Walking In and Out of Virtual Reality

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Abstract

For most people, walking occurs regularly in everyday life. How we walk, however, depends on a variety of factors; One major factor is walking with other people; humans tend to walk in stride with each other spontaneously. Understanding this phenomenon has applications for a diverse set of fields, such as gait rehabilitation, so it is of value to study gait synchronisation. However, this can be difficult due to constraints in lab settings that limit the ability to study gait synchronization. Virtual reality is a tool that can be used to bypass this issue. While virtual reality conveniently provides a method of studying gait synchronisation, it may not hold the same effect as walking with a real person. If virtual reality does not accurately mimic the real-life scenario it attempts to emulate, then the resulting data is not generalizable. The efficacy of virtual reality research for gait synchronization, a comparison will be made between walking behind a real person versus a virtual reality avatar.

Keywords: virtual reality, gait, synchronisation, avatar, walking, perception

Walking alongside others has been considerably studied. Walking (i.e., gait) consists of several parameters, such as stride length, cadence (steps per minute), and stride velocity. These parameters can be manipulated to synchronize gait when walking alongside other people. Many factors can affect the ability to synchronize gait with others. The relative position, orientation, or relative direction of the person with whom you walk are several contributing factors (Meerhoff, 2017; Soczawa-Stroncyzyk et al., 2020). Additionally, Wagnild and Wall-Scheffler (2013) discovered that the biological sex of the person you walk with can impact walking speed; walking with males increases walking speed, while walking with females slows it down. That is, when two males walk together, they are faster than a male and a female, which are faster than two females. Furthermore, being in a romantic relationship with the person you are walking with decreases walking speed by a greater extent than expected, regardless of biological sex (Wagnild & Wall-Scheffler, 2013).

Another factor that positively correlates with interpersonal synchronization is empathy. In their study, Baimel et al. (2018) discovered that performing a synchrony task resulted in a self-reported increase in the participants' ability to reciprocally reflect on the other's mental state. In a similar vein, Novembre et al. (2019) found empathetic people to have an increased ability to synchronise with each other. Tzanki (2022) connected these two findings through her proposal of a theoretical framework that relates empathy with interpersonal synchronisation in a positive feedback loop, where empathy enhances synchronisation, and in turn, synchronisation elevates empathy. Extraneous factors such as the strength of dyadic relationship and biological sex present a challenge, as they would confound the results of an observational study of gait; therefore, gait synchronisation must be studied in experimental conditions.

However, like research in other areas, issues arise when testing the synchronisation of one's gait in a lab. First, Blascovich et al. (2002) note the existence of a trade-off between experimental control and mundane realism. If the experiment is conducted in a manner that accurately mimics the real-life scenario that the conditions attempt to represent, then the extraneous variables are more likely to make an appearance in the form of confounding results. On the other hand, studying phenomena using more controlling research designs typically leads to less generalizable results. Additionally, errors in replication can occur; the initial researcher may write a procedure lacking in essential details, or the researchers attempting to replicate the study may not carry out the procedure precisely (Blascovich et al., 2002). A potential solution to these issues may lie in the use of virtual reality.

Virtual reality is a technology that debuted in entertainment but has since been used in other industries, such as research. The technology is affordable, but provides a high-quality experience for the user, due to three main attributes: immersion, presence, and interactivity. Immersion refers to the objective ability of a virtual reality system to engage the senses of the user (Petersen et al., 2022). Generally, the higher percentages of your body involved in the virtual environment correspond to higher levels of immersion (Slater, 2018). Presence examines the user's subjective experience of being in a location, regardless of the user's physical location (Mütterlein, 2018). Presence can further be categorised as telepresence, which incorporates technology to achieve states of presence (Mütterlein, 2018). Presence in virtual reality ignores cognitive appraisal of one's situation, so although the user may know that a threat, for example, is only a virtual image, the user will adopt a physical reaction that mimics what would occur if the threat were real (Slater, 2018). This interaction allows for real physiological or psychological responses to virtual stimuli. Interactivity considers the level of freedom that the user has within the virtual environment; this is usually increased by giving the user a virtual body, or otherwise by providing a handheld controller (Petersen et al., 2022). Having increased interactivity typically contributes to an increase in presence as well (Mütterlein, 2018).

