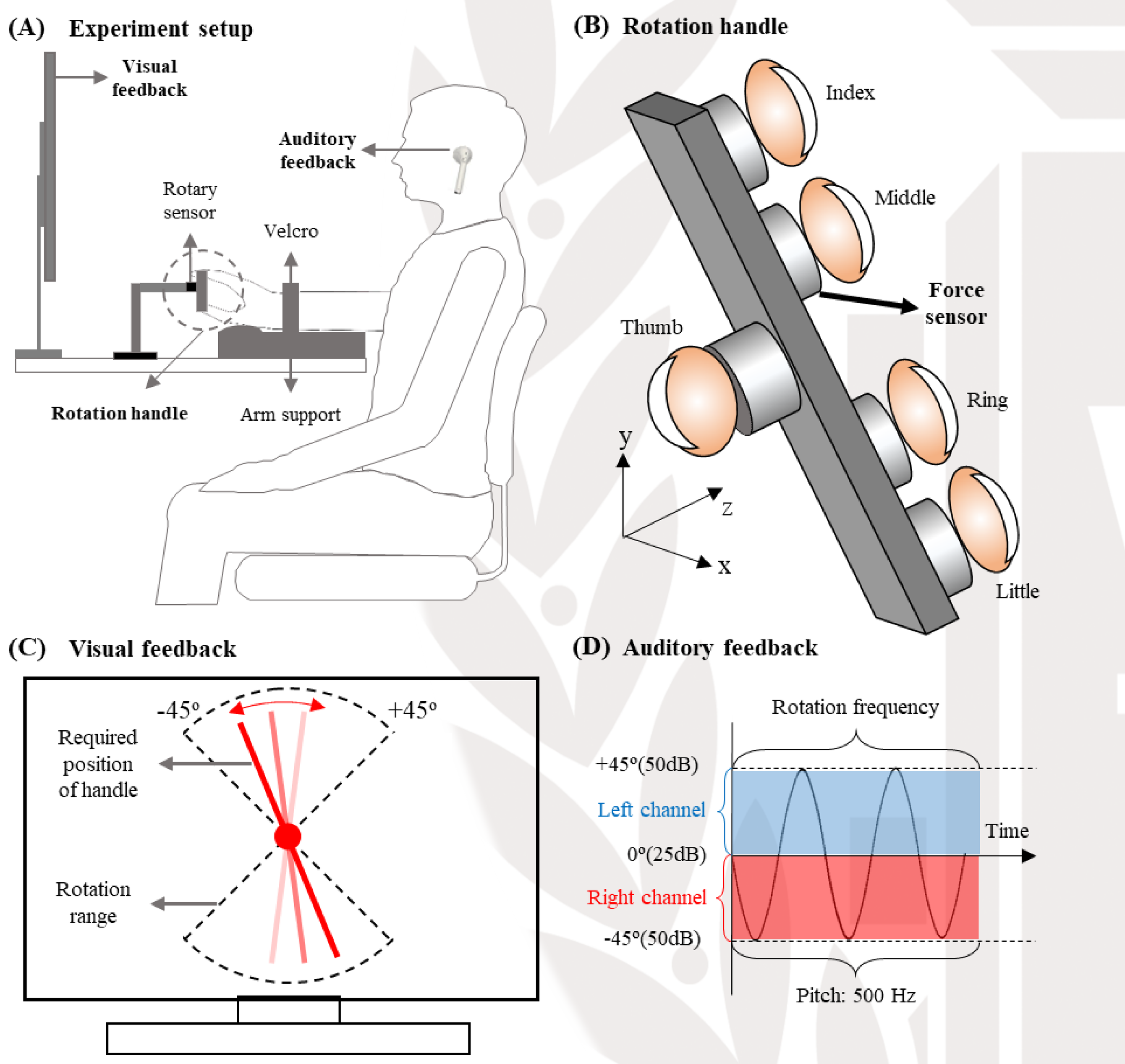


Figure 1. *Illustration of the experimental setup (A), force measurement (B), and the feedback information provides by visual (C) and auditory (D).*

- Five **force transducers** (Nano-17, ATI Industrial Automation, Garner, NC, USA) were used to measure forces of eight fingers. f_{sample}^{force} was set at 200 Hz.
- An **encoder** (AHS36A, SICK STEGMANN GmbH, DE, Germany) was attached to the center of the handle to measure its rotated angle. f_{sample}^{angle} was set as 200 Hz.

