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Rowing together: synchronisation vs. syncopation

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Crew rowing is often quoted as a natural example of perfect unity. A crew of rowers aims to optimize performance by perfectly moving in synchrony, while they apply all their power at maximum stroke rate. But do they necessarily need to move in in-phase synchrony? It has been suggested that crew members may complement each other's movements by rowing in syncopation (i.e., antiphase rowing). By perfectly alternating their strokes, a crew can reduce velocity fluctuations of the boat, which theoretically implies decreased hydrodynamic drag and, most importantly, potentially results in faster race times (Brearly, DeMestre, & Watson, 1998).

Research in both intra- and interpersonal coordination dynamics has shown that coordinating in an antiphase pattern is less stable than in an in-phase pattern. Moreover, with an increase in movement frequency the stability of both patterns decreases, yielding transitions from anti- to in-phase coordination (Haken, Kelso, & Bunz, 1985; Schmidt & Richardson, 2008). As stroke rates in races reach up to 42 strokes per minute (*spm*), rowing in antiphase needs to be sufficiently stable to be successful in competition. The aim of our experiments was to test the stability of in- and antiphase crew coordination first in the more controlled laboratory environment and after in the natural environment on the water.

Method

In the laboratory study, sixteen pairs of experienced rowers rowed eight 2-min trials (of which four trials are reported here; see Cuijpers, Den Hartigh, Zaal, & De Poel, 2019) on ergometers that were coupled through slides as to mimic the mechanical coupling between the rowers via the boat. Kinematics of rowers and ergometer-system were captured at 150 *Hz*. On-water, nine pairs of experienced rowers rowed four 1000 *m* trials in in- and antiphase at 20 and 30 strokes per minute (*spm*; Cuijpers, Zaal, Hoogerheide, Lemmink, & De Poel, *submitted*). Trials were performed in a four-person boat to leave sufficient space for the oars not to collide. Oar angles were measured at 200 *Hz*. Both in the lab and on-water the stroke rowers received feedback on their stroke rate. The occurrence of 'coordinative breakdowns', defined as a ≥ 180° deviation of relative phase value from the instructed pattern for at least one full movement cycle, were counted as deviations from steady state coordination. Next, for the steady state trials (in which no coordinative breakdown occurred), the time series were analysed over steady state bins for each condition. Based on the handle (lab) and oar angle (on-water) time series, for each condition standard deviations (*SD*) of discrete relative phase ($SD\varphi_{catch}$ and $SD\varphi_{finish}$) were calculated as measures of steady-state coordinative stability.

Results and Discussion

In the laboratory study, four coordination breakdowns occurred in antiphase coordination, of which three at 20 and one at 30 *spm*. On the water, five pairs were able to row all trials without showing breakdowns, while two other pairs showed a coordinative breakdown once (one in 20 and one in 30 *spm*). In two different pairs, coordination broke down repetitively at 30 *spm*. Both in the lab and on the water, no breakdowns in in-phase coordination occurred. The breakdowns in coordination did not seem related to a movement frequency-induced loss of stability, but seemed to be related to hitting a wave with the blade or a temporary loss of attention. Regarding the latter, various studies have shown that the degree of attention devoted to the movements of the other agent affects the stability of coordination for both inter- and intrapersonal coordination (e.g., Richardson et al., 2007; Monno, Temprado, Zanone, & Laurent, 2002). Although the coupling may remain relatively stable for a certain task or situation (e.g., the movements of the rower in front remain visible over the course of a race), the degree to which agents attend to the perceptual coupling may change, e.g., depending on other attentional demands, such as steering the boat in the crew rowing task. Given the intrinsically lower stability of the pattern, antiphase coordination remains more prone to such perturbations, which is indeed supported by the observation that coordinative breakdowns only occurred in antiphase crew coordination.

