The influence of attentional focus on balance control over seven days of training

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Abstract:

This study examined the training effect of attentional focus (external focus, internal focus, or no focus instructions) on a dynamic balance task. Participants completed baseline balance testing, seven consecutive days of dynamic balance board training, and retention testing 24 hours after the last session. The novel finding of this study was the presence of a training effect on balance control when adopting an external focus relative to an internal focus or no focus instructions. Further, we report the unique observation that more patterned behavior was adopted regardless of the focus instructions. These findings provide insight into how instructions can be altered to enhance human balance control and complement the constrained-action hypothesis.

Keywords: attentional focus | balance training | wobble board | sample entropy

Article:

1. Introduction

Balance is a critical component of functional mobility that relies on biomechanical coordination (Horak, 1997; Winter, 1995; Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998). While some balance training interventions have been shown to be effective (Buchner et al., 1997; Davis et al., 2010; Wolfson et al., 1992), others have shown less positive results (Cadore, Rodríguez-Mañas, Sinclair, & Izquierdo, 2013; Landers, Hatlevig, Davis, Richards, & Rosenlof, 2015). Differences in intervention efficacy may be partially explained by the various foci participants adopt during balance training. Complex balance training paradigms do not commonly explore how directing attention through instruction influences the performance and learning of balance control. Initially defined by Wulf, Höß, and Prinz (1998), attention directed toward movement execution is defined as an internal focus, whereas attention directed toward the effects of one's movement is defined as an external focus. Results from this line of research are robust and show that focusing externally produces greater performance and enhanced learning relative to an internal focus, or when no specific focus instruction is provided (Wulf, 2007, 2013).

According to the constrained action hypothesis (CAH) (McNevin, Shea, & Wulf, 2003; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001), an external focus permits movement automaticity and reflexivity, whereas an internal focus disrupts previously learned motor movements by consciously interfering with automatic control processes. The CAH has been substantiated with neuromuscular measures such as electromyography (EMG) (Lohse, Sherwood, & Healy, 2010), and the behavioral benefits of an external focus have been replicated in tasks ranging from basketball free-throw shooting (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002), dart-throwing (McKay & Wulf, 2012; McKay, Wulf, Lewthwaite, & Nordin, 2015), golf (Wulf & Su, 2007), to virtual target-shooting (Raisbeck & Diekfuss, 2017). While these studies are imperative to our understanding of attentional focus, they are limited by the short duration of practice time which minimizes our understanding of the within and between day motor learning trajectories. The majority of studies exploring attentional focus have participants practice 20–100 trials over the course of one session (Chiviacowsky, Wulf, & Wally, 2010; Wulf et al., 1998; Wulf, Weigelt, Poulter, & McNevin, 2003), three sessions (Laufer, Rotem-Lehrer, Ronen, Khayutin, & Rozenberg, 2007), or five sessions (Porter, Makaruk, & Starzak, 2016), and assess learning via a retention test 24 hours later. However, there is a substantial jump in the attentional focus literature from the single or few session acquisition periods used, to large scale training studies of four weeks (Landers et al., 2015) and nine weeks (Makaruk, Porter, Czaplicki, Sadowski, & Sacewicz, 2012). While patients with Parkinson's disease showed no balance control benefits when using an external focus during four weeks of training (Landers et al., 2015), benefits for an external focus on plyometrics were reported in the nine-week study conducted by Makaruk et al. (2012). One plausible explanation for the differences is that Landers et al. examined individuals with Parkinson's disease – a population that has slower motor learning rates than participants without Parkinson's disease (Nieuwboer, Rochester, Müncks, & Swinnen, 2009) – whereas participants in Makaruk et al.'s study were healthy adults.

A more complete understanding of the time-course of benefits resulting from attentional focus training is imperative to refine motor skill training programs. For instance, it is currently unknown if an external focus continues to be beneficial after multiple training sessions and whether the relative negative influence on performance and learning of internal focus can be mitigated with extended practice. There is a clear gap for our understanding of attentional focus on motor learning for periods longer than three sessions, yet shorter than four weeks. Except for the five sessions used by Porter et al. (2016), and the nine weeks of training used by Makaruk et al. (2012), we are aware of no evidence that examines training with an external focus for more than three sessions.

Disentangling the influence of attentional focus on motor learning over multiple training sessions is important for multiple reasons. First, while the beneficial effects of external focus are robust across various tasks and skill levels (Wulf, 2007, 2013), the findings are not universal. There are multiple published studies that have failed to fully replicate the benefits of an external focus in young healthy adults (Lawrence, Gottwald, Hardy, & Khan, 2011; Perkins-Ceccato, Passmore, &

Lee, 2003; Schorer, Jaitner, Wollny, Fath, & Baker, 2012; Zentgraf & Munzert, 2009), older adults (de Melker Worms, Stins, van Wegen, Loram, & Beek, 2017), and clinical populations (Gokeler et al., 2015). These discrepant findings have raised debate on the utility of an external focus for all tasks (Peh, Chow, & Davids, 2011) and for populations that have been understudied (e.g., older adults at risk for falling) (de Melker Worms et al., 2017). Second, attention is dynamic (Hutchinson & Tenenbaum, 2007) and focus is rarely static throughout a single training session (Bernier, Trottier, Thienot, & Fournier, 2016; Diekfuss & Raisbeck, 2017). Thus, to conclude that providing one "dose" of external focus instruction will remain as the prominent focus over multiple practice sessions and elicit long term changes in motor learning is unsubstantiated. Lastly, even while considering the 20 plus years of research documenting the beneficial effects of an external focus, athletes at various stages of skill development rarely report using an external focus (Diekfuss & Raisbeck, 2016; Porter, Wu, & Partridge, 2010; van der Graaff, Hoozemans, Pasteuning, Veeger, & Beek, 2017). In conjunction with recent reports questioning the efficacy of adopting an external focus (Collins, Carson, & Toner, 2016), it is premature to universally conclude that an external focus will improve motor learning over multiple training sessions. To bridge this gap, we investigated the learning of a motor task over the course of one week. The benefits of an external focus have been most replicated for balance control (Chiviacowsky et al., 2010; Jackson & Holmes, 2011; Laufer et al., 2007; McNevin & Wulf, 2002; Rotem-Lehrer & Laufer, 2007; Wulf, 2008; Wulf et al., 1998; Wulf et al., 2001; Wulf et al., 2003; Wulf, Landers, Lewthwaite, & Töllner, 2009; Wulf, Shea, et al., 2001), thus we utilized a dynamic balance task for our investigation. Moreover, falling in older adults has been deemed a public health problem (Handelsman, 2011). Thus, fall prevention programs would benefit from a stronger understanding of factors that enhance balance control.