Immersion, presence, and interactivity address many concerns with testing in a lab. Telepresence aids in certain situations where the experiment is not feasible, safe, or otherwise ethical to conduct in a lab (Pan & Hamilton, 2018). The combination of immersion and telepresence also helps to eliminate extraneous factors, while still maintaining an important level of fidelity for the environment by manipulating a single variable within a realistic virtual environment (Pan & Hamilton, 2018). This combination significantly reduces the trade-off that occurs between experimental control and mundane realism. Furthermore, virtual reality uses digital programming to create both the virtual environment and any avatars that may exist in it. Researchers can change and control variables in the virtual environment with great precision. These programs can be sent to other researchers that wish to replicate the study, which may mitigate issues with procedure reporting and execution. For all these reasons, virtual reality is an effective tool that can and has been incorporated into numerous walking and gait synchronisation studies. However, the extent of the ecological validity of virtual reality in gait synchronization has yet to be agreed upon.

Some studies suggest virtual reality portrays real life sufficiently for the data from virtual reality studies to be generalizable. Felsberg & Rhea (2021) note that humans likely synchronise with each other spontaneously. Khan et al. (2020) provided robust evidence suggesting that participants could accurately synchronise their gait to that of a virtual avatar, which indicates that virtual avatars are suitable tools for testing synchronisation. Soczawa-Stroncyzyk and Bocian (2020) further examined gait synchronisation with avatars by looking at the differences in accuracy when following a real person and a virtual avatar side-by-side or front-to-back. They reported that, within significance, the gait synchronisation accuracies are the same when walking front-to-back with an avatar, compared to a real person. Both studies provide compelling evidence for the ecological validity of virtual reality.

Behaviours in the real world similarly translate to virtual environments, indicating that virtual reality shows promise as a methodological tool. However, there are discrepancies in virtual reality that puts its generalizability in question. Distance perception is typically modified in virtual environments such that the distance to an object seems smaller than it is. The perceived distance between an observer and an external point is reduced to 73% of its actual value in virtual environments (Renner et al., 2013); a possible implication of this illusion is inconsistent gait timing in virtual reality, compared to real-life avatars. Additionally, there are signs illustrating that virtual reality avatars are treated analogously to objects, rather than people. Hackney et al. (2020) observed that individuals contort themselves more to avoid bumping into people, compared to objects. However, in situations where avoiding the participant is required, virtual avatars are treated in the same manner as objects (Hackney et al., 2020). Avatars lack the social cues seen in humans such as personal space boundaries; this absence could have made participants more aware of the avatar's synthetic nature, thereby reducing how cautious participants were about avoiding them (Hackney et al., 2020). Similarly, if humans perceive avatars as objects, humans may lack empathy for avatars, which could reduce participants' ability to synchronise with avatars, compared to people This suggestion is backed up by evidence (Novembre et al., 2019) through which the author concludes that empathising with people promotes interpersonal synchronisation.

To further add to potential issues with VR research, Soczawa-Stroncyzyk and Bocian (2020) only compared participants' synchronisation at one speed. Although participants' gait synchronisation accuracy was not significantly different when following the real person or the avatar, on average, people tended to lag behind the real person's timing, while anticipating the timing of the virtual avatar. The authors theorised that the effect occurred either because the avatar's motions were too repetitive, and therefore predictable, or because their periphery in virtual reality was obstructed, allowing participants to focus on the avatar's movements more. It is possible that this effect would be more pronounced at different walking speeds, which could lead to significant differences between the virtual and real-life conditions. These findings oppose the support for the ecological validity of virtual reality. Therefore, gait synchronisation with virtual avatars must be further investigated to come to a concrete conclusion about its generalizability.

To consider the ecological validity of VR in gait research and to confirm previous literature concerning gait synchronisation, this experimental study aims to answer the question of whether people synchronise their gait differently with a VR avatar than with a real person. The study looks at the difference in the accuracy of individuals trying to synchronize with the gait of an avatar or a real person. It builds off the Soczawa-Stroncyzyk and Bocian (2020) experiment by checking whether changing the target speed affects the differences in accuracy. It was hypothesised that no significant effect will be found between the virtual and real-life conditions at any speed. If the data confirmed this hypothesis, then it would corroborate the Soczawa-Stroncyzyk and Bocian (2020) results, and the use of virtual reality avatars would be validated for future gait synchronisation studies. The individual's empathy towards the avatar and the real person will also be assessed to test for a correlational link between empathy and accuracy in synchronisation. Under the theoretical framework initiated by Tzanki (2022), it is predicted that lower levels of empathy will correlate to lower levels of accuracy in synchronisation.

