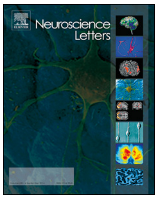
Neuroscience Letters 682 (2018) 132–136

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet



Research article

Interpersonal visual interaction induces local and global stabilisation of rhythmic coordination

Kohei Miyata[a,b,*], Manuel Varlet[c], Akito Miura[d], Kazutoshi Kudo[a], Peter E. Keller[c]

[a] Department of Life Sciences, Graduate School of Arts and Sciences, The University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo, Japan
[b] Japan Society for the Promotion of Science, 5-3-1 Kojimachi, Chiyoda-ku, Tokyo, Japan
[c] The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Bullecourt Avenue, Milperra, NSW, Australia
[d] Faculty of Sport Sciences, Waseda University, 2-579-15 Mikajima, Tokorozawa, Saitama, Japan

ARTICLE INFO

Keywords:
Anchoring
Interpersonal synchronisation
Visual coupling
Dance
Human movement

ABSTRACT

Perceptual coupling between people can lead to the spontaneous synchronisation of their rhythmic movements. In the current study, we hypothesised that the sight of a co-actor generates anchoring (local stabilisation around specific spatiotemporal points within movement cycles), and that such anchoring supports the occurrence and stability of spontaneous interpersonal synchronisation (global stabilisation across cycles). To test these hypotheses, we re-examined previously published data from a study where participants were required to perform auditory-motor coordination of whole-body movements with versus without visual contact. Paired participants performed two kinds of coordination task – either knee flexion or extension repeatedly with auditory metronome beats (Flexion-on-the-beat and Extension-on-the-beat conditions) while standing face-to-face or back-to-back to manipulate visual interaction. The analysis of individual movement trajectories showed that visual interaction led to decreased variability along the entire trajectory, except the maximum extension position. The results also indicated that the strength of this anchoring was correlated with the degree to which the variability of interpersonal phase relations decreased with visual coupling, suggesting that local stabilisation supported global interpersonal stabilisation. Therefore, the sight of a co-actor generates anchoring effects that may play a crucial role in the stabilisation of spontaneous interpersonal synchronisation.

1. Introduction

Numerous studies have demonstrated that paired individuals producing rhythmic movements tend to synchronise spontaneously through visual and auditory forms of informational interaction [1–8]. Specifically, the relative phase angles between paired individuals' movements become less variable and clustered typically around 0° (in-phase) or 180° (antiphase), with in-phase attraction being the strongest. Such spontaneous interpersonal synchronisation has been reported in various coordination tasks, ranging from those requiring the movement of only a single body segment (e.g., a finger) [1,2] to more complex whole-body movements such as postural sway or gait [3–7]. Furthermore, such synchronisation has been reported to affect us psychologically [9] (e.g., affiliation towards a co-actor) and physically (e.g., postural control) [5,10]. Despite these effects, it remains unclear how spontaneous interpersonal synchronisation comes about. This question concerns the nature of the processes by which interpersonal phase angles between paired individuals' movements are stabilised by informative coupling. Our previous work demonstrated that interpersonal visual coupling not only induces spontaneous interpersonal synchronisation in the context of auditory-motor coordination of whole-body dance-related movements performed in the presence of another person, but also affects the quality of individual auditory-motor coordination performance [10]. In the current study, we further explore these effects by investigating how interpersonal relative phase angles are stabilised by visual coupling (i.e. spontaneous interpersonal synchronisation) between paired individuals.

When two visually coupled individuals produce rhythmic movements, the vision of a co-actor can be considered as a rhythmic visual stimulus. Previous studies on visuo-motor coordination have reported that rhythmic visual stimuli 'anchor' rhythmic movements at particular points [11,12], and that such anchoring can stabilise phase relations between rhythmic visual stimuli and movements. The concept of anchoring originates in work by Peter Beek, who noted regions of reduced

---

[*] Corresponding author. Present address: Department of System Neuroscience, National Institute for Physiological Sciences, 38 Nishigonaka Myodaiji, Okazaki, Aichi, 444-8585 Japan.