The purpose of this study was to examine the effects of attentional focus on the performance and learning of a dynamic balance task over seven daily training sessions. We investigated this with a standard mean metric (mean velocity), linear variability metric (standard deviation [SD] velocity), and nonlinear variability metric (sample entropy [SampEn]). SampEn (Richman & Moorman, 2000) which has received notable attention in balance literature (Hansen et al., 2017), and is used to quantify time-series data by examining the characteristics of its structure (i.e., assess how complex a time series is), but to our knowledge has not been integrated into the attentional focus literature. Data were acquired throughout the seven daily training sessions to assess performance changes and baseline testing before the training and a retention test 24 hours after the last training session were acquired to assess learning. Due to practice effects, we predicted (1) significant improvements in balance control (lower mean and SD velocity and greater complexity [measured via SampEn]) from the early to late blocks and from the early to late days of training, regardless of condition. Further, we predicted (2) more favorable balance control characteristics (lower mean and SD velocity and greater complexity [measured via SampEn]) throughout acquisition and during retention when participants adopted an external focus of attention compared to an internal focus or no focus of attention (Wulf et al., 2003).

2. Methods

2.1. Participants

Thirty-three healthy participants (16 males, age = 23.0 ± 3.7 years, height = 175.9 ± 5.8 cm, mass = 74.0 ± 12.7 kg; 17 females, age = 22.6 ± 3.9 years, height = 164.8 ± 6.0 cm, mass = 62.0 ± 10.6 kg) volunteered to participate in this study. Sample size was based on a previous investigation using a balance board and attentional focus (Diekfuss et al., 2018). In that study, balance control was improved with an *n* of 8 using a within-subjects design. We conservatively used an *n* of 11 per group for a between subjects design to account for potential attrition. Inclusion criteria included no lower extremity injury in the last 6 months, and the left leg being the preferred stance limb when kicking a ball. Participants were excluded if they had: (1) a previous history of injury to the capsule, ligament, or menisci of either knee, (2) any inner ear or balance disorder, (3) undergone a previous balance training program, (4) were taking any medications that would affect balance, or (5) any neurological disorders. The institutional ethics committee approved the project and informed consent was obtained prior to commencing the study.

Figure 1. Participant standing on the dynamic balance board. An inertial measurement unit was attached to the center of the board to quantify balance control.

2.2. Apparatus

All balance testing was completed on a dynamic balance board (CanDo ®, NY, USA). The board is circular with a diameter of 76.2 cm. This board was attached to a half-sphere that was positioned underneath with a height of 20.3 cm. When individuals stood on the circular board, it moved in all directions to challenge the balance control system (Figure 1). This specific board and other similar “wobble boards” have been used extensively in balance training literature (Benson, Almonroeder, & O'Connor, 2017; Oliver & Di Brezzo, 2009). We attached an inertial measurement unit (IMU; Xsens; Xsens Technology, MA, USA) to the center of the board using Velcro which allowed us to quantify velocity of the board at a rate of 100 Hz. We used board velocity as an indirect measure of participants’ postural sway velocity which is hypothesized to be controlled by the nervous system for maintaining upright stance (Delignières, Torre, & Bernard, 2011; Jeka, Kiemel, Creath, Horak, & Peterka, 2004).

2.3. Procedure

This was a nine-day study with each training session separated by 24 hours (Figure 2). To note, the baseline (Day 1) and retention (Day 9) testing occurred at a separate location (Location A) from training (Days 2–8; Location B). This was necessary as this behavioral data was collected as part of a larger study (to be presented elsewhere) that required baseline and retention data to be collected offsite (Location A). For Location A, participants completed the testing in a quiet room on a solid tiled floor (hard floor). For Location B, participants also completed the testing in a quiet room, but this room's floor was fully carpeted (less dense floor). In an attempt to replicate the training conditions for baseline and retention, we placed a small piece of carpet on the hard floor during all baseline and retention collections.

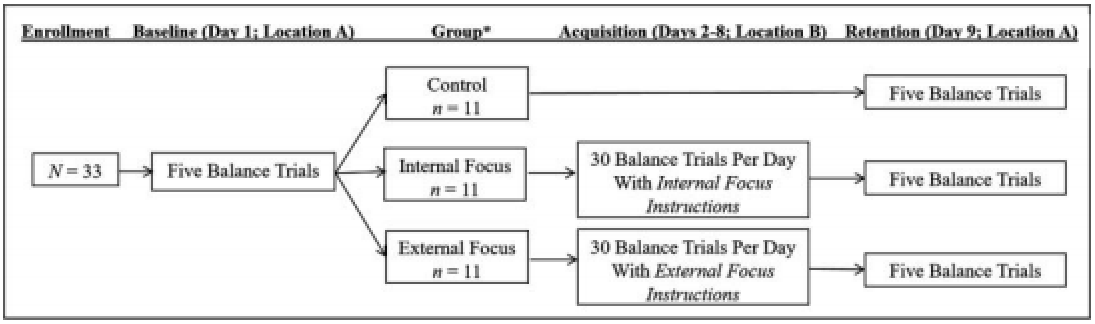

Figure 2. Study design. *Participants were randomly assigned to a control, internal focus, or external focus condition. Participants in the control condition only did baseline and retention testing, whereas those in the internal and external focus conditions also completed seven days of balance training. *Note:* baseline and retention data were collected at a different location than acquisition (see methods and limitations).

On Day 1 (baseline), participants stood on the board for 30 seconds for familiarization purposes. Participants then completed five separate 30-second trials on the balance board with a 30-second rest between trials. Participants were instructed to place both feet on their board, look forward, and asked to, ‘*do your best’* during the baseline trials. Participants were then randomly assigned to a control (*n* = 11), internal focus (*n* = 11), or external focus condition (*n* = 11). Participants in the internal and external focus conditions were asked to return to the lab at the same time for the next seven consecutive days (training/acquisition). Participants in the control condition were asked to report back to the lab on Day 9, resume normal activities, but to not complete any balance training during the seven days in-between. On days two through eight and only for those assigned to the internal or external focus condition, participants reported to the lab and completed six blocks of five separate 30-second trials (30 balance trials total per day) of the same balance task completed on Day 1. A 30-second rest was given between trials and a two-minute break was given between each block. For the internal focus trials, participants were asked to, '*focus on keeping your feet level*;' whereas, for the external focus trials participants were asked to, '*focus on keeping the board level*.' This attentional focus instruction was provided at the beginning of every test block throughout the seven days of training. No feedback or other instruction was provided throughout the training sessions. On Day 9 (24 hour retention from Day 8), congruent with the baseline test, participants completed five separate 30-second trials on the balance board with a 30-second rest between trials. No attentional focus instruction, feedback, or other additional information was provided during the retention test.

2.4. Data Reduction

Lateral stability (i.e., medial-lateral [ML]) is a greater predictor of fall-risk relative to anterior-posterior (AP) stability (Maki, Holliday, & Topper, 1994); thus, only ML data are focused on in this paper. The raw velocity time series (m/s) data in the ML direction were extracted from the IMU and filtered with a fifth-order low-pass Butterworth filter using a 5 Hz cut-off. We elected to analyze the medial-lateral direction as this closely resembles the side to side movement induced when standing on a stabilometer commonly used in attentional focus research (Chiviacowsky et al., 2010; Wulf et al., 2003). These data were then entered into customized scripts in MATLAB (MathWorks, Inc., Natick, MA) to extract the mean, SD, and SampEn of the velocity time series for each 30-second trial. To determine ideal SampEn parameters for this investigation, a customized optimization script was used to extract optimal length (m) and tolerance (r) values (Lake, Richman, Griffin, & Moorman, 2002). An $m = 2$ and $r = .15$ were used for this study.

