Synchronizing steps in running: pros and cons

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Extended abstract

Synchronizing steps in running: pros and cons

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Submitted: Sept 7th 2019

Keywords: entrainment, coupled oscillators, variability, instrumented treadmill, sensorimotor synchronization

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1 Introduction

Synchronizing to rhythmic stimuli (e.g., auditory or visual metronome), either deliberately or unintentionally, can benefit cyclical (e.g. locomotor) behavior in healthy and pathological contexts [1,2]. Such entrainment has also been demonstrated to enhance the efficiency and hence performance of strenuous cyclical movement tasks [3-5] such as running [6,7]. There are also some anecdotal examples of such entrainment benefits in world-class sporting events [see, e.g., 6]. Next to deliberate synchronizing, runners appear to be prone to spontaneously adapting to rhythms that deviate from their own cadence [8]. However, such mismatching rhythms may disturb performance in case people unintentionally entrain to these [3]. Here we therefore briefly outline pros and cons of entrainment in running alongside some preliminary results of a recent experiment at our lab.

2 Synchronizing with convenient rhythms

Extensive theoretical and empirical research from a coupled oscillator perspective [9,10] indicates that stronger coupling enhances the stability of a coordination pattern as well as the stability of each of the rhythmically moving components. For sensorimotor coordination this implies that the stability (and hence energetic economy [11]) of the runner's rhythm could be enhanced by entrainment to external rhythms. In line, results in human locomotion indicate enhanced locomotor coordination [6], lower physical strain on the body [12] and lower oxygen consumption [3,4] associated to such entrainment.

External rhythms can be of any nature: from a beat in music, to flashing lights, to rhythmic movements of someone else. Provided that it can be perceived, any rhythm offers the possibility and incentive of pacing and synchronization of movements [13]. For instance, when the tempo of an auditory rhythm is nicely aligned to the cadence of the runner, such pacing results in a less variable running pattern [6], which is thought to imply higher running efficiency [6,7,11,12]. Given that humans walking side-by-side often unintentionally fall into step with each other [14], even more so when holding hands [15], visual and haptic/physical rhythms can also entrain. For strenuous locomotion, visual entrainment effects are however rather understudied and (thereby) somewhat more disputable [16-18], hence deserving more empirical attention [16]. Also, in this context, the stringency of haptic/physical entrainment provides an exciting endeavor that has recently been taken on [e.g., 19,20].

Now, how could such entrainment effects be employed to the benefit of running performance? One could for instance think of synchronizing steps to an opponent or pacemaker. However, such a strategy would only be feasible if the pacemaker's cadence is similar, or at least sufficiently close to that of the runner [21], which is delineated next.

3 Cons of sensorimotor entrainment

When one oscillator is forced by another one with a differing eigenfrequency this leads to phase-locking, provided that the eigenfrequencies are not too far apart [9]. Accordingly, runners indeed adapt to the tempo of a sensory rhythm when it deviates 1-3% from the runner's natural cadence for a given running speed [8, 21].

Although beyond a certain tempo-difference the phase-locking effect disappears [8,21], some entrainment effects may maintain. That is, the individual component(s) keep their own movement frequency with an intermittent tendency toward synchronizing, which would yield fluctuations around the average component frequency [9]. Accordingly, coupling oscillators of mismatching frequencies entails poorer between-oscillator coordination as well as less stable component rhythms [9,10]. In strenuous tasks other than running it has been shown that entrainment to deviating rhythms indeed disturbed performance [3]. Thus, entraining to such mismatching rhythms slightly in/decreases running cadence [8] and would theoretically be at the expense of the stability and variability of the running pattern (and hence energetic efficiency and performance).

Table 1. Gait parameters (means ± SE) for each auditory condition, and according RM ANOVA results.

Variable	**Condition**			**Statistics**	
	CTRL	IN	ANTI	$F(2,26)$	p
Mean step frequency (steps/min)	163.9 ± 2.2	162.8 ± 2.1	165.5 ± 2.4	7.89	< .05
SD of step frequency (steps/min)	6.19 ± 0.36	5.49 ± 0.49	6.55 ± 0.41	3.57	< .05
SD of between-leg phase relation (°)	3.39 ± 0.2	3.04 ± 0.3	3.58 ± 0.2	4.25	< .05

4 Preliminary experimental results

Tests and reports regarding to how such 'less convenient' external rhythms affect running pattern variability and stability are lacking. In a simple lab-experiment we therefore aimed to address this issue. Fifteen experienced distance runners ran on an instrumented treadmill (Motekforce Link, Amsterdam, The Netherlands) at a self-selected endurance speed in three different counterbalanced conditions of 7 min each: a control condition without auditory stimuli (CTRL), a condition in which footfalls (determined using the force plate) instantly triggered a sound of a footfall, hence presented in-phase with the actual footfall (IN), and a condition in which the sound was presented exactly half a step duration later than the registered footfall, yielding each sound to be presented in antiphase with respect to the steps (ANTI). Thus, while the auditory rhythmic sequence was *per definition* of similar tempo as the step cadence, the intermittent antiphase stimuli were expected to induce a more variable running pattern [9,10]. Preliminary analysis indeed showed that compared to CTRL the step variability increased in ANTI, while it decreased for IN (Table 1), which supports the idea that running with a convenient external rhythm may enhance performance, while (unintentional) entrainment to an inconvenient external rhythm may lead to poorer performance.

5 Next steps

While these preliminary averaged outcomes are in line with the entrainment hypothesis, inter-individual differences existed that may be related to each runner's susceptibility to auditory entrainment [13]. Notably though, these entrainment effects were already observed despite the fact that treadmills impose substantial limits on running maneuverability and movement adaptations (e.g., due to size and set constant speed [22,23]). Together with the observation that even Usain Bolt showed surprisingly large fluctuations in step frequency in his 100m world record race [16], we therefore deem it is imperative to run experimental tests 'off the treadmill' (Blikslager & De Poel, in progress).