E-mail address: still.kzn@gmail.com (K. Miyata).

https://doi.org/10.1016/j.neulet.2018.07.024
Received 19 March 2018; Received in revised form 9 July 2018; Accepted 15 July 2018

spatiotemporal variability in the kinematics of rhythmic movements in juggling [13]. Beek considered the presence of such local regions of stability as generally indicative of informational, mechanical, or intentional constraints that act on and organise rhythmic movements [13]. Anchoring has also been reported to occur at or around the points in the movement cycle coincident with rhythmic auditory and visual stimuli [11,12,14–19]. Furthermore, it has been proposed that anchoring facilitates intra-personal coordination stability [14,18,20,21]. Fink et al. (2000) demonstrated that the presentation of rhythmic auditory stimuli produces anchoring in the phase plane trajectories of bimanual finger movements (local stabilisation) that supports bimanual coordination (global stabilisation) by reducing the variability of relative phase angles and delaying phase transitions. If these effects extend to joint action, the vision of a co-actor could produce anchoring effects in an individual's movement trajectories, which may increase the strength (occurrence and stability) of interpersonal synchronisation.

Anchoring usually occurs around the reversal points of rhythmic movements but can occur anywhere in the entire movement cycle, depending on the temporal location of the task-specific sensory information [22,23]. This is particularly relevant for visual coupling with a partner, as the visual information flow from a partner's movement is continuous and could thus result in reduced variability not only in a specific region of the movement trajectory but along the entire movement trajectory. Evidence for such stabilisation comes from a study that investigated the body sway of paired participants who either were or were not looking at each other when standing on a ship at sea [24]. Under these conditions, visual coupling resulted in the occurrence of interpersonal synchronisation and a global decrease of the magnitude of participants' body sway, though the potential role of anchoring was not addressed in that study.

Here, we investigated whether interpersonal visual interaction induces anchoring by performing further analyses on data from a study of Miyata et al. [10], which examined the effect of visual coupling between pairs of people during the task of individually bouncing in synchrony with an auditory metronome. This earlier study aimed to investigate the effects of visual coupling on interpersonal relative phase relations and individual auditory-motor coordination dynamics, indexed by phase transition frequency and coordination variability. The task isolated a single component of a complex motor skill typically performed jointly with others: a knee flexion and extension motion from the street dancing movement repertoire (see [25]). The results showed that paired participants' movements become unintentionally coordinated when moving together, and that individual differences in auditory-motor coordination performance were reduced via behavioural assimilation. The purpose of the current study is to examine the 'local' effect of interpersonal visual coupling on individual movement trajectories (i.e., anchoring) and the relation between the occurrence of anchoring (local stabilisation) and enhanced stability of interpersonal relative phase relations (global stabilisation). We hypothesised that new analyses conducted on the variability of movement trajectories would reveal a variability reduction when participants can see each other, and that this reduction would occur along the entire phase plane trajectory because of the continuous nature of visual information. In addition, we predicted a correlation between reduced variability of individual movement trajectory and increased stability of spontaneous interpersonal coordination through visual coupling, indicative of links between the two phenomena.

2. Methods

2.1. Participants

Thirty-two undergraduates from the Western Sydney University participated in this experiment for course credit and were assigned to 16 pairs (9 female pairs and 7 mixed gender pairs; 14 pairs consisted of randomly assigned individuals and 2 pairs included friends). This study was conducted in full compliance with the Declaration of Helsinki and approved by the Western Sydney University Human Research Ethics Committee. Informed consent was obtained from each individual participant.

2.2. Task and procedures

Paired participants were instructed to bounce by bending their knees to the beat while keeping a standing posture. They performed the task in two different coordination pattern conditions (Flexion-on-the-beat and Extension-on-the-beat) and two different orientation conditions (Face-to-face and Back-to-back). Participants were not explicitly instructed to coordinate with each other. They were asked to look forward and to do their best to coordinate their movement with the auditory metronome beats, which were presented over four loudspeakers. The distance between the two participants was 200 cm. The frequency of the metronome was increased from 80 (1.33 Hz) to 160 (2.67 Hz) beat per minutes (bpm) in steps of 10 bpm, every 16 beats. The duration of each trial was 75 s. Participants performed 20 trials (2 auditory-motor coordination patterns × 2 orientation conditions × 5 repetitions). The order of trials was randomised. Before the experimental recording, participants practiced the task for a few minutes. See Miyata et al. [10] for further details.

