Turn-taking and concurrent dyad practice, aid efficiency but not effectiveness of motor learning in a balance-related task

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Abstract

We studied two forms of dyad practice compared to individual practice, to determine whether and how practice with a partner impacts performance and learning of a balance task, as well as learners' subjective perceptions of the practice experience. Participants were assigned to practice alone or in pairs. Partners either alternated turns practicing and observing one another, or they practiced and observed one another concurrently. Concurrent action observation impacted online action execution, such that partners tended to show coupled movements, and it was perceived as more interfering than practicing in alternation. These differences did not impact error during practice. While dyad practice was associated with higher ratings of effort than individual practice, all groups improved and showed similar immediate and delayed retention irrespective of whether practice was alone or in pairs. These data provide evidence that a partner's concurrent practice influences one's own performance, but not to the detriment (or benefit) of learning. Thus, both alternating and concurrent forms of dyad practice are viable means of enhancing the efficiency, albeit not necessarily the effectiveness, of motor learning.

Keywords: motor learning, dyad learning, observational learning, motor contagion

Dyad, turn-taking and concurrent practice, aid efficiency but not effectiveness of motor learning in a balance-related task

People often learn motor skills in a social setting with a similarly skilled co-learner. One of the advantages of practicing in a group is that you can watch your partner and learn from their performance. However, there may also be disadvantages associated with practicing alongside someone else, where observing another person's movements could interfere with your own. Here we compared individual practice to two forms of dyad (paired) practice, where partners either took turns physically practicing and observing one another, or physically practiced and observed one another concurrently. Our aim was to provide insight into how the timing of peer observation impacts immediate performance and longer-term learning, as well as learners' subjective perceptions of such dyad practice experiences.

Observation within dyad practice

Alternating practice. How should co-learners practice together to maximize training effectiveness and efficiency? Here we refer to the effectiveness of dyad practice as increased task performance in retention and/or transfer relative to individual conditions and to the efficiency of dyad practice as decreased trainer time and resources compared to practice alone. In the latter case, efficiency would be gained if two individuals were trained in the same amount of time typically devoted to one (Shebilske, Jordan, Goettl, & Paulus, 1998). Research has shown that such potential benefits are achieved through a turn-taking form of paired practice, wherein partners alternate between physical and observational practice (e.g., Granados & Wulf, 2007; Shea, Wright, Wulf, & Whitacre, 2000; Shea, Wulf, & Whitacre, 1999). Here, efficiency is gained as one partner is able to practice during the rest periods for the other. Moreover, the opportunity to observe the partner during rest also affords efficiency and this activity is thought to enhance error detection and correction processes, as well as potentially encourage greater engagement and attention than that afforded by practice alone (see Hodges & Ste-Marie, 2013; Lewthwaite & Wulf, 2012; Shea et al., 1999, 2000; Shebilske, Jordan, Arthur, & Regian, 1993; Shebilske et al., 1998; Shebilske, Regian, Arthur, & Jordan, 1992). Interspersing physical practice with demonstrations is thought to compensate for some of the costs of pure physical or observational practice, with this type of mixed practice supporting both robust retention of the practiced skill(s) (typically promoted by physical practice) as well as more generalizable transfer to novel versions of the practiced tasks (typically promoted by observational practice; see Hodges & Ste-Marie, 2013; Ong & Hodges, 2012).

The benefits of turn-taking practice for retention and transfer have been illustrated by Wulf, Shea and colleagues (Granados & Wulf, 2007; Shea et al., 1999, 2000). For example, alternating practice of a computerized, key-press tracking task with a partner was more effective than pure physical practice alone, which in turn was more effective than pure observational practice (Shea et al., 2000). This pattern of results highlights potential additive benefits of practicing with a partner, particularly when observation can help to determine the task goal and relevant strategies (e.g., Granados & Wulf, 2007; Shebilske et al., 1992). Moreover, dyadic alternating practice of a stabiliometer balance task was more effective than individual physical practice, but also more than dyadic practice that was blocked (whereby partners switched roles half way through, Shea et al., 1999). As the amount of physical and observational practice was matched between the two dyad groups, it seems that the interactive nature of turn-taking underpinned the success of paired practice. While partners could also discuss the balance task in this study (Shea et al., 1999), the interspersed observation of a co-learner was later shown to be more important than discussion in a follow-up experiment using a different (cup-stacking) task (Granados & Wulf, 2007; see also Hebert, 2017, for a replication and extension of this paradigm).

In addition to the potential informational benefits of interleaved physical and observational practice, dyad practice might also impact the learning experience through a variety of other pathways. For instance, well studied social facilitation effects may play a role in aiding dyad practice, whereby the presence of an observer impacts cognitive and/or motor performance. In studies of social facilitation, an observer or audience typically enhances the performance of simple/well learned tasks and interferes with that of more complex tasks (e.g., Zajonc, 1965; for a review and meta-analysis, see Strauss, 2002 and Bond & Titus, 1983, respectively). Importantly, the efficacy of alternating practice has been shown to be more than the product of social facilitation effects, as previous studies have controlled for such contributions by comparing multiple forms of dyad practice (e.g., Granados & Wulf, 2007; Shea et al., 1999, 2000).

Concurrent practice. There are many situations where learners do not practice skills in a temporally independent fashion (i.e., taking turns), but rather practice concurrently with fellow learners (e.g., in yoga, dance, or team-based sports). To our knowledge, concurrent practice of the same motor skill has not yet been studied, despite many real-world contexts where individuals physically practice independently in the presence of co-learners and the potential efficiency associated with this method of practice.

Concurrent practice has been studied in a task-sharing context (e.g., Arthur, Day, Bennett, McNelly, & Jordan, 1997; Day, Paulus, Arthur, & Fein, 2003; Shebilske et al., 1992, 1993, 1998). Using the militaristic video-game "Space Fortress," Shebilske and colleagues showed that "part-task" training with a partner (what they referred to as an 'active-interlocked-modeling' (AIM) protocol) led to skill retention that did not differ from that acquired from training on the whole-task alone (e.g., Shebilske et al., 1992). In effect, the shared practice protocol afforded a 100% increase in training efficiency, as two people could be trained in the time it took to train one. However, Space Fortress is a unique task that affords a clear distribution of responsibilities and complementary part-practice with a partner, whereas this is not the case for most motor and particularly sport skills (see also Shea et al., 1999). In the current study, we provide a first look at concurrent practice of a whole task by having both members of a pair simultaneously serve as actors and observers during practice of a novel motor skill. This scenario raises the question of how the observed actions of a partner immediately influence online action production and what this might mean for longer-term motor learning.