For the trials in which no breakdowns occurred, variability of crew coordination around the catch and finish (at which the blades enter and leave the water, respectively) are shown in Figure 1 (laboratory study) and Figure 2 (on-water study). In line with predictions from the HKB-model, variability of crew coordination was higher for anti- compared to in-phase coordination (Lab: $SD\varphi_{catch}$ ($F(1,8) = 36.40$, $p < .001$, $\eta p2 = .82$) and $SD\varphi_{finish}$ ($F(1,8) = 41.29$, $p < .001$, $\eta p2 = .84$); On-water: $SD\varphi_{catch}$ ($F(1,4) = 21.06$, $p = .01$, $\eta p^2 = .84$) and $SD\varphi_{finish}$ ($F(1,4) = 21.82$, $p = .01$, $\eta p^2 = .85$). Variability of both patterns was higher at the *lower* compared to the higher stroke rate, except for variability at the finish in the laboratory study (Lab: $SD\varphi_{catch}$ ($F(1,8) = 5.48$, $p = .047$, $\eta p2 = .41$) and $SD\varphi_{finish}$ ($F(1,8) = 4.590$, $p = .07$, $\eta p2 = .37$); On-water: $SD\varphi_{catch}$ ($F(1,4) = 14.12$, $p < .05$, $\eta p^2 = .78$) and $SD\varphi_{finish}$ ($F(1,4) = 13.34$, $p < .05$, $\eta p^2 = .77$).

Although counterintuitive, higher variability in lower frequency movements has been observed earlier. Research on interpersonal pendulum swinging, in which participants had to synchronise the swinging of their pendula at a range of .6 to 2 *Hz* showed that coordinative variability increased above, but also *below* 1

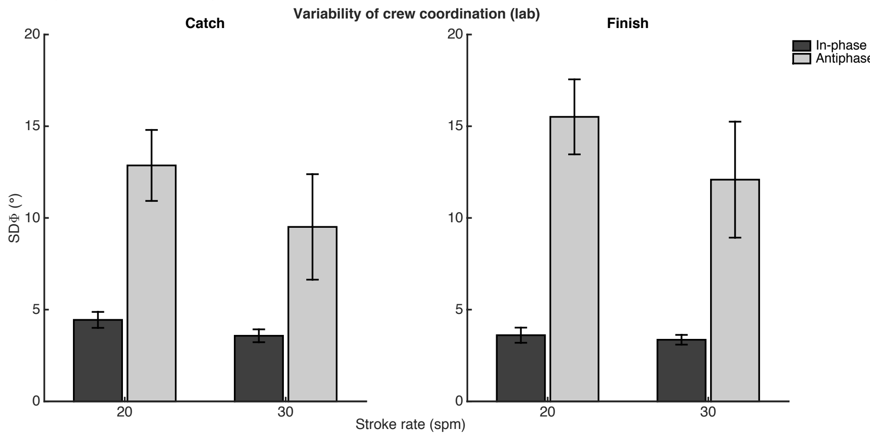

Figure 1. Variability of crew coordination around the catch (left panel) and finish (right panel) at 20 and 30 spm on the ergometer setup. Error bars represent standard errors.

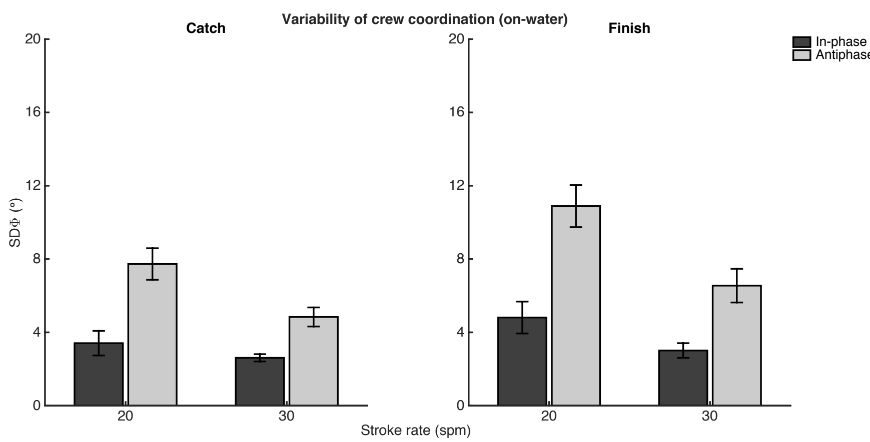

Figure 2. Variability of crew coordination around the catch (left panel) and finish (right panel) at 20 and 30 spm on the water. Error bars represent standard errors.