2.3. Data acquisition and analysis

Participants' movements were measured using a Vicon 12-camera motion capture system (Vicon Motion Systems Ltd., Oxford, UK). Knee angular displacement was calculated from markers positioned on the hip, knee and ankle joint centres of participants as a representative measure of whole-body movement. Displacement data were low-pass filtered with a bidirectional second-order Butterworth filter (cut-off frequency = 7 Hz). The first three movement cycles of each frequency plateau were discarded to remove the transient effects due to frequency change (Fig. 1).

Anchoring was examined by computing the thickness (variability) of movement trajectories in the phase plane. Both displacement and velocity data were normalised by calculating Z-values and plotted on the phase plane where X-axis is displacement and Y-axis is velocity to compute the continuous phase of each participant's movement. The thickness of the normalised phase plane trajectories was calculated by the standard deviation (SD) of vector lengths in 90-degree regions. We defined the maximum flexion point as 0°, the maximum extension point as 180°, the velocity peak of flexion as $-90°$, and the velocity peak of extension as 90°. Each vector length was calculated by the square root of the normalised velocity squared plus the normalised position squared. The mean variability of the phase plane trajectories was then calculated across trials separately for each participant, coordination pattern, orientation condition, movement phase, and beat rate. This thickness value was expected to decrease due to anchoring at specific points of the trajectory or on the entire trajectory, depending on the influence of visual coupling [23]. The SD of relative phase angles between two participants' continuous phases on the phase plane was calculated to assess interpersonal coordination stability using circular statistics [26].

In order to evaluate the correlation between anchoring and the strength of interpersonal synchronisation, the degree of anchoring was determined by subtracting the grand mean thickness in the Back-to-back condition from mean thickness in the Face-to-face condition. The grand mean thickness was calculated across all four movement phases, beat rates, and coordination patterns in each orientation condition. We used the grand mean because the main purpose of this study concerned the general effect of visual interaction. The resultant index of anchoring was then averaged within a pair. One pair was excluded from this analysis because one individual had a value greater than 3 SDs from the mean across participants. The strength of interpersonal synchronisation

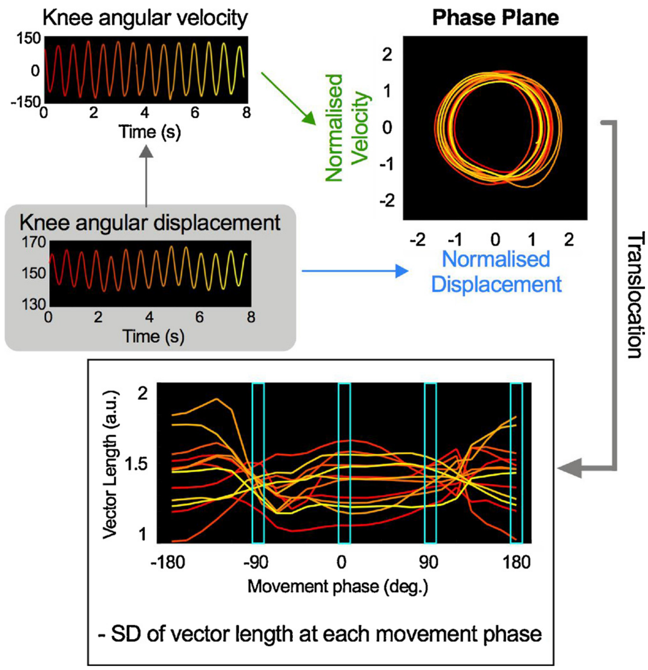


Fig. 1. Example of data processing flow. Time series data of knee angle displacement were low-pass filtered (cut-off frequency = 7 Hz). The angular velocity was, then, calculated from the displacement. Both displacement and velocity were normalised and plotted on a phase plane. The colour of displacement and velocity changes from red to yellow with time-course. We defined maximum flexion point as 0°, maximum extension point as 180°, the velocity peak of flexion as −90°, and the velocity peak of extension as 90° (Translocation). The standard deviation of vector lengths was calculated at each movement phase (blue box) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

was determined as the change induced by visual coupling in the SD of interpersonal phase relations, which was calculated by subtracting the SD in the Back-to-back condition from that in the Face-to-face condition. Negative values indicate a variability decrease with visual coupling whereas positive values indicate a variability increase with visual coupling.