2.5. Data Analyses

To assess learning, the mean, SD, and SampEn of the five trials for baseline and retention were averaged. We then conducted separate 3 (condition; control, internal focus, external focus) × 2 (time: baseline, retention) mixed ANOVAs with repeated measures on the last factor. Irrespective of any significant interaction, and to answer our *a priori* hypotheses, we conducted additional univariate ANCOVAs at retention with condition as the between-subjects' factor and baseline performance as the covariate to account for inter-individual group differences in baseline performance. For acquisition, the mean, SD, and SampEn of each block of five trials was averaged and three separate 2 (condition) × 7 (day) × 6 (block) mixed ANOVA's with repeated measures on the last two factors were conducted for the dependent variables of mean, SD, and SampEN velocity. Assessing baseline and retention data separately from acquisition data is consistent with others assessing motor performance and learning over separate days (Raisbeck & Diekfuss, 2017; Wulf, Chiviacowsky, Schiller, & Ávila, 2010). Post-hoc analyses were conducted using pair-wise comparisons (Bonferroni corrected) or Tukey's post-hoc procedure where appropriate and an alpha level of $p < .05$ was set *a priori*. All p values are reported to three decimals and adjusted per the appropriate correction (Bonferroni or Tukey's). Partial eta squared effect sizes are reported for F tests and values greater than or equal to .01, .06, and .14 deemed as small, medium, and large, respectively (Cohen, 1988). Cohen's D effect sizes are reported for post-hoc pairwise comparisons and values greater than or equal to .20, .50, and .80 deemed as small, medium, and large, respectively (Cohen, 1988).

3. Results

3.1. Mean Velocity

For learning, results revealed a main effect for time, F (1.00, 30.00) = 4.40, $p = .045$, partial ^{2} = .13, with participants reducing their medial-lateral velocity from baseline to retention. There was also a significant main effect for condition, F (2.00, 30.00) = 3.75, $p = .035$, partial ^{2} = .20, with Tukey's post-hoc analyses revealing lower mean velocity for the external focus compared to the control ($p = .045$, $d = .71$). While there was no significant interaction ($p = .272$, partial ^{2} = .08), our ANCOVA revealed a main effect for condition at retention, F (2.00, 29.00) = 4.21, $p = .025$, partial ^{2} = .23, with Tukey's post-hoc analyses revealing lower mean velocity for those in the external focus compared to the control ($p = .019$, $d = 1.21$).

During acquisition, there was a significant main effect for effect for day, Greenhouse-Geisser adjusted, F (3.67, 73.54) = 17.87, $p < .001$, partial ^{2} = .47. Pairwise comparisons (Bonferroni corrected) revealed significant reductions in mean velocity from Day 1 to Days 3 ($p = .017$, $d = .66$), 4 ($p = .009$, $d = .79$), 5 ($p = .002$, $d = .87$), 6 ($p < .001$, $d = 1.03$), and 7 ($p < .001$, $d = 1.06$), and from Day 2 to Days 4 ($p = .011$, $d = .53$), 5 ($p = .003$, $d = .60$), 6 ($p < .001$, $d = .76$), and 7 ($p < .001$, $d = .81$), and from Day 3 to Days 5 ($p = .023$, $d = .24$), 6 ($p = .019$, $d = .44$), and 7 ($p < .001$, $d = .49$). There was also a significant main effect for block, F (3.31, 66.28) = 6.98, $p < .001$, partial ^{2} = .26, with pairwise comparisons (Bonferroni corrected) revealing a significant reduction in mean velocity from Block 1 to Blocks 4 ($p = .015$, $d = .20$) and 6 ($p = .017$, $d = .19$), from Block 2 to Block 4 ($p = .042$, $d = .15$). There was a main effect for condition during acquisition with those in the external focus displaying lower mean velocity than those in the internal focus, F (1.00, 20.00) = 4.40, $p = .049$, partial ^{2} = .18. There was no block × day interaction ($p = .370$, partial ^{2} = .05), block × condition interaction ($p = .145$, partial ^{2} = .08), day × condition interaction ($p = .395$, partial ^{2} = .05), or block × day × condition interaction ($p = .508$, partial ^{2} = .04) for mean velocity. See Table 1 for all means and standard deviations for mean velocity.

Table 1. Mean medial-lateral velocity (Mean and SD) (m/s)
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3.2. Standard Deviation Velocity

For learning, there were no significant main effects for time ($p = .576$, partial ^{2} = .01) or significant interaction ($p = .621$, partial ^{2} = .03). However, there was a significant main effect for condition, F (2.00, 30.00) = 4.95, $p = .014$, partial ^{2} = .25, with Tukey's post-hoc analyses revealing lower mean velocity for the external focus compared to the control ($p = .012$, $d = 1.10$). No significant differences were revealed for the follow up ANCOVA at retention ($p = .292$, partial ^{2} = .08).

During acquisition, there was a significant main effect for effect for day, Greenhouse-Geisser adjusted, *F* (1.62, 32.40) = 8.19, *p* = .002, partial ^{2} = .29. Pairwise comparisons (Bonferroni corrected) revealed significant reductions in SD velocity from Day 2 to Days 6 (*p* = .036, *d* = .63) and 7 (*p* = .005, *d* = .69), and from Day 3 to Day 7 (*p* = .046, *d* = .44). There was a significant main effect for block, *F* (3.03, 60.64) = 13.72, *p* < .001, partial ^{2} = .41, with pairwise comparisons (Bonferroni corrected) revealing a significant reduction in SD velocity from Block 1 to Blocks 3 (*p* = .016, *d* = .15), 4 (*p* = .006, *d* = .21), 5 (*p* = .002, *d* = .27), and 6 (*p* = .003, *d* = .30), and from Block 2 to Blocks 4 (*p* = .008, *d* = .15), 5 (*p* < .001, *d* = .20), and 6 (*p* = .003, *d* = .23). Also, there was a main effect for condition during acquisition with those in the external focus displaying lower SD velocity than those in the internal focus, *F* (1.00, 20.00) = 4.49, *p* = .047, partial ^{2} = .18. There was no block × day interaction (*p* = .522, partial ^{2} = .04), block × condition interaction (*p* = .145, partial ^{2} = .08), day × condition interaction (*p* = .727, partial ^{2} = .02), or block × day × condition interaction (*p* = .651, partial ^{2} = .04) for SD velocity.
See Table 2for all means and standard deviations for standard deviation velocity.

Table 2. Standard deviation medial-lateral velocity (Mean and SD) (m/s)
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Table 3. Sample entropy medial-lateral velocity (Mean and SD) (no units)
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3.3. Sample Entropy Velocity

For learning, there were no significant main effects for time (*p* = .164, partial 2 = .06) or condition (*p* = .231, partial ^{2} = .09). While there was a significant time × condition interaction, *F*(2.00, 30.00) = 3.35, *p* = .049, partial ^{2} = .18, this was driven by inter-individual differences at baseline, as no significant differences at retention were observed when baseline was added as a covariate (*p* = .135, partial ^{2} = .13).