Acknowledgements

The authors would like to thank Raoul Bongers for his role in the reported experiment in the sudden absence of the first author.

References

1. Repp, B. H.; Su, Y. H. Sensorimotor synchronization: a review of recent research (2006–2012). *Psych Bull & Rev.* **2013**, 20(3), 403-452.
2. Bank, P.J.M.; Roerdink, M.; Peper, C. E. Comparing the efficacy of metronome beeps and stepping stones to adjust gait: steps to follow! *Exp Brain Res*. **2011**, *209(2)*: 159-169.

3. Bacon, C.J.; Myers, T.R.; Karageorghis, C.I. Effect of music-movement synchrony on exercise oxygen consumption. *J Sport Med Phys Fit*. **2012**, *52(4)*, 359–365.
4. Bardy, B.G.; Hoffmann, C.P.; Moens, B.; Leman, M.; Dalla Bella, S. Sound-induced stabilization of breathing and moving. *Ann NY Ac Sci*. **2015**, *1337(1)*, 94–100.
5. Cohen, E.E.; Ejsmond-Frey, R.; Knight, N.; Dunbar, R.I. Rowers' high: behavioural synchrony is correlated with elevated pain thresholds. *Biol Lett*. **2009,** *6(1)*, 106-108.
6. Bood, R. J.; Nijssen, M.; van der Kamp, J.; Roerdink, M. The power of auditory-motor synchronization in sports: enhancing running performance by coupling cadence with the right beats. *PLoS ONE*. **2013**, *8(8)*.
7. Terry, P.C.; Karageorghis, C.I.; Saha, A.M.; D'Auria, S. Effects of synchronous music on treadmill running among elite triathletes. *J Sci Med Sport*. **2012**, *15(1)*, 52-7.
8. Van Dyck, E.; Moens, B.; Buhmann, J.; Demey, M.; Coorevits, E.; Dalla Bella, S.; Leman, M. Spontaneous entrainment of running cadence to music tempo. *Sports Med Open*. **2015,** *1(1)*, 15.
9. Kelso, J.A.S. *Dynamic patterns: The self-organization of brain and behavior*. Champaign: MIT Press, **1995**
10. Schmidt, R.C.; Richardson, M.J. Dynamics of interpersonal coordination. In: *Coordination: neural, behavioral, and social dynamics*; Fuchs, A., Jirsa, V.K., Eds.; Champaign: Springer, **2008**; pp. 281-308.
11. Diedrich, F.J.; Warren, W.H. Why change gaits? Dynamics of the walk-run transition. *JEP:HPP*. **1995**, *21(1)*, 183–202.
12. Bigliassi, M.; León-Domínguez, U.; Buzzachera, C. F.; Barreto-Silva, V.; Altimari, L. R. How does music aid 5 km of running? *J Strength Cond Res*. **2015**, *29(2)*, 305–14.
13. Withagen, R.; Araújo, D.; De Poel, H.J. Inviting affordances and agency. *New Ideas Psych*. **2017**, *100(45)*, 11-8.
14. Van Ulzen, N.R.; Lamoth, C.J.; Daffertshofer, A.; Semin, G.R.; Beek, P.J. Characteristics of instructed and uninstructed interpersonal coordination while walking side-by-side. *Neurosc Lett*. **2008**, *432(2)*, 88-93.
15. Roerdink, M.; van Ulzen, N.R.; De Poel, H.J. When two become one: Spontaneous pattern formation in side-by-side and hand-in-hand walking. *Poster presented at Joint Action Meeting*, **2017**, London, United Kingdom.
16. Blikslager, F.; De Poel, H.J. Sync or separate? No compelling evidence for unintentional interpersonal coordination between Usain Bolt and Tyson Gay on the 100-meter world record race. *JEP:HPP*. **2017**, *43(7)*, 1466-1471.
17. Eaves, D. L.; Hodges, N. J.; Williams, A. M. Energetic costs of incidental visual coupling during treadmill running. *Med Sci Sport Exer.* **2008,** *40(8)*, 1506–1514.
18. Varlet, M.; Richardson, M. J. What would be Usain Bolt's 100-meter sprint world record without Tyson Gay? Unintentional interpersonal synchronization between the two sprinters. *JEP:HPP*. **2015,** *41(1)*, 36–41.
19. De Poel, H.J.; De Brouwer, A.J.; Cuijpers, L.S. Crew rowing: an archetype of interpersonal coordination dynamics. In: *Interpersonal coordination and performance in social systems*; Passos, P., Chow, J.Y., Davids, K., Eds.; Routledge, **2016**, 140-153.
20. Cuijpers, L.S.; Den Hartigh, R.J.; Zaal, F.T.J.M; De Poel, H.J. Rowing together: Interpersonal coordination dynamics with and without mechanical coupling. *Hum Mov Sc*. **2019**, *64*, 38-46.
21. Moens, B.; Leman, M. Alignment strategies for the entrainment of music and movement rhythms. *Ann NY Ac Sci*. **2015,** *1337(1)*, 86–93.
22. Roerdink, M.; Daffertshofer, A.; Marmelat, V.; Beek, P. J. How to sync to the beat of a persistent fractal metronome without falling off the treadmill? *PloS ONE*. **2015**, *10(7)*, e0134148.
23. Roerdink, M.; de Jonge, C.P.; Smid, L.M; Daffertshofer, A. Tightening up the control of treadmill walking: Effects of maneuverability range and acoustic pacing on stride-to-stride fluctuations. *Front Phys*. **2019**., *10*, 257.