Procedure

- The main task: cyclically rotate the handle from –45º (pronation) to 45º (supination) using five fingers of right hand and following the required frequency.
- Three manners to provide information about required frequency (feedback conditions):
  (1). Visual – cyclic rotated bar showed in the computer screen
  (2). Auditory - cyclically changed volume of sound in alternate left or right earphone
  (3). Visual+Auditory – both visual and auditory information simultaneously
- Three required rotation speed (frequency conditions):
  (1). Slow - 0.1 Hz; (2). Middle - 0.5 Hz; (3). Fast - 1 Hz
- After enough practice, 20 cycles in one of 9 conditions in a random sequence.

Data analysis

1. Pre-processing of force and angle data

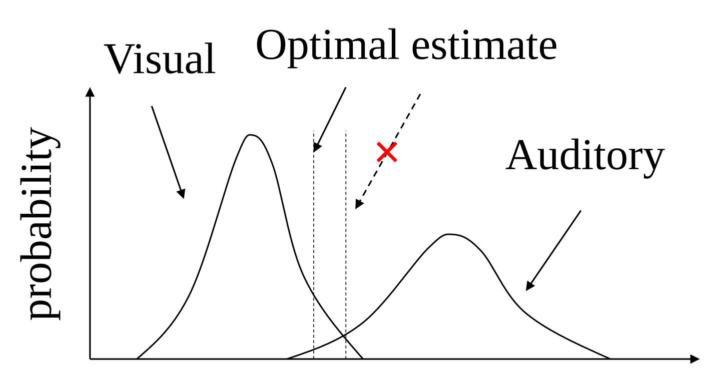
- Customized MATLAB (MathWorks Inc., Natick, MA, USA) codes were written.
- Low-pass filtering with a 4th-order Butterworth filter at 10 HZ.

2. Maximum likelihood estimation (MLE)

- When integrating two resources, more reliable resource will be assigned larger weight.
- The theoretical distribution of RMSE under multi-sensory integration was computed based on MLE and compared to the RMSE measured in Visual + Auditory condition.
- $\mu_{MLE} = \omega_V \mu_V + \omega_A \mu_A$;

$\omega_V = \frac{\sigma_V^2}{\sigma_V^2+\sigma_A^2}$, $\omega_A = \frac{\sigma_A^2}{\sigma_V^2+\sigma_A^2}$;

V: visual condition; A: auditory condition.



3. Uncontrolled Manifold (UCM) Analysis

- Synergy was quantified based on the UCM hypothesis (Scholz et al., 2003).
- The synergy index (ΔV) was quantified as the relative value of V_{UCM} in total variance.

$$\Delta V = \frac{V_{UCM}/3 - V_{ORT}/1}{(V_{UCM}+V_{ORT})/4}$$

V_{UCM}: Variance on UCM space.
V_{ORT}: Variance on orthogonal space.

4. Statistical analysis

- Repeated-measure ANOVAs were performed to compare results in 9 experimental conditions and compare MEL results to measurement in Visual + Auditory condition.
- All statistical significance level (α) was set at 0.05.