2.4. Statistics

A 4-way analysis of variance (ANOVA) with within-subject factors coordination pattern (Flexion-on-the-beat and Extension-on-the-beat), orientation condition (Face-to-face and Back-to-back), beat rate (from 80 to 160 bpm in steps of 10 bpm), and movement phase (−90°, 0°, 90°, and 180°) was performed on the thickness values of the phase plane trajectories. The Greenhouse-Geisser correction was used in cases where Mauchly's test of sphericity was significant. Tests of simple effects were performed to follow up significant interactions. The Pearson correlation coefficient was computed to assess the relationship between the changes with visual coupling in the thickness of the phase plane trajectories and the variability of interpersonal coordination. For all analyses, the statistical significance level was set at $p < .05$.

3. Results

Fig. 2 shows the thickness (variability) of the phase plane trajectories. The ANOVA revealed significant main effects of orientation condition, $F(1, 31) = 17.16$, $p < .001$, $\eta_p^2 = .36$, beat rate, $F(2.25, 69.82) = 18.92$, $p < .001$, $\eta_p^2 = .38$, and movement phase, $F(1.78, 55.23) = 161.06$, $p < .001$, $\eta_p^2 = .84$, but not coordination pattern, $F(1, 31) = .00$, $p = .998$, $\eta_p^2 = .00$. The phase plane was thinner when standing face-to-face compared to back-to-back condition. It became thicker with beat rate except at 80 bpm, which was as thick as at 120 bpm. The phase plane was the thinnest at the extension velocity peak and followed by the flexion velocity peak. It was almost the same between the maximum flexion position and the maximum extension position. However, there were significant interactions for these main effects. The ANOVA yielded a significant two-way interaction of orientation condition × movement phase, $F(1.83, 56.63) = 6.83$, $p = .003$, $\eta_p^2 = .18$, and a significant three-way interaction of coordination pattern × beat rate × movement phase, $F(6.94, 215.15) = 3.55$, $p = .001$, $\eta_p^2 = .10$. Tests of simple effects unpacking the orientation condition × movement phase interaction revealed that phase plane trajectories were significantly thinner when paired participants were standing face-to-face compared to back-to-back at −90°, 0° and 90° ($p = .016$, $p < .001$, and $p < .001$, respectively), corresponding to the flexion velocity peak, maximum flexion position, and the extension velocity peak, respectively. There was no significant difference in phase plane trajectory thickness at 180° (maximum extension position), $F(1, 31) = 2.56$, $p = .120$, indicating that the sight of a partner reduced thickness along the entire trajectory of rhythmic movements except at the maximum extension point.

We broke down the three-way ANOVA of coordination pattern × beat rate × movement phase into two-way analyses as post hoc tests to explore the effect of coordination pattern. We found significant interactions of coordination pattern × beat rate at each level of movement phase (*ps* < .001), and coordination pattern × movement phase at each level of beat rate (*ps* < .05) except for 140 and 160 bpm. Tests of simple effects indicated that the phase plane trajectories at all movement phases were thinner in the Flexion-on-the-beat pattern than in the Extension-on-the-beat pattern at 140 and 160 bpm (*ps* < .01). Compared with the Extension-on-the-beat pattern, the thickness in the Flexion-on-the-beat pattern was thinner at −90° (flexion velocity peak) when beat rate was 130 bpm ($p = .011$), and at 90° (peak extension velocity) from 100 to 160 bpm (*ps* < .05). Furthermore, the thickness in the Extension-on-the-beat pattern was thinner at −90° (flexion velocity peak) and 0° (maximum flexion position) at 80 bpm ($p = .003$ and $p = .006$, respectively), and at 180° (maximum extension position) from 80 to 120 bpm (*ps* < .05). These results indicate that the phase plane trajectories were thinner at the point of the extension velocity peak at faster beat rates in the Flexion-on-the-beat pattern and at the point of maximum extension in the Extension-on-the-beat pattern at slower beat rates.