Concurrent observation and execution of action

Motor contagion during action observation. A growing body of research provides evidence for interactions between observed and executed actions, such that observing movements can result in ‘motor contagion,’ which can facilitate or interfere with simultaneous action execution (for reviews, see Blakemore & Frith, 2005; Schütz-Bosbach & Prinz, 2007; Sebanz & Shiffrar, 2007). It has been shown that even when observers are not required to perform a motor task (other than to remain standing), action observation can elicit behavioural responses (e.g., Sebanz & Shiffrar, 2007; Tia, Paizis, Mourey, & Pozzo, 2012; Tia et al., 2011). Viewing actors in states of imbalance disturbed passive observers’ own postural stability and different postural reactions were elicited based on the orientation of the actor (e.g., Sebanz & Shiffrar, 2007; Tia et al., 2012). Of particular relevance to the current study, observing an actor in disequilibrium face-on (i.e., third-person perspective) gave rise to ‘imitative’ movements, such that the observer showed a propensity for ‘mirrored’ movements (Sebanz & Shiffrar, 2007). Such observation-induced movements have been referred to as ‘ideomotor movements’, due to the link between the idea and the action (e.g., De Maeght & Prinz, 2004; Häberle, Schütz-Bosbach, Laboissière, & Prinz, 2008; Knuf, Aschersleben, & Prinz, 2001). This terminology is derived from the ideomotor theory (James, 1890) and later extensions of this theory which have provided a framework for conceptualizing links between the imagination, perception, and production of action (e.g., Greenwald, 1970, 1972; Hommel, Müssler, Aschersleben, & Prinz, 2001; Prinz, 1997).

Motor contagion during action production. There is also compelling evidence that engaging in action observation during simultaneous action execution modulates online motor performance of intentional movements. This is thought to be due to the activation of overlapping neural structures involved in both action-related activities (e.g., Kilner, Paulignan, & Blakemore, 2003). Observation of biological movements, incongruous to the to-be-enacted movements, had an interference effect on action (Kilner et al., 2003). When participants made arm movements while observing an actor or a robot making congruent or incongruent movements, participants' movement variance (indexing interference in motor control) was increased only when observing the human incongruent movements (Kilner et al., 2003). Subsequent studies have since elucidated that a critical feature eliciting this interference is the velocity profile of biological motion (e.g., Bouquet, Gaurier, Shipley, Toussaint, & Blandin, 2007; Kilner, Hamilton, & Blakemore, 2007), that motor contagion is greater when viewing goal-directed compared to non-goal-directed actions (Bouquet, Shipley, Capa, & Marshall, 2011), and that some contagion effects may at least in part be due to the execution of incongruent eye movements (Constable et al., 2016).

While there are clearly interactions between concurrent observation and execution of actions, much remains to be learned about the conditions (and boundaries) of such contagion mechanisms. For instance, such research has been largely limited to the manipulations' immediate effects on action production and perception, with little empirical attention devoted to the learning process and any potential lasting effects on perceptual-motor processes (for exceptions, see Celnik et al., 2006; Stefan, Classen, Celnik, & Cohen, 2008; Weeks, Hall, & Anderson, 1996). Additionally, motor contagion paradigms have involved a unidirectional relationship between an experimenter or videoed model as the actor and a participant. Here we extend this line of research to study the bidirectional influence of a partner's practice on concurrent, independent motor performance, where there is the potential for partner-related interference during practice. Practice conditions that place higher demands on learners' information processing capabilities (e.g., through increased interference) have been shown to hinder acquisition performance but benefit learning compared to less challenging conditions (see Guadagnoli & Lee, 2004; Lee, Swinnen, & Serrien, 1994; Schmidt & Bjork, 1992). Additionally, social practice conditions might engender increased effort related to being observed (e.g., Strauss, 2002), as well as potentially creating an element of competition, particularly when the relative success of a co-actors' performance is easily observed (e.g., Rhea, Landers, Alvar, & Arent, 2003).

Study aims

We implemented a unique dyad-practice paradigm, whereby co-learners engaged in concurrent physical and observational practice of a stabiliometer balance task. We compared this to turn-taking and individual (physical practice only) forms of practice (see Shea et al., 1999). Our aim was to determine if and how observing a partner's practice, and particularly the timing of this peer observation, influences practice behaviours, learning outcomes, and subjective perceptions of the practice experience (see also Day et al., 2003 for a comparison of AIM and turn-taking protocols). Based on previous findings (Shea et al., 1999), we anticipated that turn-taking would enhance learning compared to individual practice, potentially because of opportunities to engage in additional problem-solving activities via observation of a learning model (e.g., Lee et al., 1994).

In addition to processes related to information processing, it may be that practice and learning are moderated by factors related to motivational factors associated with practice in pairs, including increased intrinsic motivation towards the task (e.g., Lewthwaite & Wulf, 2012), and/or increased effort, as a function of being observed (e.g., Strauss, 2002). Therefore, in addition to studying outcome and learning effects associated with dyad practice, we were also interested in impacts of shared practice on markers, or regulators of motivation. According to Self Determination Theory (SDT), intrinsic motivation is theorized to occur when three fundamental psychological needs for autonomy, competence, and relatedness are satisfied (e.g., Ryan & Deci, 2000; Deci & Ryan, 2017). We were particularly interested in how practising in pairs, versus alone, would impact factors related to intrinsic motivation towards the task, including interest/enjoyment, perceived competence and choice, pressure/tension and effort. There is reason to think that these factors may also differentially drive learning in alternating versus paired conditions, such that factors related to pressure/tension and effort would be higher when practising concurrently, versus in alternation, because of the immediate feedback provided by a partner in online conditions. Therefore, we used the Intrinsic Motivation Inventory (IMI; Deci & Ryan, n.d.) to assess variables related to the various forms of pracrice in addition to formulating customized questions to probe perceptions of the dyad practice experience.