Results

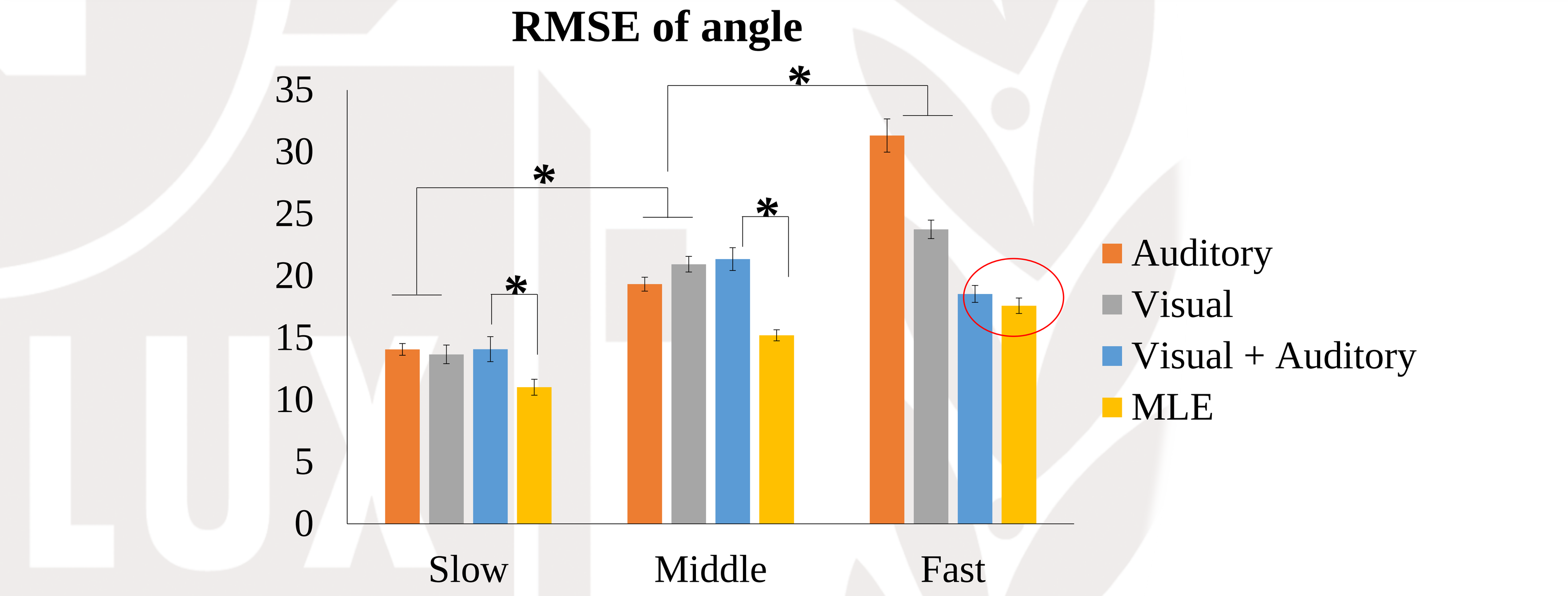


Figure 2. *Root mean square error (RMSE) between measured and required angles in 9 experimental conditions and computed using maximum likelihood estimation (MLE)*

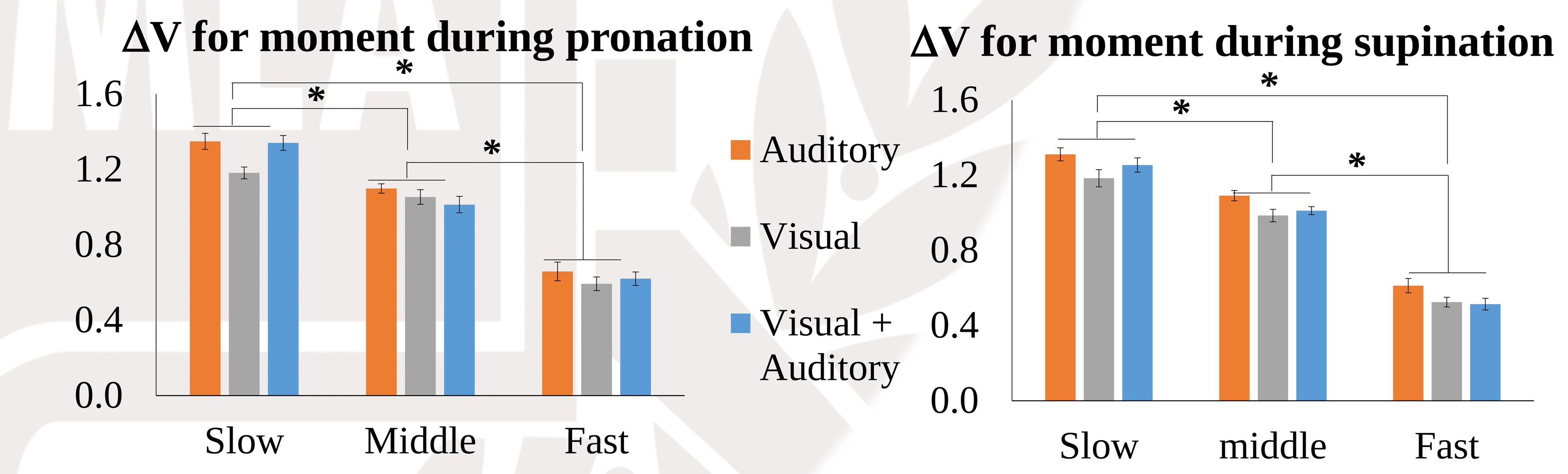


Figure 3. *Synergy index averaged across participants in 9 experimental conditions during pronation (A) and supination (B) phases.*

Discussion & Conclusion

- Increased speed incited worse performance and smaller synergy index
- Performance improved when receiving both visual and auditory information in fast speed condition rather than slow and middle speed conditions.
- No change in synergy index associate with the success of multi-sensory integration.

References

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