Method

Participants

Participants (n = 8, 4 male, mean age = 19.14 ± 1.07) were recruited from the SONA database and compensated 1.5 participation credits in their introductory psychology course for their participation. Participants were fluent in English, had no neurological disorders, had normal or corrected-to-normal vision, had no hearing impairments, and were able to walk unassisted for 30 minutes. Participants with incomplete data or that the leader's cadence did not match the metronome's temp were excluded from analysis. The experiment was approved by the Health Science Research Ethics Board at Western. Participants provided written consent before commencing the experiment.

Stimuli

Participants walked on a pressure-sensing *Zeno™ Walkway* from ProtoKinetics, and their stride length, stride velocity and cadence were measured using the *ProtoKinetics Movement Analysis Software*. The walkway was sixteen feet in length and three feet wide.

The *BiomotionLab Toolkit for Unity Experiments (bmlTUX)* program created by Bebko and Troje (2020) was used to create the virtual environment and the avatar, as well as to control the walking speed of the avatar. *Oculus Quest 2*, a virtual headset developed by Meta Platforms, was used to place the participant in the virtual environment for the VR trials. For the real-world trials, a metronome was used to provide the pace for the lead walker; the leader walked in time with the tempo of the metronome. The leader was given Bluetooth headphones to hear the metronome. Metronome cues during walking trials were either five percent faster or slower than participants' baseline walking speed in the virtual environment.

Procedure

Habituation and Baseline Gait

Participants completed two baseline walking trials in the virtual and real environments. To get adjusted to the environments, participants completed two loops of the walking path before their baseline measurements were taken. To obtain these baseline measurements, participants walked the length of the gait mat at a comfortable speed for four loops. These baseline measurements were taken so that the shifts in speed could be tailored to the specific participant. These shifts in the speeds were at a 5% rate change from the baseline speeds so the participant would have to actively change their walking speed or stride length to synchronise with the leader's gait (Leow et al., 2018, 2021). A baseline walk in both environments was performed both before and in between conditions. One last baseline walk was performed after but in the same environment as the final walking trial.

Walking Trials

After the first two baseline measurements are taken, participants completed twenty-four walking trials. For the first twelve walking trials, participants were told to walk behind and follow the leader without further instructions regarding synchronising their steps to the leader; these trials are referred to from here on out as the no instructions condition. The leader in the real-life condition was a person that was trained to walk on the pressure sensor walkway identically to the virtual avatar. The real person's pace was dictated using a metronome; the person listened to and walked in time with the pulse of the metronome. The leader wore Bluetooth headphones, as to prevent the metronome from being an auditory cue with which the participant could synchronise their gait. The avatar's velocity was controlled with the bmlTUX program by changing the avatar's cadence and stride velocity. Within the no instructions condition, participants walked in both the virtual and real environments at a fast pace or a slow pace. The fast pace was operationalised as a five per cent increase from their baseline speed, and a slow pace was operationalised as a five per cent decrease from their baseline speed. For the remaining twelve trials, participants were instructed to synchronise the timing of their footsteps and walking speed with the leading person/avatar. These trials from here on out are referred to as the instructions condition. The order of the trials mirrored that of the no instructions condition. Each trial was performed three times, where each trial was composed of four loops of the pressure sensor walkway. Within each condition, the order in which individuals walked in the virtual or real environment was counterbalanced, and the order of the speeds within an environment was randomised. This experimental design is illustrated in Figure 1.

Leow et al. (2018) observed in their study that the spontaneous gait synchronisation to the beat of music is almost non-existent without explicit instructions to synchronise. However, participants in the Leow et al. (2018) study did not display a high level of synchronisation even when they were instructed to synchronise to the beat. Therefore, the instructions condition acted as a sanity check to ensure that participants had the capability to synchronise to both the avatar and real person. In line with Leow et al. (2018), it was predicted that levels of synchronisation would be higher in the instructions condition, compared to the no instructions condition. Between the no instructions condition and the instructions condition, participants were given a seven-minute break from walking to prevent fatigue from affecting their ability to synchronise in the instructions condition.