To study the effects of a partner on practice (and potentially retention), we also measured online motor performance. Concurrent observation of a partner could potentially interfere with online movements or provide a stabilizing role. We know that incongruent movements lead to interference in the form of increased action variability (e.g., Kilner et al., 2003), particularly in balance-based tasks (e.g., Sebanz & Shiffrar, 2007; Tia et al., 2011, 2012). As such, concurrent practice with a partner might be expected to degrade performance during practice as compared to alternating or alone conditions. However, it may be that watching someone perform similar movements has a stabilizing role, where concurrent practice would be associated with greater coupling between partners' movements (see Eaves, Hodges, & Williams, 2008; Sebanz & Shiffrar, 2007). With respect to long-term learning, there is evidence that conditions of practice that serve to challenge the individual, resulting in more cognitively effortful practice, can promote better long-term learning as measured in retention tests (e.g., Lee et al., 1994; Schmidt & Bjork, 1992). Concurrent practice with a partner might be considered a more challenging condition than practice alone, due to the potential for interference from the partner's movements.

Methods

Participants and Groups

Thirty-six females (M = 23.2 yr, SD = 4.6) volunteered to participate individually and were reimbursed for their time ($10.25/hr). Participants had normal or corrected-to-normal vision, no injury to the lower back or limbs, and limited balance training (gymnasts and dancers were not eligible to participate, nor were individuals with experience using balance training devices). Participants were pseudo-randomly assigned based on availability to practice individually (Alone group) or to practice in pairs, with pairs randomly assigned to the Turn-taking or Concurrent group (n = 12/group). The study was conducted in accordance with the ethical guidelines of the university and all participants provided informed consent.

Task and Apparatus

The experimental task was based on Shea et al. (1999) and involved learning to balance under individual or paired conditions on one of two stabiliometer platforms (Lafayette Instruments, IN). The task was to keep the stabiliometer platform in a horizontal/balanced position for as long as possible during each trial. The front edges of the two stabiliometers were positioned 0.5 m apart.

Two black rectangles (45 cm x 30 cm) were marked on each platform to indicate where the feet should be positioned (one foot on either side of the midline, in the centre of each rectangle). The displacement of each platform was measured by the addition of a potentiometer, which detected angular deviation (sampled at 100 Hz). A Toshiba laptop was used to control trial initiation and termination and record the potentiometer data via customized LABview programming.

Procedure

The study was conducted over two consecutive days, with Day 1 completed individually or in pairs and Day 2 completed alone. Within each pair, one partner was randomly assigned to be Partner 1 and the other to be Partner 2, which dictated which stabiliometer was used during practice (all participants used the same stabiliometer for test phases). For control purposes, the Alone group participants were also assigned to be Partner 1 or Partner 2 in alternation.

On Day 1, the platforms were raised 18 cm from their base, such that their maximum possible deviation to either side of horizontal was 21°. For the paired groups, Day 1 began with a brief period during which the experimenter initiated some exchange with the participants (who did not know one another), before running participants through the familiarization and pretest phases individually. When one partner was being tested the other waited outside and responded to questionnaires regarding their handedness (Oldfield, 1971) and previous balance training experiences. During task familiarization, the experimenter explained to participants how to position themselves when on the stabiliometer. They were instructed to keep the platform as level as possible, to keep their arms crossed while balancing, and to visually focus on a fixation cross that was attached to a wall at chest level. No other instructions were given. After a brief warmup, participants completed one, 60-s pretest trial. This and all subsequent trials started with the participant holding onto a safety bar and bringing the platform into the horizontal position. On the experimenter's 'go,' data collection was initiated and the participant brought their arms into the crossed position to begin balancing. Participants were told their 'percent time-on-target' (%TOT) score for this pretest trial and familiarized with the meaning of this measure. All participants used the same stabiliometer for familiarization and all test phases, and across all groups, the Partner 1s used this same platform for practice, while the Partner 2s used the second platform.

Participants received twelve, 60-s practice trials either individually (Alone group) or together (Turn-taking and Concurrent groups). In the Concurrent group, partners each stood on one of the platforms facing one another and attempted to balance simultaneously. In the Turn-taking group, partners alternated trials physically practicing and observing their partner. When observing, participants sat in a chair facing their partner's platform, to mimic the observation perspective of the Concurrent pairs. During physical practice trials, participants were asked to focus on a cross that was attached at approximately chest level to the wall (Alone and Turn-taking groups) or to their partner's body (Concurrent group). Participants rested for ~60 s at the end of each trial. Participants were asked not to discuss the task at any point during the study. To encourage participants to attend to their partner, dyad group participants were asked to write down an estimate of their partner's %TOT. Participants also estimated their own %TOT after their own trials.[1] No feedback about %TOT was provided (see Shea et al., 1999).

After the acquisition session, participants responded to the Intrinsic Motivation Inventory (IMI) consisting of the interest/enjoyment (7 items), perceived choice (5 items), perceived competence (5 items), pressure/tension (5 items), and effort subscales (5 items; Deci & Ryan, n.d.). The wording of the IMI items was customized to the task, such that the original references to the "task" were modified to specify the "balancing task" (e.g., "Doing the balancing task was fun"). Dyad groups additionally responded to an adapted version of the perceived competence subscale

(5 items), probing their perceptions of their partner's competence. These adaptations consisted of changing references to oneself within the items (e.g., "I am," "I did," "my performance") to references to the partner (e.g., "my partner is," "my partner did," "my partner's performance"). For example, the competence item became "I think my partner is pretty good at this balancing task". Participants in the dyad groups additionally rated the truthfulness of the following three items, to provide insight into how helpful and interfering they found watching their partner, as well as their desire to be more accurate than their partner: 1) "Watching my partner helped my own performance/learning," 2) "Watching my partner interfered with my own performance/learning," 3) "I wanted to be more accurate than my partner." Responses to all questionnaire items were based on a 7-point Likert-type scale, where 1 = not at all true and 7 = very true. Upon completing the questionnaires, participants individually performed an immediate retention test (post-test) consisting of three, 60-s trials. Partners completed this test in the same order as for the pretest.

Participants returned alone the next day for delayed testing. The platform was raised such that its maximum possible deviation to either side of the horizontal was 27°. This transfer test consisted of six, 60-s trials. We decided to increase the difficulty of this test (i.e., increase height), to better probe how well individuals had learnt to balance and compensate for errors, given our predictions that practice with a partner would aid error detection and correction processes. At the end of testing, participants were debriefed and compensated for their time.