For acquisition, there was no significant main effect for day (*p* = .437, partial ^{2} = .04), condition (*p* = .906 partial ^{2} = .001), block × condition interaction (*p* = .709, partial ^{2} = .02), block × day interaction (*p* = .33, partial ^{2} = .08), day × condition interaction (*p* = .208, partial ^{2} = .08), or block × day × condition interaction (*p* = .085, partial ^{2} = .05) for SampEn velocity. However, there was a significant main effect for block, *F* (2.78, 55.57) = 21.16, *p* < .001, partial ^{2} = .51, with pairwise comparisons (Bonferroni corrected) revealing a significant reduction in SampEn velocity from Block 1 to Blocks 4 (*p* = .013, *d* = .21), 5 (*p* = .001, *d* = .29), and 6 (*p* < .001, *d* = .33), and from Block 2 to Blocks 4 (*p* = .003, *d* = .16), 5 (*p* < .001, *d* = .23), and 6 (*p* < .001, *d* = .27), and from Block 3 to Blocks 5 (*p* < .001, *d* = .16) and 6 (*p* < .001, *d* = .20), and from Block 4 to Block 6 (*p* = .008, *d* = .11). See Table 3 for all means and standard deviations for SampEn velocity.

4. Discussion

The purpose of this study was to examine the effects of attentional focus on the performance and learning of a dynamic balance task over seven training sessions. This was accomplished by having participants practice a dynamic balance task over the course of seven days and assessed balance control changes via an inertial measurement unit. While we predicted more favorable balance control characteristics over the course of seven days regardless of condition due to practice effects, we expected those who were given external focus instruction to display superior balance control characteristics throughout acquisition and at retention relative to the internal focus and the control condition.

Congruent with our first hypothesis, both training groups did improve their performance from early to late blocks within each day, while also improving over the course of seven days as measured by mean velocity. A reduction in mean velocity is considered favorable as it represents superior neuromotor control function needed for maintaining upright stance (Baloh, Jacobson, Beykirch, & Honrubia, 1998; Baloh, Jacobson, Enrietto, Corona, & Honrubia, 1998; Davids, Kingsbury, George, O'Connell, & Stock, 1999; Le Clair & Riach, 1996). The reduced mean velocity indicate that participants improved their ability to control the balance board throughout training regardless of group assignment. This is congruent with previous interventions that have demonstrated improvements in balance control following training (Buchner et al., 1997; Davis et al., 2010; Wolfson et al., 1992) and further supports the use of balance boards as training instruments (Söderman, Werner, Pietilä, Engström, & Alfredson, 2000; Verhagen et al., 2004).

In partial support of our second hypothesis, those in the external focus condition displayed more favorable balance control characteristics during performance as measured by medial-lateral board mean and SD velocity and at retention as measured by the board medial-lateral velocity. This supports previous attentional focus literature which has demonstrated superior balance control when individuals adopt an external focus (Chiviacowsky et al., 2010; Jackson & Holmes, 2011; Landers, Wulf, Wallmann, & Guadagnoli, 2005; McNevin & Wulf, 2002; Wulf et al., 2001) and contributes to previous research (McNevin & Wulf, 2002; Wulf et al., 2003) by extending the typical time frames of these studies to seven days. Our data indicate that an external focus continues to be beneficial after multiple training sessions and continuous practice with an internal focus does not supersede the benefits of an external focus. Thus, attentional focus influences the trajectory in which novel motor tasks are learned with participants performing and learning at a superior rate when given external focus instruction. This has implications for previously ineffective fall-prevention programs (de Vries et al., 2010; Hendriks et al., 2008). The failure to include an external focus with balance training might minimize the efficacy of such programs as participants behave in a manner consistent with an internal focus when no instruction is given (Landers et al., 2005; McNevin & Wulf, 2002; Wulf, Zachry, Granados, & Dufek, 2007). Practitioners should consider implementing an external focus when developing interventions designed to reduce fall-risk.

Similar results relative to improved retention or performance effects of external focus did not manifest when examining participants' balance control using a nonlinear variability metric (SampEn). We did, however, find a block main effect for SampEn velocity that revealed significant reductions in SampEn velocity from early to late blocks. Following the framework proposed by Lipsitz (2002), reductions in SampEn reflect more rigid, patterned, and potentially less adaptive behavior. Our interpretation of this finding, however was task-dependent. Considering we also found reductions in mean and SD velocity from early to late blocks, we consider the reduction in SampEn velocity as an indicator that the motor system selected a patterned behavior as most appropriate for this dynamic balance task. Participants may have adopted a patterned and rigid approach to reduce velocity and the magnitude of the variability to effectively keep the board (or their feet) level. This is an important contribution as balance boards have rapidly gained popularity to easily assess (Diekfuss et al., 2018) and train balance (Cloak, Nevill, Day, & Wyon, 2013; Söderman et al., 2000), and this is the first data documenting the dynamical movement strategies participants adopt while practicing. The adoption of a balance board should be context dependent. Based on our data, patients who currently have more random control of their motor behavior may benefit from the balance board, which was shown to move people toward a more patterned motor behavior in our study.

This study is limited by our assessment of balance control at two different locations with different floors. Our board velocity was qualitatively poorer (higher mean and SD velocity and lower SampEN) during baseline and retention relative to training. While this unintentionally influenced our findings, we deemed this satisfactory as we statistically compared the baseline and retention data independent from the training data. To our knowledge, no previous research has reported differences in balance board movement on different floors, but recognize that future work should consider completing all testing at the same location. We also did not have our control group practice the motor task with no focus instruction throughout the acquisition. We elected to do this as previous balance training paradigms have had control groups refrain from any form of training (Drijkoningen et al., 2015) or have completed other unrelated training such as general conditioning (McGuine & Keene, 2006) and standard protocols used for rehabilitation purposes (Eser, Yavuzer, Karakus, & Karaoglan, 2008). Future work could also examine variations in intensity or duration. For example, instead of completing 30 trials a day for 7 straight days, it would be interesting to increase the duration of training (e.g., 60 trials), but with longer periods between session (e.g., three times per week) as distributed practice is associated with more effective learning (Benjamin & Tullis, 2010). It would also be important to integrate variations in practice schedules as this has been shown to interact with attentional focus (Raisbeck, Regal, Diekfuss, Rhea, & Ward, 2015).

Despite these limitations, this study makes two important contributions. First, our data supports the CAH and fills a gap in the literature by assessing balance performance and learning over the course of seven straight days. Classical attentional focus effects, specifically during acquisition, were confirmed supporting an external focus for training a dynamic balance task. Per the CAH, focusing on the effects of one's movement permits more automatic and reflexive behavior which has been substantiated using neuromuscular measures such as EMG (Lohse et al., 2010; Vance, Wulf, Töllner, McNevin, & Mercer, 2004). While our study did not integrate such measures, our data indicate that focusing on the movement outcome improved participants' motor control by reducing the board's velocity and linear variability. In contrast, focusing on movement execution has been shown to induce a higher degree of cocontractions between agonist and antagonist muscles (Lohse, Sherwood, & Healy, 2011) which may have contributed to the relative increased velocity and linear variability when participants were asked to focus on their feet. Secondly, albeit our data did not reveal attentional focus differences for nonlinear variability (SampEn velocity), it furthered our understanding of how participants modify their dynamic balance strategy within-training sessions. Specifically, participants may adopt a patterned and rigid behavior to succeed with their respective instruction (feet or board level). The balance board used in this study is similar to a variety of attentional focus studies that have used stabilometers (Chiviacowsky et al., 2010) and it would be interesting to assess changes in SampEn on these or similar apparatuses. In conclusion, this research supports the use of an external focus for balance training and provides additional information pertaining to participants' balance control strategy within training sessions on a dynamic balance board.