Additional Measures

During the break between the no instructions condition and the instructions condition, participants completed two tasks. The first task was the production section of the Beat Alignment Test (BAT) created by Iversen and Patel (2008). This subtest evaluated participants' ability to produce the beat of songs in synchronization with the music to help identify if trends exist because of the variables manipulated for the experiment, or if the innate ability of participants to synchronise is a confound. Participants then completed the Toronto Empathy Questionnaire (TEQ) developed by Spreng et al. (2009) to assess their general level of empathy. At the end of the experiment, participants were assessed for their musical and dancing experience.

Statistical Analysis

Each participant had individual differences in their physical features that impact gait (e.g., height would affect stride length); to account for these differences, the gait analyses were normalised. The following formula obtained from Ready et al. (2019) was used to normalise the gait analyses:

$$\text{Normalized Change Score} = \frac{\text{cued gait parameter} - \text{baseline gait parameter}}{\text{baseline gait parameter}}$$

These scores were then analyzed using in a three-way repeated measures analysis of variance (ANOVA) looking at the condition (no instructions, instructions), environment (virtual reality, real world), and speed (fast, slow). Interactions significant at the $\alpha = 0.05$ level were further analyzed with a Bonferroni test. As it is imperative that the real person mimics the avatar's gait characteristics (cadence, stride length, stride velocity), the synchrony of the real person's stride velocity to that of the avatar's was verified. The person's stride velocity across all trials was normalised to the target speed, and then averaged for each participant. From there, the averaged normalised stride velocities were standardised. Trials that deviated beyond $\alpha = 0.05$ level were seen as outliers and excluded from further analysis.

Results

Stride Velocity Synchronisation

To quantify synchrony of participants across conditions, their raw data for stride velocity was normalized as a percentage from their baseline walk. Next, five percentage points (*pp*) were added or subtracted from all fast or slow trials, respectively. This data was analyzed with a 2 (no instructions, instructions) × 2 (virtual reality, real world) × 2 (fast, slow) repeated measures ANOVA (see Table 1 for full details). A main effect was seen for condition ($F(1,6) = 20.55$, $p = .004$, $\eta_p^2 = .77$), environment ($F(1,6) = 17.79$, $p = .006$, $\eta_p^2 = .75$) and speed ($F(1,6) = 146.99$, $p < .001$, $\eta_p^2 = .96$). Participants displayed more asynchrony in the no instructions condition, compared to the instructions condition ($pp = 4.37$, $t(6) = 4.53$, $p_{bonf} = .004$), in the real environment, compared to the virtual environment ($pp = 3.09$, $t(6) = 4.22$, $p_{bonf} = .006$), and in the slow trials, compared to the fast trials ($pp = 7.21$, $t(6) = 12.12$, $p_{bonf} < .001$). Further interactions were found in condition and environment ($F(1,6) = 14.41$, $p = .009$, $\eta_p^2 = .71$), condition and speed ($F(1,6) = 138.06$, $p < .001$, $\eta_p^2 = .96$), and environment and speed ($F(1,6) = 15.68$, $p = .007$, $\eta_p^2 = .72$). When not instructed to synchronize, participants displayed higher asynchrony when walking within the real environment, compared to the virtual environment ($pp = 4.82$, $t(6) = 5.59$, $p_{bonf} = .001$). Additionally, when given no instructions on synchronization, participants synchronised more in the fast trials, compared to the slow trials ($pp = 12.22$, $t(6) = 16.7$, $p_{bonf} <.001$). For fast trials, participants showed more asynchrony in the real environment than the virtual environment and their stride velocity tended to lag behind the avatar's but was faster than that of the real person (*pp* = 5.86, $t(6) = 5.78$, $p_{bonf} < .001$).