Measures and Analysis

Error. For each 60-s trial, each platform's potentiometer data was transformed into degrees out of balance, and the average deviation of the platform was calculated as root-mean-square-error (RMSE; e.g., Shea et al., 1999; Wulf, Lewthwaite, & Hooyman, 2013).[2] Because of our specific predictions, instead of testing for the overall group effect and then running post hoc tests, we ran two orthogonal, preplanned contrasts comparing; 1) the individual group to the two paired groups combined and 2) the two paired groups to each other. RMSE data was analyzed for each phase and submitted to separate Group (Alone vs. Pairs or Turn-taking vs. Concurrent) x Trial ANOVAs, with repeated measures (RM) on the last factor.[3]

Coupling. For each acquisition trial, the data was first filtered with a fourth-order low-pass Butterworth filter (cut-off frequency = 8 Hz). The velocity profiles of the Concurrent partners' platforms were compared (based on the 100 Hz sampling), and the overall percentage of the trial during which the platforms moved the same direction in space was computed. This was also done for the Turn-taking pairs and Alone group 'pairs' to provide a reference of the 'coupling' that occurred between partners by chance. These data were submitted to a 3 Group x 12 Trial RM ANOVA. We again ran preplanned contrasts on these data, although this time our primary interest was the comparison between the Concurrent group and the two other groups, which did not practice at the same time as a partner.[4]

Questionnaires. Participants' mean score of all the items in each multi-item subscale of the IMI (interest/enjoyment, perceived choice, perceived competence, pressure/tension, effort) and the adapted partner-related competence scale was calculated and first submitted to an omnibus MANOVA analysis, with group as the between variable. Preplanned contrasts based on univariate ANOVAs were used for follow-up analyses comparing the paired groups to the individual group and then the two paired groups to each other. For the dyad groups, an additional 2 Group (Turn-taking, Concurrent) x 2 Competence (Own, Partner) RM ANOVA was conducted. For the current sample, Cronbach's alpha values were good for the interest/enjoyment (α = 0.91), perceived competence (α = 0.87), and pressure/tension (α = 0.83) subscales; however, the values were weak to acceptable for the adapted partner-related competence (α = 0.78), perceived choice (α = 0.57), and effort (α = 0.69) subscales, and therefore the results of these scales should be interpreted with caution. Responses to the three dyad practice experience questions were analyzed using separate univariate ANOVAs.

Greenhouse-Geisser corrections were applied to the degrees of freedom for violations to sphericity. Significant effects were followed up with Tukey HSD procedures where relevant (all *p*s $< .05$ reported). Partial eta squared values (η_p^2) and Chosen's *d* are reported as measures of effect size for all significant effects, and power values ($1 - \beta$) are given for non-statistically significant effects where $F > 1$.

Results

Measures of balance performance

Error. The groups' mean RMSE across the study is presented in Figure 1. There were no group-related differences in the pretest (Alone vs. Pairs contrast, $p = .97$; Concurrent vs. Turn-taking contrast, $p = .81$). Groups improved across practice, $F(6.04, 199.46) = 25.30$, $p < .001$, $\eta_p^2 = .43$, confirmed by a linear trend component to the trial effect ($p < .001$). Surprisingly, performance in acquisition did not vary as a function of group (Alone vs. Pairs contrast, $p = .83$; Concurrent vs. Turn-taking contrast, $p = .34$). A similar pattern was observed in the individual, immediate retention test (post-test) and in delayed retention testing on the higher platform (i.e., improvements across trials but no group differences evidenced for any of the contrasts).

Coupling. Analysis of the movement coupling between pairs (i.e., the percent of each acquisition trial where partners moved in the same direction in space) revealed that the Concurrent pairs displayed significantly more coupling ($M = 53.9\%$, $SD = 4.8\%$) than the Turn-taking ($M = 50.7\%$, $SD = 4.6\%$) and Alone pairs ($M = 51.0\%$, $SD = 3.8\%$), although these differences were small. Statistical differences were confirmed based on preplanned contrasts comparing the

Concurrent group to the mean of the two non-concurrent groups (*M* = 50.9%, *SD* = 4.2%), $p < .001$, $d = 0.68$ (the latter two groups did not differ from each other, $p = .72$). Examples of the Concurrent pairs' performance and movement coupling during acquisition are presented in Figure 2 (depicting each pair's final acquisition trial). Although there was no main effect of trial (F<1), there was a Group X Trial interaction, XXX. Only for the ….

Measures of affective experiences

Intrinsic Motivation Inventory. Responses to the IMI are presented in Table 1. The preplanned contrast between the individual and pair groups revealed that practice with a partner was associated with higher ratings of effort (*M* = 6.15, *SD* = 0.56) than practice alone (*M* = 5.33, *SD* = 0.85), $p = .001$, $d = 1.15$. There were no significant differences in learners' perceptions of interest/enjoyment ($p = .47$), competence ($p = .28$), choice ($p = .74$), or pressure/tension ($p = .15$). When comparing the two dyad groups, perceptions of practice did not vary as a function of concurrent versus turn-taking practice (all *p*s > .32). Dyad participants rated their partner's competence as higher than their own, $F(1, 22) = 9.89$, $p = .005$, $\eta_\rho^2 = .31$, but this did not depend on group ($F < 1$).

Paired practice experience. Observing a partner's practice was perceived as relatively helpful by both the Concurrent (*M* = 4.4, *SD* = 2.2) and Turn-taking groups (*M* = 4.8, *SD* = 0.8), $F < 1$. As anticipated, concurrent partners rated watching their partner as more interfering for their own performance (*M* = 3.7, *SD* = 2.1) than turn-taking partners (*M* = 2.1, *SD* = 1.0), $F(1, 22) = 5.75$, $p = .025$, $\eta_\rho^2 = .21$. There was no difference between the Concurrent (*M* = 5.3, *SD* = 1.9) and Turn-taking (*M* = 5.8, *SD* = 1.5) groups' desire to be more accurate than their partner, $F < 1$.

Discussion

The challenge of how best to incorporate observation into the motor learning process is of long-standing interest to researchers and practitioners alike. Dyad practice is a method that achieves this aim, whilst being high in external validity and efficiency and potentially promoting other positive benefits associated with this more social type of practice. In previous studies, both dyadic alternating and concurrent part-practice were shown to modulate motor performance and learning compared to practice alone (e.g., Granados & Wulf, 2007; Shea et al., 1999, 2000; Shebilske et al., 1992). To date, concurrent practice of a whole skill for "independent" learners has not been studied, even though this method is efficient and allows study of how the presence of a partner influences performance online in addition to longer-term learning.

Physically practicing at the same time as another learner was expected to interfere with performance (e.g., Kilner et al., 2003). While concurrent practice was indeed perceived as more interfering than turn-taking practice, this perceived interference did not manifest as greater error during practice. Of note, the dyad groups' similar performance might still reflect different underpinning mechanisms and pathways to learning (e.g., turn-taking practice might be more strategy-mediated whilst concurrent practice might be more effort-mediated). However, there were no differences between the groups with respect to the IMI.