REFERENCES

Al-Abood, S. A., Bennett, S. J., Hernandez, F. M., Ashford, D., & Davids, K. (2002). Effect of verbal instructions and image size on visual search strategies in basketball free throw shooting. *Journal of Sports Sciences*, *20*(3), 271–278. doi:10.1080/026404102317284817

Baloh, R. W., Jacobson, K. M., Beykirch, K., & Honrubia, V. (1998). Static and dynamic posturography in patients with vestibular and cerebellar lesions. *Archives of Neurology*, *55*(5), 649–654. doi:10.1001/archneur.55.5.649

Baloh, R. W., Jacobson, K. M., Enrietto, J. A., Corona, S., & Honrubia, V. (1998). Balance disorders in older persons: Quantification with posturography. *Otolaryngology—Head and Neck Surgery*, *119*(1), 89–92. doi:10.1016/S0194-5998(98)70177-9

Benjamin, A. S., & Tullis, J. (2010). What makes distributed practice effective? *Cognitive Psychology*, *61*(3), 228–247. doi:10.1016/j.cogpsych.2010.05.004

Benson, L. C., Almonroeder, T. G., & O'Connor, K. M. (2017). Quantifying knee mechanics during balance training exercises. *Human Movement Science*, *51*, 138–145. doi:10.1016/j.humov.2016.12.005

Bernier, M., Trottier, C., Thienot, E., & Fournier, J. (2016). An investigation of attentional foci and their temporal patterns: A naturalistic study in expert figure skaters. *The Sport Psychologist*, *30*(3), 256–266. doi:10.1123/tsp.2013-0076

Buchner, D. M., Cress, M. E., de Lateur, B. J., Esselman, P. C., Margherita, A. J., Price, R., & Wagner, E. H.(1997). The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *52*(4), M218–M224. doi:10.1093/gerona/52A.4.M218

Cadore, E. L., Rodríguez-Mañas, L., Sinclair, A., & Izquierdo, M. (2013). Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: A systematic review. *Rejuvenation research*, *16*(2), 105–114. doi:10.1089/rej.2012.1397

Chiviacowsky, S., Wulf, G., & Wally, R. (2010). An external focus of attention enhances balance learning in older adults. *Gait and Posture*, *32*(4), 572–575. doi:10.1016/j.gaitpost.2010.08.004

Cloak, R., Nevill, A., Day, S., & Wyon, M. (2013). Six-week combined vibration and wobble board training on balance and stability in footballers with functional ankle instability. *Clinical Journal of Sport Medicine*, *23*(5), 384–391. doi:10.1097/JSM.0b013e318291d22d

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences*. Hillside, NJ: Lawrence Earlbaum Associates.

Collins, D., Carson, H. J., & Toner, J. (2016). Letter to the editor concerning the article "Performance of gymnastics skill benefits from an external focus of attention" by Abdollahipour, Wulf, Psotta & Nieto (2015). *Journal of Sports Sciences*, *34*(13), 1288–1292. doi:10.1080/02640414.2015.1098782

Davids, K., Kingsbury, D., George, K., O'Connell, M., & Stock, D. (1999). Interacting constraints and the emergence of postural behavior in ACL-deficient subjects. *Journal of Motor Behavior*, *31*(4), 358–366. doi:10.1080/00222899909601000

Davis, J. C., Robertson, M. C., Ashe, M. C., Liu-Ambrose, T., Khan, K. M., & Marra, C. A. (2010). Does a home-based strength and balance programme in people aged ≥80 years provide the best value for money to prevent falls? A systematic review of economic evaluations of falls prevention interventions. *British Journal of Sports Medicine*, *44*, 80–89. doi:10.1136/bjsm.2008.060988

de Melker Worms, J. L., Stins, J. F., van Wegen, E. E., Loram, I. D., & Beek, P. J. (2017). Influence of focus of attention, reinvestment and fall history on elderly gait stability. *Physiological Reports*, *5*(1), e13061. doi:10.14814/phy2.13061

de Melker Worms, J. L., Stins, J. F., van Wegen, E. E., Verschueren, S. M., Beek, P. J., & Loram, I. D.(2017). Effects of attentional focus on walking stability in elderly. *Gait and Posture*, *55*, 94–99. doi:10.1016/j.gaitpost.2017.03.031

de Vries, O. J., Elders, P. J., Muller, M., Knol, D. L., Danner, S. A., Bouter, L. M., & Lips, P. (2010).Multifactorial intervention to reduce falls in older people at high risk of recurrent falls: A randomized controlled trial. *Archives of Internal Medicine*, *170*(13), 1110–1117. doi:10.1001/archinternmed.2010.169

Delignières, D., Torre, K., & Bernard, P.-L. (2011). Transition from persistent to anti-persistent correlations in postural sway indicates velocity-based control. *PLoS Computational Biology*, *7*(2),e1001089. doi:10.1371/journal.pcbi.1001089

Diekfuss, J. A., Janssen, J. A., Slutsky, A. B., Berry, N. T., Etnier, J. L., Wideman, L., & Raisbeck, L. D.(2018). An external focus of attention is effective for balance control when sleep-deprived.*International Journal of Exercise Science*, *11*(5), 84–94.

Diekfuss, J. A., & Raisbeck, L. D. (2016). Focus of attention and instructional feedback from NCAA division 1 collegiate coaches. *Journal of Motor Learning and Development*, *4*(2), 262–273. doi:10.1123/jmld.2015-0026

Diekfuss, J. A., & Raisbeck, L. D. (2017). Attentional focus in NCAA division 1 Golfers. *Journal of Motor Learning and Development*, *5*, 240–251. doi:10.1123/jmld.2016-0025

Drijkoningen, D., Caeyenberghs, K., Leunissen, I., Vander Linden, C., Leemans, A., Sunaert, S., …Swinnen, S. P. (2015). Training-induced improvements in postural control are accompanied by alterations in cerebellar white matter in brain injured patients. *NeuroImage: Clinical*, *7*, 240–251. doi:10.1016/j.nicl.2014.12.006

Eser, F., Yavuzer, G., Karakus, D., & Karaoglan, B. (2008). The effect of balance training on motor recovery and ambulation after stroke: A randomized controlled trial. *European Journal of Physical and Rehabilitation Medicine*, *44*(1), 19–25.