TEQ and BAT

Participants completed the TEQ (*M* = 48.71, *Median* = 51, *SD* = 3.73, *Range* = 10) and the BAT (mean asynchrony = .18, *CoV* = .13). TEQ scores had a significant, negative correlation with participants asynchrony of stride velocity across all trials ($r_s(12) = -.85$, $p = .015$). No significant correlation was determined between BAT scores and stride velocity asynchrony ($r_s = -.37$, $p = .497$) or between BAT and TEQ scores ($r_s = .52$, $p = .288$).

Baselines

A 1×5 repeated-measures ANOVA was conducted to examine the effect of time on participants' cadence across the baselines. The assumption of sphericity was violated, as determined by Mauchly's test of sphericity ($\chi^2(9) = 36.89$, $p < .001$). Therefore, the Greenhouse-Geisser correction was applied to adjust for violations of sphericity. The results demonstrated that baseline cadence did not change over time within significance, $F(\varepsilon(2.36, 9.44)) = 2.71$, $p = .113$, $\eta_p^2 = .40$, $\varepsilon = .59$. Additionally, cadence was not significantly different between environments for the first baseline ($t(7) = .45$, $p = .665$) nor the second baseline ($t(7) = 1.17$, $p = .282$). This finding justifies using only the baseline cadence from the virtual environment.

Cadence

A 2×2×2 repeated measures ANOVA (see Table 2 for full statistical details) revealed a main effect of speed ($F(1, 6) = 43.83$, $p < .001$, $\eta_p^2 = .88$). Further analysis revealed a *pp* increase of 5.04 in fast trials, compared to slow trials, $t(6) = 6.62$, $p_{bonf} < .001$. No main effect of environment was found, $F(1, 6) = .002$, $p = .966$, $\eta_p^2 = 3.38 \times 10^{-4}$. An interaction between environment and speed occurred ($F(1, 6) = 7.29$, $p = .036$, $\eta_p^2 = .55$). The disparity in participants' cadence between fast and slow speeds was greater in the real environment (*pp* = 6.85, $t(6) = 6.75$, $p_{bonf} < .001$) than in the virtual environment (*pp* = 3.23, $t(6) = 3.18$, $p_{bonf} = .048$). This disparity was further made larger between conditions ($F(1, 6) = 9.75$, $p = .021$, $\eta_p^2 = .62$); the instructions condition saw a significant increase in the cadence difference for fast and slow trials within the real environment (*pp* = 9.87, $t(6) = 6.93$, $p_{bonf} < .001$), as opposed to the virtual environment (*pp* = 2.52, $t(6) = 1.77$, $p_{bonf} < 1.000$). Cadence values are illustrated in Figure 2.

Stride Length

A 2×2×2 repeated measures ANOVA (see Table 3 for full details) revealed a main effect of speed, $F(1,6) = 20.66$, $p = .004$, $\eta_p^2 = .78$. Participants portrayed larger stride lengths in the fast, compared to the slow trials, *pp* = 2.89, $t(6) = 4.54$, $p_{bonf} = .004$. No main effect of environment was found, $F(1, 6) = 1.87$, $p = .221$, $\eta_p^2 = .24$. Stride length values are illustrated in Figure 3.

Stride Velocity

A 2×2×2 repeated measures ANOVA (see Table 4 for full details) revealed a main effect of condition ($F(1,6) = 12.35$, $p = .013$, $\eta_p^2 = .67$) and speed ($F(1,6) = 81.57$, p < .001, $\eta_p^2 = .93$). Participants walked faster in the instructions condition, compared to the no instructions condition (*pp* = 2.79, $t(6) = 2.93$, $p_{bonf} = .013$), and at fast trials, compared to the slow trials (*pp* = 8.05; $t(6) = 9.03$, $p_{bonf} < .001$). No main effect of environment was found, $F(1, 6) = 1.46$, $p = .272$, $\eta_p^2 = .20$. However, an interaction between environment and speed was noticed, $F(1,6) = 6.97$, $p = .039$, $\eta_p^2 = .54$. Further analysis revealed a larger disparity in stride velocity occurred between walking in the real environment in fast trials versus slow trials in the virtual environment (*pp* = 9.28, $t(6) = 6.86$, $p_{bonf} < .001$) compared to walking in slow trials within the real environment (*pp*

= 9.11, $t(6) = 9.32$, $p_{bonf} < .001$). Additionally, a larger disparity in stride velocity occurred between walking in the virtual environment in fast trials versus slow trials in the virtual environment (*pp* = 6.99, $t(6) = 7.15$, $p_{bonf} < .001$) compared to walking in slow trials within the real environment (*pp* = 6.82, $t(6) = 5.05$, $p_{bonf} = .002$). Furthermore, the velocity difference of the fast and slow trials within the real environment (*pp* = 9.11, $t(6) = 9.32$, $p_{bonf} < .001$) was larger than the velocity difference within the virtual environment (*pp* = 6.99, $t(6) = 7.15$, $p_{bonf} < .001$). Stride velocity values are illustrated in Figure 4.