Concurrent observation of a partner did however impact acquisition in another manner; co-learners' movements showed more coupling, showing a greater (though small) tendency to move in a directionally compatible way. This extends previous research showing that viewing unstable postures elicits bodily sway in the observer (e.g., Tia et al., 2011, 2012), and that these observation-induced movements are imitative (mirror-like) in nature when face-to-face with the actor (Sebanz & Shiffrar, 2007). It is likely that if learners, or at least one co-learner, was more errorful during practice, this would have promoted increased error within concurrent practice. In future studies it will be important to manipulate the skill level (and error) of the partner to test this hypothesis. Additionally, because the concurrent situation elicited coupled behaviour, the observed and executed movements were not strictly incongruent (*cf.* Kilner et al., 2003) and likely diminished interference-related effects. As such, we would be less likely to find differences in retention as a result of challenge or practice-related interference (*cf.* Guadagnoli & Lee, 2004).

Observing an actor from the front (i.e., facing) has been shown to elicit greater postural sway than that elicited from the side (Tia et al., 2012). Observing an unstable actor from the front has also been shown to promote imitative movements as opposed to compensatory movements that are elicited when viewing an actor from behind (i.e., a first-person perspective; Sebanz & Shiffrar, 2007). In the current study, individuals in the Concurrent group were always facing each other and as such, it was not possible to make conclusions about how perspective moderates the coupling between the partners. Such differing perspectives would provide additional insight into when and why individuals' motor performance is susceptible to the behaviours of others (and what this might mean for learning).

Contrary to a similar study using this stabiliometer task and dyad practice, we did not show any evidence that alternating practice was beneficial to performance or learning compared to pure physical practice alone (*cf.* Shea et al., 1999). The major difference between our protocol and that of Shea and colleagues' was that we did not allow partners to discuss the task, and all participants were told at the start of practice how to stand (i.e., arms crossed, looking straight ahead). This suggests that these procedural details (i.e., more opportunity to learn how to stand from watching and to discuss why) were responsible for the positive benefits in this earlier study and not necessarily turn-taking per se. However, in subsequent work, albeit with a different task, observation and not dialogue underpinned the benefits of alternating practice (Granados & Wulf, 2007). It was also shown that it was this alternating schedule that was responsible for benefits of observation, rather than a period of watching followed by all physical practice, or vice versa (Shea et al., 1999). However, the benefits may also have been related to the rest between trials (which was not controlled between Shea et al.'s two dyad groups), rather than observation per se, given that distributed practice or spacing effects impact memory processes (Donovan & Radosevich, 1999; Lee & Genovese, 1988). Additionally, neither the previous dyad practice studies (e.g., Granados & Wulf, 2007; Shea et al., 1999), nor our own, controlled for mental practice during rest intervals (for example, by providing a distraction task during breaks). Some participants may have engaged in more practice-related activities than others, such that more control over this interval may be necessary in future work.

Despite the lack of group differences with respect to dyad practice in our study, it is important to point out that these methods did not incur costs and hence there are potential efficiencies to be gained from this type of practice compared to practice alone. Two people could be trained in the same amount of time as that of an individual learner. In our study, as in other alternating dyad practice paradigms (e.g., Granados & Wulf, 2007; Shea et al., 1999, 2000), each member of the dyad received the same amount of physical practice as the individual learners (with breaks interspersed into the individual practice protocol to match the duration of the dyad training protocol). While there is evidence that physical practice of task components can be reduced when engaging in concurrent, part-practice with a partner (e.g., Shebilske et al., 1992), we did not test whether practice with a partner can compensate for and potentially replace some physical practice of the whole skill. This would be particularly important for training settings where there are high physiological demands, training-related expenses, or limited training time. While we chose to match the durations of practice and rest between individual and dyad groups, it will also be important to compare dyad practice to individual practice conditions where learners can self-pace their rest intervals and/or self-direct their amount of practice (e.g., Post, Fairbrother, & Barros, 2011). This would allow further testing of potential efficiency benefits to be gained from dyad practice when individual practice time is less controlled and potentially more representative of practical settings.

Given our interest in the impact of partners on the learning process more generally and the potential social benefits to be gained from practicing in pairs, we also asked participants to respond to the Intrinsic Motivation Inventory (Deci & Ryan, n.d.). Participants rated their practice experience positively, but contrary to predictions, paired practice was not associated with higher perceptions of interest/enjoyment compared to individual practice (*cf*. Lewthwaite & Wulf, 2012). It is possible that the subjective experience of paired practice would have been enhanced had co-learners been given increased opportunity to interact and potentially contribute to one another's learning experience more explicitly (e.g., encouragement during or between practice trials, discussion during inter-trial breaks; e.g., Granados & Wulf, 2007; Shea et al., 1999). It is important to note, though, that the IMI scales we used did not necessarily capture the range of motives along the SDM continuum (see Ryan & Deci, 2000; Ryan & Deci, 2017). Indeed, a number of external factors likely mediate motivation in lab-based settings (e.g., financial compensation, being observed by an experimenter and in some cases a peer), that were not picked up by our measures. It is also of relevant to note that in our study and presumably others involving dyad practice (e.g., Granados & Wulf, 2007; Shea et al., 1999), an experimenter was present within all conditions. As such, any potential social facilitation effects would have been moderated by the presence of the experimenter potentially masking differences between individual and dyad practice conditions that might exist in less supervised, real-world settings.

Dyad practice was, as hypothesized, associated with higher effort. Being in a pair can of course encourage competition and social comparisons that are not necessarily positive and hence there is a need to assess potential learning effects against these general perceptions of the learning environment. It may be that perceptions of competence moderate any potential benefits from seeing and interacting with a partner. Indeed, there was a tendency to perceive a partner's competence as higher than one's own which may have impacted potential benefits. Comparative feedback about others' motor skill performance (e.g., a peer or group average) has been shown to impact one's own competency beliefs as well as learning (e.g., Wulf, Chiviacowsky, & Lewthwaite, 2010). Whereas the majority of research evaluating social-comparative feedback effects has been based on virtual or experimenter-provided comparisons (e.g., Wulf et al., 2010, 2013), personal perceptions of a veridical partner are potentially more meaningful to a learner. Interestingly, the opportunity for social comparisons within an ecologically valid social setting (weight training class) enhanced performance in competitive contexts compared to non-competitive contexts (Rhea et al., 2003). Further research is required to delineate when and why genuine comparative feedback impacts not only immediate performance but also longer-term behavioural outcomes.