Fig. 3 shows the scatter plot of the reduced thickness of the phase plane trajectories versus the strength of interpersonal synchronisation. The correlation between these two measures was significant, $r = .62$, $p = .001$, $r^2 = .39$, indicating that the thinner phase plane trajectories became with visual coupling, the more the SD of interpersonal phase relation decreased (i.e., interpersonal synchronisation strengthened).

4. Discussion

The current study investigated the effect of interpersonal visual interaction on individual phase plane trajectories during a rhythmic coordination task. While previous studies examined anchoring generated by external sensory stimuli on individual bimanual coordination, we here examined anchoring effects induced by the sight of a co-actor on the stability of interpersonal phase relations. The results showed that visual coupling reduced the thickness (variability) of individual phase plane trajectories, which correlated with increased stability of interpersonal coordination.

Previous studies on sensorimotor coordination have reported that rhythmic sensory stimuli generate anchoring effects, which are manifest as reduced variability in phase plane trajectories [11,12,14–19]. In the current study, we predicted that anchoring would occur via interpersonal visual interaction to the extent that the sight of a co-actor

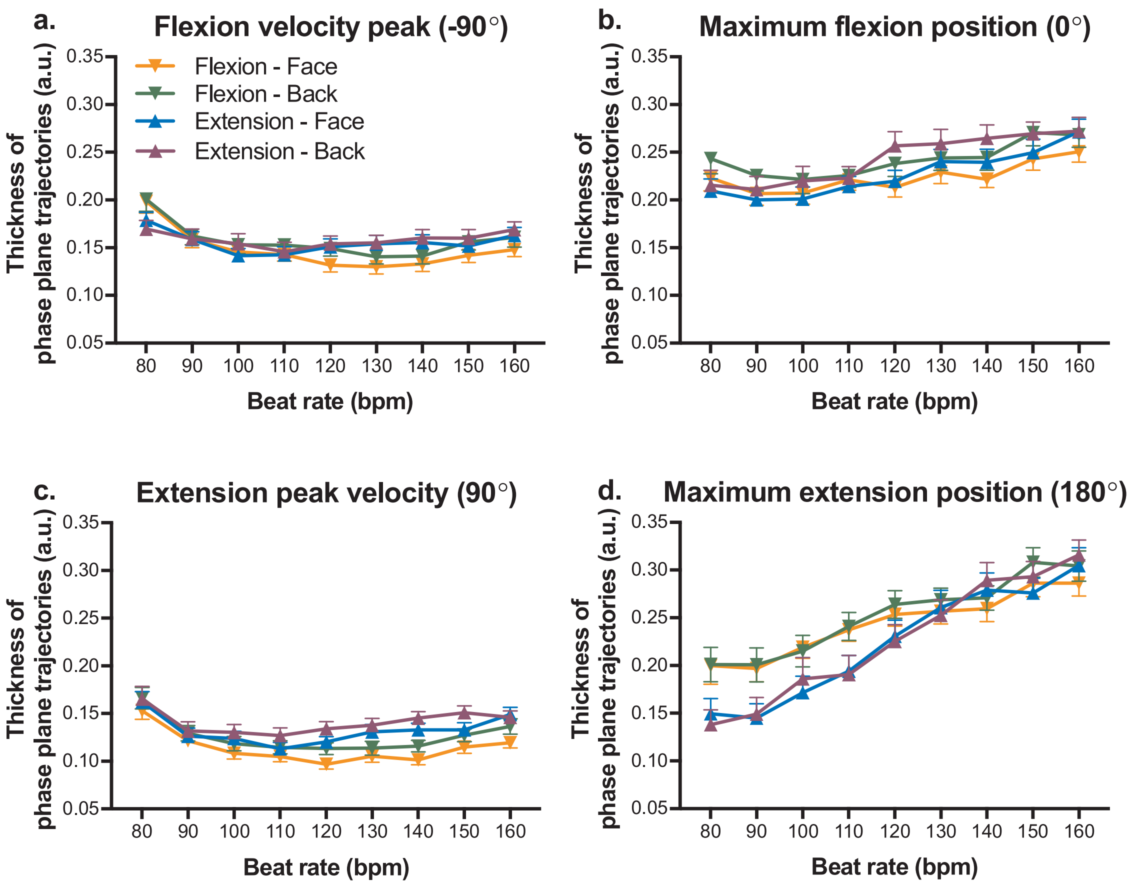


Fig. 2. Mean thickness of the normalised phase plane trajectories at −90° (a), 0° (b), 90° (c), and 180° (d). The x axis indicates beat rate and the y axis represents the thickness of the phase plane trajectories. The error bars represent standard error.

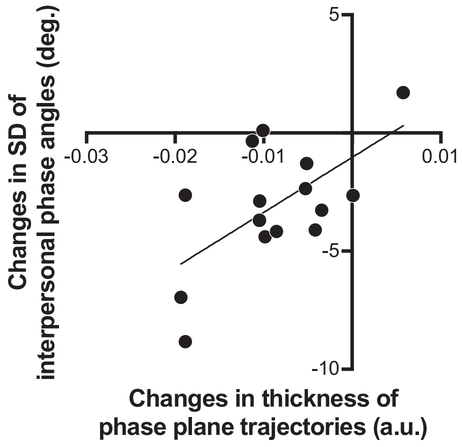


Fig. 3. Scatter plot of changes with visual interaction in the thickness of the phase plane trajectories and the SD of interpersonal phase relation. Each marker represents a pair. The trend line represents a linear regression line.

serves as a rhythmic visual stimulus. Our results showed that visual interaction led to decreased variability of movement trajectories, except for the maximum extension position. This exception might have been because the maximum extension position was close to the basic fully upright standing posture employed in our study, and was therefore less visually salient than other movement phases. The result thus partly supports our hypothesis that visual coupling reduces variability along the entire phase plane trajectory because the flow of visual information about a partner is continuous. Visual coupling between individuals has been shown in earlier work to result in a reduction in the magnitude of participants' body sway [24] and our findings extend the scope of such stabilisation effects of