Discussion

In real life, when we walk with others, we tend to synchronise our gait spontaneously (Felsberg & Rhea, 2021). Many social factors influence how we walk, however, and so to study this phenomenon, studies have utilised virtual avatars as controllable leaders. The ecological validity of using avatars, rather than humans to cue synchronisation is largely unexplored; therefore, this study aimed to verify the validity of using virtual avatars in gait synchronisation studies. Gait characteristics (cadence, stride length, stride velocity) of people walking behind a real person versus an avatar at different speeds and instructions were analyzed for differences.

Each parameter studied had a significantly larger value at faster speeds. Stride velocity saw an expected difference in stride velocities between fast and slow trials, despite no instructions to synchronise. An additional difference in participants' stride velocity was seen when people were told to synchronise. These findings confirm that when walking with others, one's stride velocity is influenced by others' gait, even though it may not be to the point of perfect synchronisation. In line with the results from Soczawa-Stroncyzyk and Bocian (2020), no significant differences between trials were due to only the environment. Unlike in this experiment, Soczawa-Stroncyzyk and Bocian (2020) did not explore the role of different speeds in influencing others' gait. A significant interaction between the environment and the speed of the leader was seen. When walking with a real person, the difference in participants' cadences and stride velocities was more drastic between the fast and slow trials, compared to when walking with the avatar. This finding indicates that people are more heavily influenced by a real person to walk faster or slower than they are with an avatar.

A secondary aim of this study was to determine a correlational link between empathy and synchrony; a positive correlation between the two attributes was predicted. Empathy was found to be strongly and negatively correlated with asynchrony, which is consistent with the framework proposed by Tzanki (2022) showing that empathy plays a role in interpersonal synchrony.

This study is not without its limitations. The sample size for this study was low, so the statistical power for this experiment is not high enough to make conclusive claims about the validity of virtual avatars. Further data collection will take place to address this issue. Additionally, even when stride velocity and stride length matched that of the participants, the cadence of the virtual avatar was not able to match that. This prevents conclusions about the spontaneous synchronisation of cadence, as the changes in cadence among different speeds cannot be quantified. Furthermore, when the avatar would turn corners, it would travel at the same speed; however, people tend to slow down around corners. Although the leader was trained to not slow down, the corner was taken off the bounds of the pressure-sensor gait mat, and therefore whether the leader did not slow down on the corner cannot be quantified. Therefore, it is unknown if and how this uncertainty impacted how people walked.

Overall, these findings support the idea of using virtual avatars for studies, but further research is required to fully comprehend the differences between using virtual avatars and humans. Despite these limitations, this study nonetheless sheds light on the external validity of using avatars as leaders for gait synchronisation studies and corroborates previous literature.

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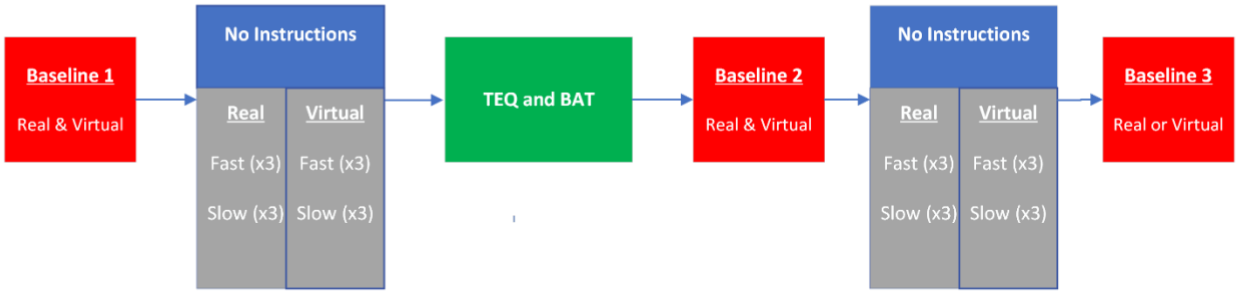
Figure 1