In summary, we have provided the first evidence that concurrent dyad practice of a whole skill is as effective as individual and turn-taking practice, despite the potential for interference brought about by perception-action links. Partners that practiced concurrently showed susceptibility to the movements of their partner, but not to the detriment of their learning (nor to their benefit). This study adds to the growing literature showing that practicing with a partner is an effective and efficient means of practice, which can be undertaken in various forms with positive outcomes (see also Karlinsky & Hodges, 2014 and McRae, Patterson, & Hansen, 2015 for peer-directed practice; and Shebilske et al., 1992 for 'interlocked' practice). However, our results also suggest that while dyad training protocols typically enhance the efficiency of practice, they do not always result in superior learning compared to practice alone and may be perceived as more effortful and interfering, and encourage comparative judgments that may not be favourable for learning. Considering the ecological validity of peer-based practice settings, where learners frequently observe and potentially compare themselves to their peers (e.g., physical education classes, physical activity classes, or team sports), it will be important to continue such inquiries into when and why such conditions support learning.

References

Arthur, W., Jr., Day, E. A., Bennett, W., Jr., McNelly, T. L., & Jordan, J. A. (1997). Dyadic versus individual training protocols: Loss and reacquisition of a complex skill. *Journal of Applied Psychology, 82*(5), 783-791.

Blakemore, S. J., & Frith, C. (2005). The role of motor contagion in the prediction of action. *Neuropsychologia, 43*(2), 260-267.

Bond, C. F., Jr., & Titus, L. J. (1983). Social facilitation: A meta-analysis of 241 studies. *Psychological Bulletin, 94*(2), 265-292.

Bouquet, C. A., Gaurier, V., Shipley, T., Toussaint, L., & Blandin, Y. (2007). Influence of the perception of biological or non-biological motion on movement execution. *Journal of Sports Sciences, 25*(5), 519-530.

Bouquet, C. A., Shipley, T. F., Capa, R. L., & Marshall, P. J. (2011). Goal-directed actions are more contagious than non-goal-directed actions. *Experimental Psychology, 58*(1), 71-78.

Celnik, P., Stefan, K., Hummel, F., Duque, J., Classen, J., & Cohen, L. G. (2006). Encoding a motor memory in the older adult by action observation. *NeuroImage, 29*(2), 677-684.

Constable, M. D., de Grosbois, J., Lung, T., Tremblay, L., Pratt, J., & Welsh, T. N. (2016). Eye movements may cause motor contagion effects. *Psychonomic Bulletin & Review, 24*(3), 835-841.

Day, E. A., Paulus, L. E., Arthur, W., Jr., & Fein, E. C., Jr. (2003). Dyadic protocols, observational learning, and the acquisition of complex skills. *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting, 47*(19), 2050-2053.

De Maeght, S., & Prinz, W. (2004). Action induction through action observation. *Psychological Research*, *68*(2-3), 97-114.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior.* New York: Plenum.

Deci, E. L., & Ryan, R. M. (n.d.). *Intrinsic Motivation Inventory.* Available at: http://www.selfdeterminationtheory.org/questionnaires/10-questionnaires/50

Donovan, J. J., & Radosevich, D. J. (1999). A meta-analytic review of the distribution of practice effect: Now you see it, now you don't. *Journal of Applied Psychology, 84*(5), 795-805.

Eaves, D. L., Hodges, N. J., & Williams, A. M. (2008). Energetic costs of incidental visual coupling during treadmill running. *Medicine & Science in Sports & Exercise, 40*(8), 1506-1514.

Granados, C., & Wulf, G. (2007). Enhancing motor learning through dyad practice. *Research Quarterly for Exercise and Sport, 78*(3), 197-203.

Greenwald, A. G. (1970). A choice reaction time test of ideomotor theory. *Journal of Experimental Psychology, 86*(1), 20-25.

Greenwald, A. G. (1972). On doing two things at once: Time sharing as a function of ideomotor compatibility. *Journal of Experimental Psychology, 94*(1), 52-57.

Guadagnoli, M. A., & Lee, T. D. (2004). Challenge point: A framework for conceptualizing the effects of various practice conditions in motor learning. *Journal of Motor Behavior, 36*(2), 212-224.

Häberle, A., Schütz-Bosbach, S., Laboissière, R., & Prinz, W. (2008). Ideomotor action in cooperative and competitive settings. *Social Neuroscience*, *3*(1), 26-36.

Hebert, E. (2017). The effect of observing a learning model (or two) on motor skill acquisition. *Journal of Motor Learning and Development, 5,* 1-24.

Hodges, N. J., & Ste-Marie, D. S. (2013). Observation as an instructional method. In D. Farrow, J. Baker, & C. MacMahon (Eds.), *Developing Sport Expertise: Researchers and Coaches Put Theory into Practice* (2nd ed.) (pp. 115-128). London, UK: Routledge.

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24*(5), 849-878.

James, W. (1890). Principles of Psychology. New York, NY: Holt.

Karlinsky, A., & Hodges, N. J. (2014). Evaluating the effectiveness of peer-scheduled practice. *Journal of Motor Learning and Development, 2*(4), 63-68.

Kilner, J. M., Paulignan, Y., & Blakemore, S. J. (2003). An interference effect of observed biological movement on action. *Current Biology*, *13*(6), 522-525.

Knuf, L., Aschersleben, G., & Prinz, W. (2001). An analysis of ideomotor action. *Journal of Experimental Psychology: General*, *130*(4), 779-798.

Lee, T. D., & Genovese, E. D. (1988). Distribution of practice in motor skill acquisition: Learning and performance effects reconsidered. *Research Quarterly for Exercise and Sport, 59*(4), 277-287.

Lee, T. D., Swinnen, S. P., & Serrien, D. J. (1994). Cognitive effort and motor learning. *Quest, 46*(3), 328-344.

Lewthwaite, R., & Wulf, G. (2012). Motor learning through a motivational lens. In N. J. Hodges & A. M. Williams (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice* (2nd ed.) (pp. 173-191). London, UK: Routledge.

McRae, M., Patterson, J. T., & Hansen, S. (2015). Examining the preferred self-controlled KR schedules of learners and peers during motor skill learning. *Journal of Motor Behavior, 47*(6), 527-534.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*(1), 97-113.