Gokeler, A., Benjaminse, A., Welling, W., Alferink, M., Eppinga, P., & Otten, B. (2015). The effects of attentional focus on jump performance and knee joint kinematics in patients after ACL reconstruction. *Physical Therapy in Sport*, *16*(2), 114–120. doi:10.1016/j.ptsp.2014.06.002

Handelsman, J. (2011). Falls among older adults: A public health concern. *Perspectives on Public Health Issues Related to Hearing and Balance*, *12*(1), 13. doi:10.1044/hcoa12.1.13

Hansen, C., Wei, Q., Shieh, J.-S., Fourcade, P., Isableu, B., & Majed, L. (2017). Sample entropy, univariate, and multivariate multi-scale entropy in comparison with classical postural sway parameters in young healthy adults. *Frontiers in Human Neuroscience*, *11*. doi:10.3389/fnhum.2017.00206

Hendriks, M. R., Bleijlevens, M. H., Van Haastregt, J., Crebolder, H. F., Diederiks, J. P., Evers, S. M., …Ruijgrok, J. M. (2008). Lack of effectiveness of a multidisciplinary fall-prevention program in elderly people at risk: A randomized, controlled trial. *Journal of the American Geriatrics Society*, *56*(8), 1390–1397. doi:10.1111/j.1532-5415.2008.01803.x

Horak, F. B. (1997). Clinical assessment of balance disorders. *Gait and Posture*, *6*(1), 76–84. doi:10.1016/S0966-6362(97)00018-0

Hutchinson, J. C., & Tenenbaum, G. (2007). Attention focus during physical effort: The mediating role of task intensity. *Psychology of Sport and Exercise*, *8*(2), 233–245. doi:10.1016/j.psychsport.2006.03.006

Jackson, B. H., & Holmes, A. M. (2011). The effects of focus of attention and task objective consistency on learning a balancing task. *Research Quarterly for Exercise and Sport*, *82*(3), 574–579. doi:10.1080/02701367.2011.10599791

Jeka, J., Kiemel, T., Creath, R., Horak, F., & Peterka, R. (2004). Controlling human upright posture: Velocity information is more accurate than position or acceleration. *Journal of Neurophysiology*, *92*(4),2368–2379. doi:10.1152/jn.00983.2003

Lake, D. E., Richman, J. S., Griffin, M. P., & Moorman, J. R. (2002). Sample entropy analysis of neonatal heart rate variability. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*,*283*(3), R789–R797. doi:10.1152/ajpregu.00069.2002

Landers, M., Hatlevig, R. M., Davis, A. D., Richards, A. R., & Rosenlof, L. E. (2015). Does attentional focus during balance training in people with Parkinson's disease affect outcome? A randomised controlled clinical trial. *Clinical Rehabilitation*, *30* (1), 53–63. doi:10.1177/0269215515570377.

Landers, M., Wulf, G., Wallmann, H., & Guadagnoli, M. (2005). An external focus of attention attenuates balance impairment in patients with Parkinson's disease who have a fall history. *Physiotherapy*, *91*(3), 152–158. doi:10.1016/j.physio.2004.11.010

Laufer, Y., Rotem-Lehrer, N., Ronen, Z., Khayutin, G., & Rozenberg, I. (2007). Effect of attention focus on acquisition and retention of postural control following ankle sprain. *Archives of Physical Medicine and Rehabilitation*, *88*(1), 105–108. doi:10.1016/j.apmr.2006.10.028

Lawrence, G. P., Gottwald, V. M., Hardy, J., & Khan, M. A. (2011). Internal and external focus of attention in a novice form sport. *Research Quarterly for Exercise and Sport*, *82*(3), 431–441. doi:10.1080/02701367.2011.10599775

Le Clair, K., & Riach, C. (1996). Postural stability measures: What to measure and for how long. *Clinical Biomechanics*, *11*(3), 176–178. doi:10.1016/0268-0033(95)00027-5

Lipsitz, L. A. (2002). Dynamics of stability the physiologic basis of functional health and frailty. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *57*(3), B115–B125. doi:10.1093/gerona/57.3.B115

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2010). How changing the focus of attention affects performance, kinematics, and electromyography in dart throwing. *Human Movement Science*, *29*(4),542–555. doi:10.1016/j.humov.2010.05.001

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2011). Neuromuscular effects of shifting the focus of attention in a simple force production task. *Journal of Motor Behavior*, *43*(2), 173–184. doi:10.1080/00222895.2011.555436

Makaruk, H., Porter, J. M., Czaplicki, A., Sadowski, J., & Sacewicz, T. (2012). The role of attentional focus in plyometric training. *The Journal of Sports Medicine and Physical Fitness*, *52*(3), 319–327.

Maki, B. E., Holliday, P. J., & Topper, A. K. (1994). A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. *Journal of Gerontology*, *49*(2), M72–M84. doi:10.1093/geronj/49.2.M72

McGuine, T. A., & Keene, J. S. (2006). The effect of a balance training program on the risk of ankle sprains in high school athletes. *The American Journal of Sports Medicine*, *34*(7), 1103–1111. doi:10.1177/0363546505284191

McKay, B., & Wulf, G. (2012). A distal external focus enhances novice dart throwing performance. *International Journal of Sport and Exercise Psychology*, *10*(2), 149–156. doi:10.1080/1612197X.2012.682356

McKay, B., Wulf, G., Lewthwaite, R., & Nordin, A. (2015). The self: Your own worst enemy? A test of the self-invoking trigger hypothesis. *The Quarterly Journal of Experimental Psychology*, *68*(9), 1910–1919. doi:10.1080/17470218.2014.997765

McNevin, N. H., Shea, C. H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research*, *67*(1), 22–29.

McNevin, N. H., & Wulf, G. (2002). Attentional focus on supra-postural tasks affects postural control. *Human Movement Science*, *21*(2), 187–202. doi:10.1016/S0167-9457(02)00095-7

Nieuwboer, A., Rochester, L., Müncks, L., & Swinnen, S. P. (2009). Motor learning in Parkinson's disease: Limitations and potential for rehabilitation. *Parkinsonism & Related Disorders*, *15*, S53–S58. doi:10.1016/S1353-8020(09)70781-3

Oliver, G. D., & Di Brezzo, R. (2009). Functional balance training in collegiate women athletes. *The Journal of Strength & Conditioning Research*, *23*(7), 2124–2129. doi:10.1519/JSC.0b013e3181b3dd9e

Peh, S. Y.-C., Chow, J. Y., & Davids, K. (2011). Focus of attention and its impact on movement behaviour. *Journal of Science and Medicine in Sport*, *14*(1), 70–78. doi:10.1016/j.jsams.2010.07.002

Perkins-Ceccato, N., Passmore, S. R., & Lee, T. D. (2003). Effects of focus of attention depend on golfers' skill. *Journal of Sports Sciences*, *21*(8), 593–600. doi:10.1080/0264041031000101980

Porter, J., Makaruk, H., & Starzak, M. (2016). The role of vision and movement automization on the focus of attention effect. *Journal of Motor Learning and Development*, *4*(2), 152–168. doi:10.1123/jmld.2015-0020

Porter, J., Wu, W., & Partridge, J. (2010). Focus of attention and verbal instructions: Strategies of elite track and field coaches and athletes. *Sport Science Review*, *19*(3–4), 77–89.