interpersonal coupling by revealing stabilisation in individual spatiotemporal phase planes. It should be noted that metronome beats also generated anchoring effects in the current study. This is supported by the results for phase plane trajectories at the maximum extension point, which were less variable in the Extension-on-the-beat pattern than in the Flexion-on-the beat pattern at slower beat rates. This reduction might disappear at higher beat rates due to a phase transition from the Extension-on-the-beat pattern to the Flexion-on-the-beat pattern.

Previous findings showing that local anchoring facilitates global coordination stability at the individual level [14,20,21] motivated our hypothesis that interpersonal visual coupling produces anchoring and may thereby facilitate interpersonal synchronisation. Here, we found that decreases in thickness of the phase plane trajectories correlated with reduced variability of interpersonal phase relations (Fig. 3), suggesting that vision of a partner induces anchoring, which supports the occurrence and stability of interpersonal synchronisation. These results extend previous findings at the individual level to the interpersonal level. Anchoring has been taken to indicate informational, mechanical, or intentional constraints that organise rhythmic movements [13] not only at the local level of movement cycles but also for global coordinative behaviour [15], that is, between an individual and the environment. In the present study, interpersonal synchronisation occurred in the absence of instruction or mechanical connection between individuals. Thus, we assume that the informational constraints that led to interpersonal synchronisation were related to anchoring.

In the current study participants were just instructed to look straight ahead during the auditory-motor synchronisation task. Previous studies have found that eye-movements play a crucial role in visuomotor synchronisation performance, including the occurrence and stability of interpersonal synchronisation [27,28]. Locally reduced variability (i.e., anchoring) movements has been found when participants fixed their gaze on a turning point of an oscillatory stimulus movement trajectory but not when tracking the stimulus [27]. Although it is largely unknown whether visual tracking could result in a more distributed reduction in variability, evidence indicates that visually tracking stimulus movement leads to stronger synchronisation than non-tracking visual behaviours [28]. Further studies will therefore be needed in the future to investigate to what extent eye movements contribute to the modulation of individual movement stability (i.e., anchoring) and the occurrence of spontaneous interpersonal synchronisation.