Hz (Schmidt, Bienvenu, Fitzpatrick, & Amazeen, 1998; for bimanual coordination see also Monno et al., 2002). Altogether, this suggests that at lower movement frequencies, coupling strength (and, hence, attractor strengths) may actually increase with an increase in movement frequency, also in other interpersonal coordination tasks. This hypothesis needs to be tested further by examining, in different interpersonal coordination tasks, how the attractor strength evolves across different movement frequencies. Moreover, the movement frequency in the study of Schmidt et al. (1998) at which coordination was most stable was close to the eigenfrequencies (the natural oscillation frequency) of the pendula that the participants were swinging. This suggests that coordinative stability may be related to the eigenfrequency of the components that constitute the system, even if that component is not an agent or passive (e.g., Schmidt & Richardson, 2008). The system of a rowing crew consists of relatively high inertia components in comparison to other coordination dynamics tasks and not only includes two agents, but also a boat with its own inertial characteristics. Possibly, characteristics such as the rigging settings of the boat (i.e., the length of the oars, which may be adjusted to change the lever of the oars; or the resistance of the ergometer flywheel in the laboratory setup) may influence coordinative stability like the eigenfrequencies of the pendula in Schmidt et al. (1998). As such, crew rowing may provide an interesting experimental task to study the effects of component characteristics in relation to coordinative stability, as the task allows manipulations of the characteristics of the boat/ergometer system (e.g., through rigger- and flywheel settings).

Together, the results illustrate the suitability of crew rowing as a task to study coordination dynamics aspects in the natural environment. Given that rowers were mostly able to perform the antiphase pattern on the water, especially at higher racing rates, these results provide a promising first indication of the benefits of antiphase rowing on water.

References

Brearley, M.N., De Mestre, N.J., Watson, D.R. (1998). Modelling the rowing stroke in racing shells. *Mathematical Gazette, 82*, 389–404.

Cuijpers, L.S., Den Hartigh, R.J.R., Zaal, F.T.J.M, De Poel, H.J. (2019). Rowing together: interpersonal coordination dynamics with and without mechanical coupling. *Human Movement Sciences, 64*, 38-46.

Cuijpers, L.S., Zaal, F.T.J.M., Hoogerheide, A., Lemmink, K.A.P.M., & De Poel, H.J. (*submitted*). Exploring the potential benefits of antiphase crew rowing on water.

Haken, H., Kelso, J.A.S., Bunz, H. (1985). A theoretical model of phase transitions in human hand movements. *Biological cybernetics, 51,* 347-356.

Monno, A., Temprado, J.J., Zanone, P.G., & Laurent, M. (2002). The interplay of attention and bimanual coordination dynamics. *Acta Psychologica, 110* , 187-211.

Richardson, M.J., Marsh, K.L., Isenhower, R.W., Goodman, J.R.L., Schmidt, R.C. (2007). Rocking together: dynamics of intentional and unintentional coordination. *Human Movement Science, 26*, 867-991.

Schmidt, R.C., Bienvenu, M., Fitzpatrick, P.A., Amazeen, P.G. (1998). A comparison of intra- and interpersonal interlimb coordination: coordination breakdowns and coupling strength. *Journal of Experimental Psychology, Human Perception and Performance, 24*, 884-900.

Schmidt, R.C., Richardson, M.J. (2008). Dynamics of interpersonal coordination. In: Fuchs, A. & Jirsa, V.K. (Ed.). *Coordination: neural, behavioural, and social dynamics* (p. 281-308). Champaign: Springer.