Raisbeck, L. D., & Diekfuss, J. A. (2017). Verbal cues and attentional focus: A simulated target-shooting experiment. *Journal of Motor Learning and Development*, *5*(1), 148–159. doi:10.1123/jmld.2016-0017

Raisbeck, L. D., Regal, A., Diekfuss, J. A., Rhea, C. K., & Ward, P. (2015). Influence of practice schedules and attention on skill development and retention. *Human Movement Science*, *43*, 100–106. doi:10.1016/j.humov.2015.07.004

Richman, J. S., & Moorman, J. R. (2000). Physiological time-series analysis using approximate entropy and sample entropy. *American Journal of Physiology-Heart and Circulatory Physiology*, *278*(6), H2039–H2049. doi:10.1152/ajpheart.2000.278.6.H2039

Rotem-Lehrer, N., & Laufer, Y. (2007). Effect of focus of attention on transfer of a postural control task following an ankle sprain. *Journal of Orthopaedic and Sports Physical Therapy*, *37*(9), 564–569. doi:10.2519/jospt.2007.2519

Schorer, J., Jaitner, T., Wollny, R., Fath, F., & Baker, J. (2012). Influence of varying focus of attention conditions on dart throwing performance in experts and novices. *Experimental Brain Research*, *217*(2),287–297. doi:10.1007/s00221-011-2992-5

Söderman, K., Werner, S., Pietilä, T., Engström, B., & Alfredson, H. (2000). Balance board training: Prevention of traumatic injuries of the lower extremities in female soccer players? *Knee Surgery, Sports Traumatology, Arthroscopy*, *8*(6), 356–363. doi:10.1007/s001670000147

van der Graaff, E., Hoozemans, M., Pasteuning, M., Veeger, D., & Beek, P. J. (2017). Focus of attention instructions during baseball pitching training. *0*(0), 1–7. *International Journal of Sports Science & Coaching*. doi:10.1177/1747954117711095

Vance, J., Wulf, G., Töllner, T., McNevin, N., & Mercer, J. (2004). EMG activity as a function of the performer's focus of attention. *Journal of Motor Behavior*, *36*(4), 450–459. doi:10.3200/JMBR.36.4.450-459

Verhagen, E., Van der Beek, A., Twisk, J., Bouter, L., Bahr, R., & Van Mechelen, W. (2004). The effect of a proprioceptive balance board training program for the prevention of ankle sprains. *The American Journal of Sports Medicine*, *32*(6), 1385–1393. doi:10.1177/0363546503262177

Winter, D. A. (1995). Human balance and posture control during standing and walking. *Gait and Posture*, *3*(4), 193–214. doi:10.1016/0966-6362(96)82849-9

Winter, D. A., Patla, A. E., Prince, F., Ishac, M., & Gielo-Perczak, K. (1998). Stiffness control of balance in quiet standing. *Journal of Neurophysiology*, *80*(3), 1211–1221. doi:10.1152/jn.1998.80.3.1211

Wolfson, L., Whipple, R., Derby, C. A., Amerman, P., Murphy, T., Tobin, J. N., & Nashner, L. (1992). A dynamic posturography study of balance in healthy elderly. *Neurology*, *42*(11), 2069–2069. doi:10.1212/WNL.42.11.2069

Wulf, G. (2007). Attentional focus and motor learning: A review of 10 years of research. *E-journal Bewegung und Training*, *1*(2-3), 1–11.

Wulf, G. (2008). Attentional focus effects in balance acrobats. *Research Quarterly for Exercise and Sport*, *79*(3), 319–325. doi:10.1080/02701367.2008.10599495

Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport and Exercise Psychology*, *6*(1), 77–104. doi:10.1080/1750984X.2012.723728

Wulf, G., Chiviacowsky, S., Schiller, E., & Ávila, L. T. G. (2010). Frequent external focus feedback enhances motor learning. *Frontiers in Psychology*, *1*, 190. doi:10.3389/fpsyg.2010.00190

Wulf, G., Höß, M., & Prinz, W. (1998). Instructions for motor learning: Differential effects of internal versus external focus of attention. *Journal of Motor Behavior*, *30*(2), 169–179. doi:10.1080/00222899809601334

Wulf, G., Landers, M., Lewthwaite, R., & Töllner, T. (2009). External focus instructions reduce postural instability in individuals with Parkinson disease. *Physical Therapy*, *89*(2), 162–168. doi:10.2522/ptj.20080045

Wulf, G., McNevin, N., & Shea, C. H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *The Quarterly Journal of Experimental Psychology: Section A*, *54*(4), 1143–1154. doi:10.1080/713756012

Wulf, G., Shea, C., & Park, J.-H. (2001). Attention and motor performance: Preferences for and advantages of an external focus. *Research Quarterly for Exercise and Sport*, *72*(4), 335–344. doi:10.1080/02701367.2001.10608970

Wulf, G., & Su, J. (2007). An external focus of attention enhances golf shot accuracy in beginners and experts. *Research Quarterly for Exercise and Sport*, *78*(4), 384–389. doi:10.1080/02701367.2007.10599436

Wulf, G., Weigelt, M., Poulter, D., & McNevin, N. (2003). Attentional focus on suprapostural tasks affects balance learning. *The Quarterly Journal of Experimental Psychology: Section A*, *56*(7), 1191–1211. doi:10.1080/02724980343000062

Wulf, G., Zachry, T., Granados, C., & Dufek, J. (2007). Increases in jump-and-reach height through an external focus of attention. *International Journal of Sports Science and Coaching*, *2*(3), 275–284. doi:10.1260/174795407782233182

Zentgraf, K., & Munzert, J. (2009). Effects of attentional-focus instructions on movement kinematics. *Psychology of Sport and Exercise*, *10*(5), 520–525. doi:10.1016/j.psychsport.2009.01.006

Table 1. Mean medial-lateral velocity (Mean and SD) (m/s)

Day		Baseline	1						2						3						4						5						6						7						Retention
Mean Velocity (*M*)	Block	1	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1
Control		0.0146	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0143
Internal Focus		0.0136	0.0135	0.0131	0.0130	0.0129	0.0129	0.0129	0.0126	0.0127	0.0127	0.0124	0.0126	0.0126	0.0121	0.0118	0.0121	0.0115	0.0115	0.0116	0.0117	0.0118	0.0113	0.0116	0.0113	0.0110	0.0117	0.0120	0.0116	0.0114	0.0117	0.0111	0.0118	0.0113	0.0114	0.0108	0.0114	0.0109	0.0117	0.0115	0.0112	0.0111	0.0111	0.0112	0.0130
External Focus		0.0140	0.0121	0.0126	0.0122	0.0120	0.0120	0.0118	0.0118	0.0117	0.0116	0.0116	0.0115	0.0114	0.0112	0.0111	0.0110	0.0109	0.0107	0.0109	0.0109	0.0109	0.0105	0.0104	0.0101	0.0106	0.0104	0.0102	0.0100	0.0102	0.0104	0.0103	0.0101	0.0100	0.0098	0.0096	0.0095	0.0099	0.0097	0.0094	0.0094	0.0096	0.0093	0.0096	0.0125
Day		Baseline	1						2						3						4						5						6						7						Retention
Mean Velocity (*SD*)	Block	1	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1
Control		0.0016	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0016
Internal Focus		0.0018	0.0023	0.0019	0.0019	0.0024	0.0021	0.0019	0.0022	0.0016	0.0017	0.0020	0.0025	0.0027	0.0019	0.0016	0.0016	0.0012	0.0012	0.0015	0.0012	0.0017	0.0018	0.0017	0.0014	0.0015	0.0016	0.0018	0.0014	0.0015	0.0012	0.0012	0.0018	0.0015	0.0014	0.0017	0.0017	0.0013	0.0017	0.0017	0.0019	0.0019	0.0018	0.0018	0.0015
External Focus		0.0021	0.0017	0.0018	0.0017	0.0018	0.0018	0.0017	0.0017	0.0021	0.0018	0.0019	0.0021	0.0021	0.0015	0.0016	0.0020	0.0020	0.0019	0.0019	0.0020	0.0020	0.0022	0.0023	0.0021	0.0022	0.0022	0.0022	0.0018	0.0017	0.0017	0.0017	0.0019	0.0021	0.0022	0.0021	0.0023	0.0020	0.0020	0.0022	0.0020	0.0021	0.0022	0.0024	0.0019