Ong, N. T., & Hodges, N. J. (2012). Mixing it up a little: How to schedule observational practice. In N. J. Hodges & A. M. Williams (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice* (2nd ed.) (pp. 22-39). London, UK: Routledge.

Post, P. G., Fairbrother, J. T., & Barros, J. A. C. (2011). Self-controlled amount of practice benefits learning of a motor skill. *Research Quarterly for Exercise and Sport, 82*(3), 474-481.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology, 9*(2), 129-154.

Rhea, M. R., Landers, D. M., Alvar, B. A., & Arent, S. M. (2003). The effects of competition and the presence of an audience on weight lifting performance. *Journal of Strength and Conditioning Research, 17*(2), 303-306.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78.

Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3*(4), 207-217.

Schütz-Bosbach, S., & Prinz, W. (2007). Perceptual resonance: Action-induced modulation of perception. *Trends in Cognitive Sciences, 11*(8), 349-355.

Sebanz, N., & Shiffrar, M. (2007). Bodily bonds: Effects of social context on ideomotor movements. In P. Haggard, Y. Rossetti, & M. Kawato (Eds.), *Sensorimotor Foundations* *of Higher Cognition: Attention and Performance XXII* (pp. 267-291). New York, NY: Oxford University Press.

Shea, C. H., Wright, D. L., Wulf, G., & Whitacre C. (2000). Physical and observational practice afford unique learning opportunities. *Journal of Motor Behavior, 32*(1), 27-36.

Shea, C. H., Wulf, G., & Whitacre, C. (1999). Enhancing training efficiency and effectiveness through the use of dyad training. *Journal of Motor Behavior, 31*(2), 119-125.

Shebilske, W. L., Jordan, J. A., Arthur, W., Jr., & Regian, J. W. (1993). Combining a multiple emphasis on components protocol with small group protocols for training complex skills. *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, 37*(18), 1216-1220.

Shebilske, W. L., Jordan, J. A., Goettl, B. P., & Paulus, L. E. (1998). Observation versus hands-on practice of complex skills in dyadic, triadic, and tetradic training-teams. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 40*(4), 525-540.

Shebilske, W. L., Regian, J. W., Arthur, W., & Jordan, J. A. (1992). A dyadic protocol for training complex skills. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *34*(3), 369-374.

Stefan, K., Classen, J., Celnik, P., & Cohen, L. G. (2008). Concurrent action observation modulates practice-induced motor memory formation. *European Journal of Neuroscience, 27*(3), 730-738.

Strauss, B. (2002). Social facilitation in motor tasks: A review of research and theory. *Psychology of Sport and Exercise, 3*(3), 237-256.

Tia, B., Paizis, C., Mourey, F., & Pozzo, T. (2012). Do equilibrium constraints modulate postural reaction when viewing imbalance? *Brain and Cognition, 79*(2), 89-95.

Tia, B., Saimpont, A., Paizis, C., Mourey, F., Fadiga, L., & Pozzo, T. (2011). Does observation of postural imbalance induce a postural reaction? *PLoS ONE, 6*(3), 1-8.

Weeks, D. L., Hall, A. K., & Anderson, L. P. (1996). A comparison of imitation strategies in observational learning of action patterns. *Journal Motor Behavior, 28*(4), 348-358.

Wulf, G., Chiviacowsky, S., & Lewthwaite, R. (2010). Normative feedback effects on learning a timing task. *Research Quarterly for Exercise and Sport, 81*(4), 425-431.

Wulf, G., Lewthwaite, R., & Hooyman, A. (2013). Can ability conceptualizations alter the impact of social comparison in motor learning? *Journal of Motor Learning and Development, 1*(1), 20-30.

Zajonc, R. B. (1965). Social facilitation. *Science, 149*(3681), 269-274.

Footnotes

1: Analysis of the estimation data (i.e., absolute difference between actual percent time-on-target (%TOT) and estimated %TOT) did not yield any group or estimation-type (Own, Partner) effects. Participants were just as good at estimating their own error as they were for their partner. We did not expect this to depend on group.

2: We also analyzed %TOT; the results mirrored those of RMSE and were omitted for brevity.

3: Pilot testing revealed that despite being set at the same height and having the same maximum deviation, one stabiliometer was associated with lower error than the other. We labelled this 'easier' platform as stabiliometer 2 (which was an older, wooden platform compared to the newer, metal version). All Partner 2s used stabiliometer 2 for acquisition, while all participants completed testing phases on stabiliometer 1. As anticipated, the Partner 2s had lower error across acquisition (M = 4.7°, SD = 1.7°) than the Partner 1s (M = 6.7°, SD = 2.3°), $F(1, 30) = 12.93$, $p = .001$, $\eta_p^2 = .30$. However, as there was no Partner x Trial interaction in acquisition, $F(6.00, 180.11) = 1.19$, $p = .31$, $1 - \beta = .46$, nor any partner-related effects or interactions in any other phase of the study when all participants used stabiliometer 1, we attributed this partner-effect to the more stable platform and collapsed across partners in all reported analyses and results.

Table 1: *Mean ratings (and SDs) for the Intrinsic Motivation Inventory subscales and customized partner-related competence subscale*

Group	Interest/ enjoyment	Competence		Choice	Pressure/ tension	Effort
		Own	Partner			
Alone	4.5 (1.0)	3.9 (1.1)	N/A	5.7 (0.8)	3.0 (0.9)	5.3 (0.9)
Concurrent	4.5 (1.1)	4.2 (1.2)	5.1 (0.8)	5.6 (1.9)	3.4 (1.3)	6.1 (0.4)
Turn-taking	5.0 (1.1)	4.5 (1.0)	5.4 (0.9)	5.5 (0.9)	3.9 (1.7)	6.2 (0.7)