5. Conclusion

The main finding of the present study is that interpersonal visual coupling induces anchoring effects that decrease the spatiotemporal variability of individual rhythmic movements. This local stabilisation might play a crucial role in strengthening interpersonal synchronisation (global stabilisation) and thus support group performance in a variety of joint activities requiring precise interpersonal coordination (e.g., musical or dance ensemble performance).

Author contributions

All authors designed the experiments. K.M. and M.V. performed the experiments and analysed the data. All authors participated in discussions about the interpretation of the results. K.M., V.M. and P.K. wrote the manuscript with input from A.M. and K.K. All authors reviewed the manuscript.

Declarations of interest

None.

Acknowledgements

This study was supported by a Grant-in-Aid for JSPS Fellows (14J09838) and a Grant-in-Aid for Young Scientists (B) (17K13177) from Japan Society for the Promotion of Science awarded to K.M. P.K. is supported by a Future Fellowship grant from the Australian Research Council (FT140101162). The authors wish to express our gratitude to Prof. Kate Stevens for her helpful comments, and to Ms. Jia Ying and the MARCS Technical team for their kind support in conducting the experiment.

References

[1] R.C. Schmidt, B. O'Brien, Evaluating the dynamics of unintended interpersonal coordination, Ecol. Psychol. 9 (1997) 189–206.

[2] M.J. Richardson, K.L. Marsh, R.C. Schmidt, Effects of visual and verbal interaction on unintentional interpersonal coordination, J. Exp. Psychol. Hum. Percept. Perform. 31 (2005) 62–79, https://doi.org/10.1007/s10919-004-0888-9.

[3] M.J. Richardson, K.L. Marsh, R.W. Isenhower, J.R.L. Goodman, R.C. Schmidt, Rocking together: dynamics of intentional and unintentional interpersonal coordination, Hum. Mov. Sci. 26 (2007) 867–891, https://doi.org/10.1016/j.humov.2007.07.002.

[4] N.R. van Ulzen, C.J.C. Lamoth, A. Daffertshofer, G.R. Semin, P.J. Beek, Characteristics of instructed and uninstructed interpersonal coordination while walking side-by-side, Neurosci. Lett. 432 (2008) 88–93, https://doi.org/10.1016/j.neulet.2007.11.070.

[5] M. Varlet, L. Marin, J. Lagarde, B.G. Bardy, Social postural coordination, J. Exp. Psychol. Hum. Percept. Perform. 37 (2011) 473–483, https://doi.org/10.1037/a0020552.

[6] A.P. Demos, R. Chaffin, K.T. Begosh, J.R. Daniels, K.L. Marsh, Rocking to the beat: effects of music and partner's movements on spontaneous interpersonal coordination, J. Exp. Psychol. Gen. 141 (2012) 49–53, https://doi.org/10.1037/a0023843.

[7] M. Varlet, B.G. Bardy, F.C. Chen, C. Alcantara, T.A. Stoffregen, Coupling of postural activity with motion of a ship at sea, Exp. Brain Res. 233 (2015) 1607–1616, https://doi.org/10.1007/s00221-015-4235-7.

[8] M. Varlet, M.J. Richardson, What would be Usain Bolt's 100-meter sprint world record without Tyson Gay? Unintentional interpersonal synchronization between the two sprinters, J. Exp. Psychol. Hum. Percept. Perform. 41 (2015) 36–41, https://doi.org/10.1037/a0038640.

[9] M.J. Hove, J.L. Risen, It's all in the timing: interpersonal synchrony increases affiliation, Soc. Cogn. 27 (2009) 949–961.

[10] K. Miyata, M. Varlet, A. Miura, K. Kudo, P.E. Keller, Modulation of individual auditory-motor coordination dynamics through interpersonal visual coupling, Sci. Rep. 7 (2017) 1–11, https://doi.org/10.1038/s41598-017-16151-5.

[11] M. Roerdink, C.E. Peper, P.J. Beek, Effects of correct and transformed visual feedback on rhythmic visuo-motor tracking: tracking performance and visual search behavior, Hum. Mov. Sci. 24 (2005) 379–402, https://doi.org/10.1016/j.humov.2005.06.007.