For learning, significant main effect for time with lower mean velocities at retention compared to baseline, p < .05. A follow up ANCOVA revealed a main effect at retention when controlling for baseline with those in the external focus displaying significantly lower mean velocity than control, p < .05. During acquisition, significant within-day and between-day effects with lower mean velocity from early to late blocks and early to late days, all p < .05. Significant main effect for condition throughout acquisition with a lower mean velocity for those in the external focus compared to the internal focus, p < .05. Baseline and retention data were collected at a different location with a denser floor than acquisition (see methods and limitations).

Table 2. Standard deviation medial-lateral velocity (Mean and SD) (m/s)

Day		Baseline	1						2						3						4						5						6						7						Retention
SD Velocity (*M*)	Block	1	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1
Control		0.0087	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0087
Internal Focus		0.0081	0.0089	0.0088	0.0087	0.0086	0.0084	0.0082	0.0080	0.0082	0.0078	0.0078	0.0076	0.0076	0.0078	0.0077	0.0076	0.0075	0.0075	0.0075	0.0078	0.0079	0.0076	0.0077	0.0076	0.0075	0.0077	0.0078	0.0076	0.0076	0.0075	0.0074	0.0078	0.0076	0.0076	0.0074	0.0075	0.0074	0.0077	0.0076	0.0076	0.0073	0.0074	0.0074	0.0081
External Focus		0.0080	0.0082	0.0082	0.0081	0.0079	0.0079	0.0077	0.0077	0.0077	0.0076	0.0077	0.0075	0.0075	0.0074	0.0074	0.0073	0.0073	0.0071	0.0073	0.0073	0.0072	0.0070	0.0069	0.0068	0.0069	0.0070	0.0067	0.0067	0.0066	0.0068	0.0067	0.0069	0.0068	0.0066	0.0065	0.0064	0.0066	0.0067	0.0065	0.0065	0.0066	0.0064	0.0065	0.0077
Day		Baseline	1						2						3						4						5						6						7						Retention
SD Velocity (*SD*)	Block	1	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1
Control		0.0009	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0011
Internal Focus		0.0006	0.0026	0.0022	0.0024	0.0024	0.0022	0.0015	0.0011	0.0013	0.0007	0.0006	0.0007	0.0009	0.0009	0.0008	0.0008	0.0006	0.0006	0.0007	0.0006	0.0013	0.0011	0.0015	0.0008	0.0009	0.0008	0.0010	0.0009	0.0009	0.0006	0.0007	0.0008	0.0009	0.0010	0.0009	0.0008	0.0008	0.0008	0.0009	0.0010	0.0008	0.0009	0.0009	0.0009
External Focus		0.0009	0.0017	0.0018	0.0016	0.0013	0.0015	0.0013	0.0008	0.0011	0.0009	0.0009	0.0008	0.0011	0.0008	0.0009	0.0011	0.0010	0.0010	0.0012	0.0082	0.0010	0.0012	0.0011	0.0011	0.0009	0.0010	0.0011	0.0008	0.0008	0.0007	0.0008	0.0009	0.0009	0.0011	0.0010	0.0011	0.0009	0.0009	0.0011	0.0010	0.0009	0.0010	0.0010	0.0006

No significant main effects for learning (p > .05). During acquisition, significant within-day and between-day effects with lower SD velocity from early to late blocks and early to late days, all p < .05. Significant main effect for condition throughout acquisition with a lower SD velocity for those in the external focus compared to the internal focus, p < .05. Baseline and retention data were collected at a different location with a denser floor than acquisition (see methods and limitations).

Table 3. Sample entropy medial-lateral velocity (Mean and SD) (no units)

Day		Baseline	1						2						3						4						5						6						7						Retention
SampEn Velocity (*M*)	Block	1	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1
Control		0.3732	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.3861
Internal Focus		0.3575	0.4379	0.4386	0.4135	0.4026	0.3804	0.3720	0.4033	0.3755	0.3770	0.3599	0.3514	0.3327	0.3796	0.4000	0.3730	0.3856	0.3899	0.3841	0.3993	0.3842	0.3846	0.3682	0.3656	0.3681	0.3848	0.3765	0.3682	0.3710	0.3651	0.3527	0.3778	0.3780	0.3505	0.3664	0.3504	0.3579	0.3733	0.3709	0.3708	0.3576	0.3584	0.3552	0.3297
External Focus		0.2983	0.3929	0.3715	0.3833	0.3711	0.3617	0.3655	0.3993	0.3935	0.3978	0.3764	0.3725	0.3701	0.4127	0.3983	0.3972	0.3890	0.3788	0.3723	0.4018	0.3977	0.3880	0.3830	0.3816	0.3673	0.3940	0.3905	0.3904	0.3843	0.3679	0.3695	0.3930	0.4004	0.3878	0.3877	0.3733	0.3786	0.3944	0.3965	0.3857	0.3772	0.3720	0.3609	0.3618
Day			1						2						3						4						5						6						7						Retention
SampEn Velocity (*SD*)	Block		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1
Control		0.0810	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0850
Internal Focus		0.0999	0.0795	0.0650	0.0791	0.0819	0.0772	0.0937	0.1024	0.0947	0.0915	0.1047	0.1083	0.1200	0.1046	0.0781	0.1069	0.1675	0.0796	0.0732	0.0842	0.0870	0.0871	0.0913	0.0809	0.0697	0.0875	0.0830	0.0903	0.0971	0.0915	0.0887	0.0917	0.0952	0.0900	0.0897	0.0925	0.0921	0.1011	0.0887	0.0939	0.1026	0.0916	0.0923	0.0797
External Focus		0.1043	0.0824	0.1037	0.1035	0.4741	0.1008	0.0981	0.0930	0.1093	0.0966	0.1098	0.0882	0.1121	0.0923	0.1082	0.1086	0.1081	0.1025	0.1038	0.1084	0.1104	0.1066	0.1113	0.1092	0.1067	0.0902	0.1149	0.1050	0.1113	0.1130	0.1121	0.1011	0.0984	0.1013	0.0981	0.1010	0.1043	0.1049	0.1089	0.1078	0.1004	0.1114	0.1123	0.0838

No significant main effects for learning (p > .05). During acquisition, significant block £ day interaction (p < .05), with significant reductions in SampEn from early to late blocks for days 1, 2, 4, 5, 6, 7. No differences or interactions for the focus of attention between days, all p > .05. Baseline and retention data were collected at a different location with a denser floor than acquisition (see methods and limitations).