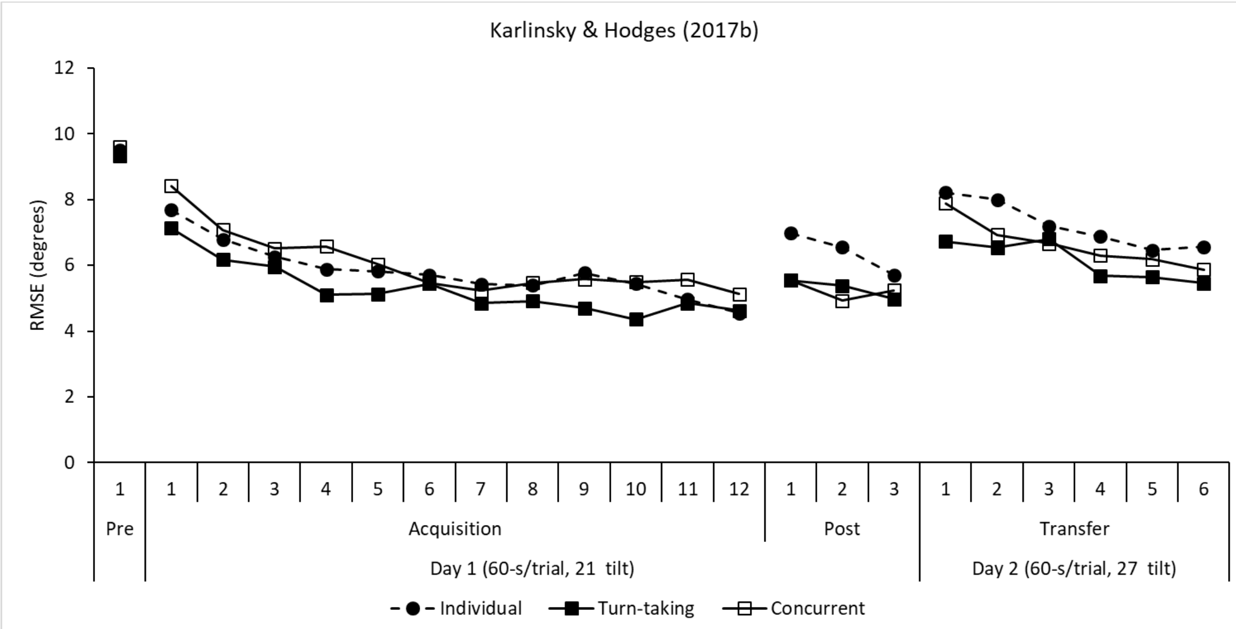
Note. Scales ranged from 1-7, with higher scores representing more of the relevant construct.

Figure Captions

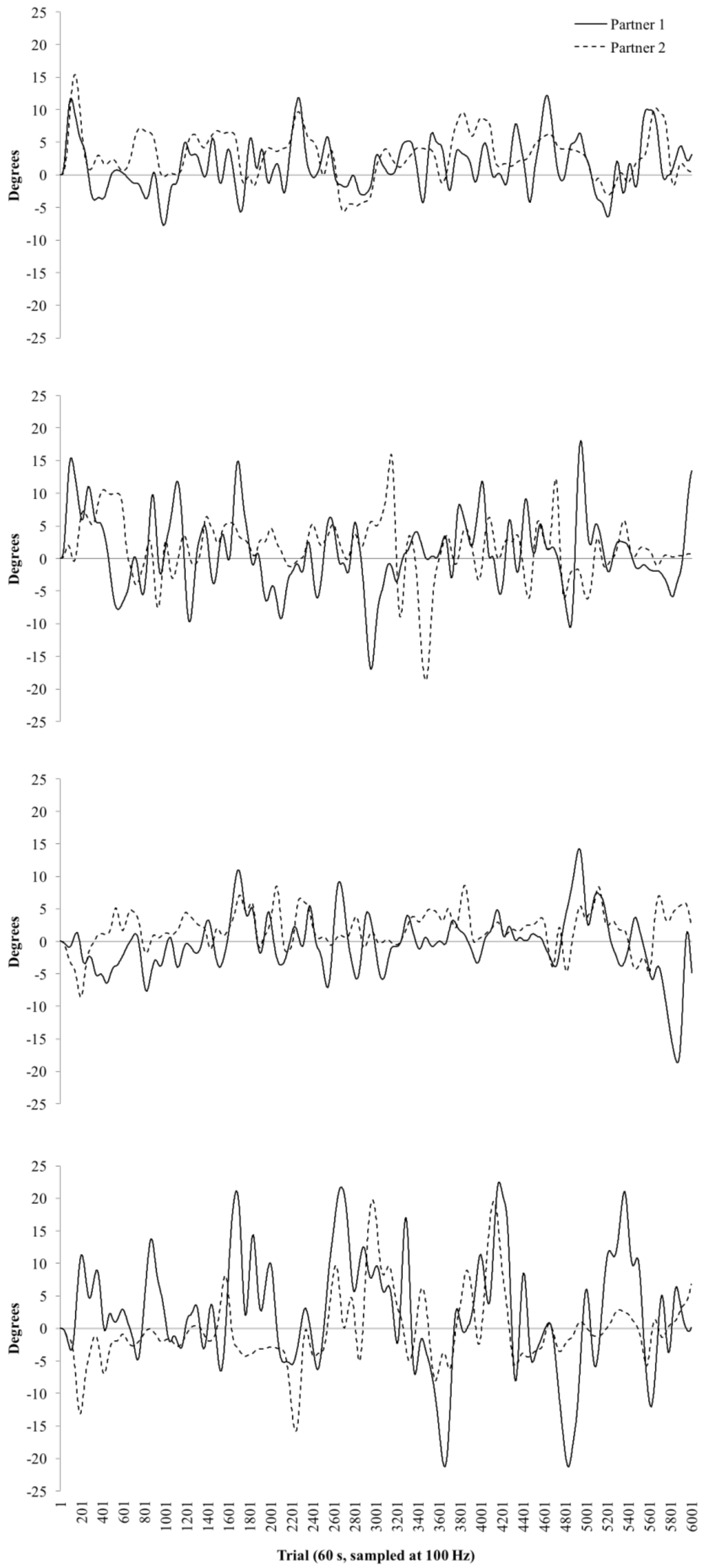
Figure 1. Root-mean-square-error (RMSE) in degrees of the Alone, Concurrent, and Turn-taking groups across the study.

Figure 2. Displacement data for the last acquisition trial for pairs 1 to 6 (top-bottom) in the Concurrent group, with % coupling being 59%, 57%, 60%, 61%, 58%, and 54%, respectively.

1


Karlinsky & Hodges (2017b)
RMSE (degrees)
12
10
8
6
4
2
0
1 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 1 2 3 4 5 6
Pre
Acquisition
Post
Transfer
Day 1 (60-s/trial, 21 tilt)
Day 2 (60-s/trial, 27 tilt)
Individual
Turn-taking
Concurrent

1


Partner 1
Partner 2
Degrees
Trial (60 s, sampled at 100 Hz)