Modeling Spatial Asymmetry in Visuomotor Coordination

Kolby Brink, Aaron Likens, and Nicholas Stergiou
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: kolbybrink@unomaha.edu

Presentation Preference: **Podium**

INTRODUCTION

Coordination is foundational to human movement[1]. One prominent model of coordination is the Haken-Kelso-Bunz (HKB) which predicts change in relative phase between two oscillators according to the following equation:

$$\dot{\phi} = \Delta\omega - a\sin(\phi) - 2b\sin(2\phi) - \sqrt{Q}\zeta_t,$$

where Δω quantifies differences in natural periods between the oscillators. The ratio, *b/a*, models the collective frequency of coordinated oscillation. $\sqrt{Q}\zeta_t$ is a noise term with strength Q. $\Delta\omega$ is an 'imperfection parameter' that predicts deviations in relative phase, ϕ, due to timing differences in oscillators. Another possibility is that deviations of ϕ might result from asymmetries in spatial alignment of oscillators, such as in visual motor coordination. We propose two possible mechanisms for modeling asymmetry based on a modified HKB model:

$$\dot{\phi} = \Delta\omega + \Delta s - a\sin(\phi - \eta) - 2b\sin(2\phi) - \sqrt{Q}\zeta_t$$

Two potential terms, Δs and η, can model the effects of spatial asymmetries of oscillators. Both predict shifts in mean relative phase, $\bar{\phi}$, away from stable fixed points. Only the Δs parameter predicts a shift in $SD_{\bar{\phi}}$, a decrease in the stability of coordination. This study was designed to distinguish which, if either, of those parameters best models spatial asymmetry.

METHODS

10 healthy adults (26.4 ± 6.87 years, 7 males, 3 females) participated in this study. A 6-camera system (Optotrak, NDI) measured upper body movement at 100 Hz. The aim was to investigate the effects of reference frame alignment on the form and stability of visuomotor coordination. Participants coordinated their arm movements with a visually displayed sinusoidally oscillating stimulus (S_{Sine}). Forearm movements pivoted about the elbow which rested on a rotating platform. A user controlled visual stimulus (S_{RA}) was displayed on the screen that oscillated due to elbow rotation. Figure 1A shows a display in which the horizontal centers of oscillation of S_{Sine} and S_{RA} are manipulated. Given horizontal screen coordinates (x) an amplitude of oscillation (A) of S_{Sine}, we scaled this offset parameter as ρ = x_{shift}/A (Figure 1C). Figure 1B depicts the relative positions of S_{Sine} and S_{RA} for ρ = -2.0 over several cycles. We hypothesized that particular spatial offsets will be preferred. To test this hypothesis, we studied preferences for particular spatial arrangements of S_{Sine} and S_{RA} that arise from initial arrangements of ρ = -3, -2, -1, 0, 1, 2 or 3. Participants were free to move the location of S_{RA} as long as they could comfortably perform anti-phase and in-phase coordination. Subjects performed 3 trials for each phase (in-phase, anti-phase) × ρ pair, each lasting 60 seconds. 3 practice trials were given at ρ = 0 to familiarize subjects with the task.

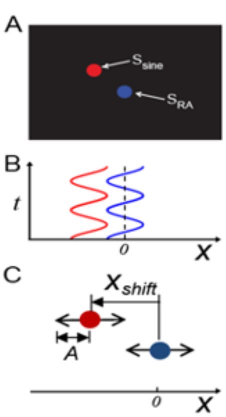

Figure 1. See Text

Analysis Strategy. We computed instantaneous relative phase between S_{Sine} and S_{RA} for all trials, along with circular means and standard deviations.[2] We then modeled $\bar{\phi}$ and $SD_{\bar{\phi}}$ as a function of ρ and phase (inphase/antiphase) in separate Bayesian multilevel models developed specifically for circular/directional dependent variables.[3]

RESULTS AND DISCUSSION

Estimates in Table 1 replicate well known differences between required phases because the 95% credible intervals defined by LB and UB do not overlap. Modeling results in Table 2 show that most slope estimates indicate that a one unit change in ρ predicts a negative change in $\bar{\phi}$ because credible intervals do not contain 0. Models relating ρ and $SD_{\bar{\phi}}$ (not reported to due to space) found no evidence of such a relationship, implying that Δs may not be useful in modeling asymmetry effects.

Table 1. Estimated circular descriptive statistics for $\bar{\phi}$ as a function of required phase. Estimates are in radians.

	Mean	Mode	SD	LB	UB
Anti-phase	-2.82	-2.87	0.13	-2.98	-2.59
In-phase	0.14	0.12	0.03	0.08	0.21

Table 2. Slope estimates for ρ predicting $\bar{\phi}$

Slopes	Mean	SD	Mode	LB	UB
β_c	-0.18	-0.22	0.23	-0.31	0.14
AS	-0.08	-0.08	0.15	-0.22	-0.02
SAM	-0.08	-0.09	0.06	-0.20	-0.02

Note: β_c = Slope at inflection point, AS = Average Slope, SAM = Slope at Grand Mean, LB/UB = Upper and lower bounds of 95 % credible interval from Bayesian estimates.

CONCLUSIONS

Results suggest that, in the current context, spatial asymmetries may best be modeled via the η parameter in the modified HKB model. Future work will investigate the extent to which this modification transfers to other conditions of asymmetry.

REFERENCES

1. Kelso, J., *MIT PRESS*, (1995).
2. Lamb, P.F., et al. *Clinical Biomech.*, (2014) ***29(5),*** *484-493.*
3. Cremers, J. et al, *Frontiers in psychology* (1994). **9**, 2040.

ACKNOWLEDGEMENTS

This work was supported by NIH P20GM10909 and a Pilot Project Award to A. Likens from the Center for Research in Human Movement Variability and the NIH.