[12] M. Roerdink, P.J.M. Bank, C.E. Peper, P.J. Beek, Anchoring in rhythmic in-phase and antiphase visuomotor tracking, Motor Control 17 (2013) 176–189.

[13] P.J. Beek, Juggling Dynamics, Free University Press, 1989.

[14] P.W. Fink, P. Foo, V.K. Jirsa, J.A.S. Kelso, Local and global stabilization of coordination by sensory information, Exp. Brain Res. 134 (2000) 9–20, https://doi.org/10.1007/s002210000439.

[15] W.D. Byblow, R.G. Carson, D. Goodman, Expressions of asymmetries and anchoring in bimanual coordination, Hum. Mov. Sci. 13 (1994) 3–28.

[16] M. Roerdink, A. Ridderikhoff, C.E. Peper, P.J. Beek, Informational and neuromuscular contributions to anchoring in rhythmic wrist cycling, Ann. Biomed. Eng. 41 (2013) 1726–1739, https://doi.org/10.1007/s10439-012-0680-7.

[17] W.D. Byblow, R. Chua, D. Goodman, Asymmetries in coupling dynamics of perception and action, J. Mot. Behav. 27 (1995) 123–137.

[18] K. Kudo, H. Park, B.A. Kay, M.T. Turvey, Environmental coupling modulates the attractors of rhythmic coordination, J. Exp. Psychol. Hum. Percept. Perform. 32 (2006) 599–609, https://doi.org/10.1037/0096-1523.32.3.599.

[19] A. Coste, R.N. Salesse, M. Gueugnon, L. Marin, B.G. Bardy, Standing or swaying to the beat: discrete auditory rhythms entrain stance and promote postural coordination stability, Gait Posture 59 (2018) 28–34, https://doi.org/10.1016/j.gaitpost.2017.09.023.

[20] V.K. Jirsa, P.W. Fink, P. Foo, J.A.S. Kelso, Parametric stabilization of biological coordination: a theoretical model, J. Biol. Phys. 26 (2000) 85–112.

[21] P.E. Keller, B.H. Repp, Multilevel coordination stability: integrated goal representations in simultaneous intra-personal and inter-agent coordination, Acta Psychol. (Amst.) 128 (2008) 378–386, https://doi.org/10.1126/scisignal.2001449.Engineering.

[22] D. Maslovat, R. Chua, T.D. Lee, I.M. Franks, Anchoring strategies for learning a bimanual coordination pattern, J. Mot. Behav. 38 (2006) 101–117.

[23] R.G. Carson, W.D. Byblow, D. Goodman, The dynamical substructure of bimanual coordination, Interlimb Coord. (1994), pp. 319–337.

[24] M. Varlet, T.A. Stoffregen, F. Chen, C. Alcantara, L. Marin, B.G. Bardy, Just the sight of you: postural effects of interpersonal visual contact at sea, J. Exp. Psychol. Hum. Percept. Perform. 40 (2014) 1–9, https://doi.org/10.1037/a0038197.

[25] A. Miura, K. Kudo, T. Ohtsuki, H. Kanehisa, Coordination modes in sensorimotor synchronization of whole-body movement: a study of street dancers and non-dancers, Hum. Mov. Sci. 30 (2011) 1260–1271, https://doi.org/10.1016/j.humov.2010.08.006.

[26] E. Batschelet, Circular Statistics in Biology, Academic Press, London, 1981.

[27] M. Roerdink, E.D. Ophoff, C.E. Peper, P.J. Beek, Visual and musculoskeletal underpinnings of anchoring in rhythmic visuo-motor tracking, Exp. Brain Res. 184 (2008) 143–156, https://doi.org/10.1007/s00221-007-1085-y.

[28] R.C. Schmidt, M.J. Richardson, C. Arsenault, B. Galantucci, Visual tracking and entrainment to an environmental rhythm, J. Exp. Psychol. Hum. Percept. Perform. 33 (2007) 860–870, https://doi.org/10.1037/0096-1523.33.4.860.