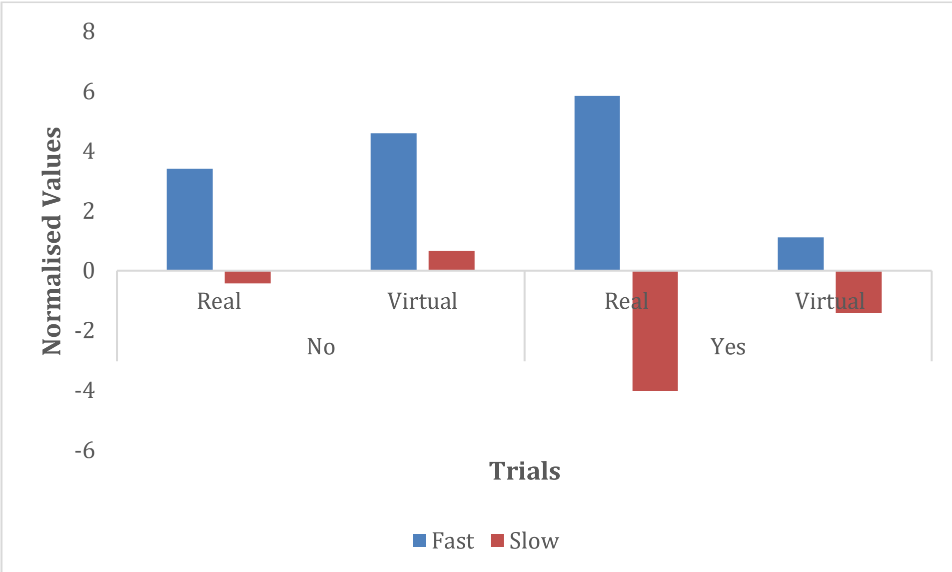
Experimental Order of Trials



Note. The order of the environments was counterbalanced both between-subjects and within-subjects. The order of speed trials was randomised between-subjects and constant within subjects.

Figure 2

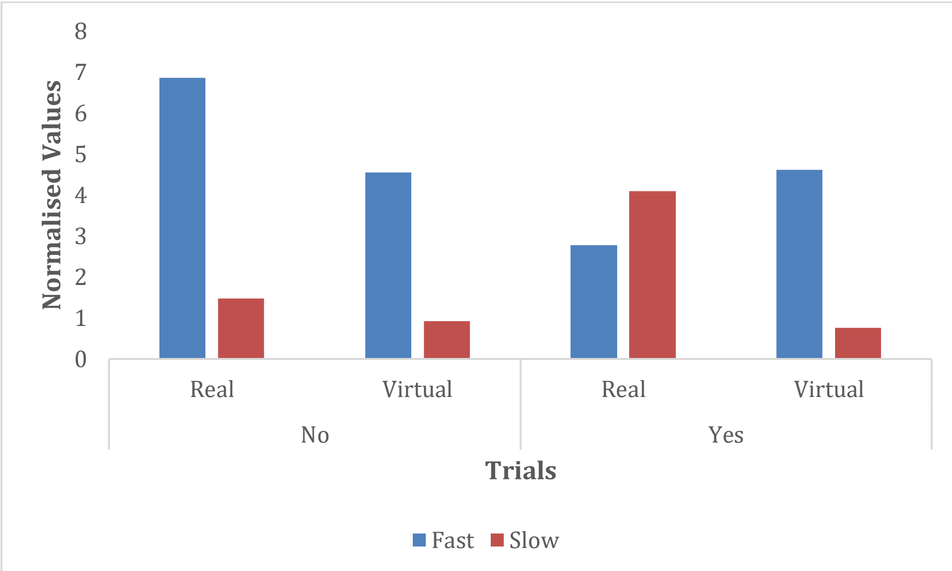
Normalised Cadence Values



Note. Normalised cadence values across trials.

Figure 3

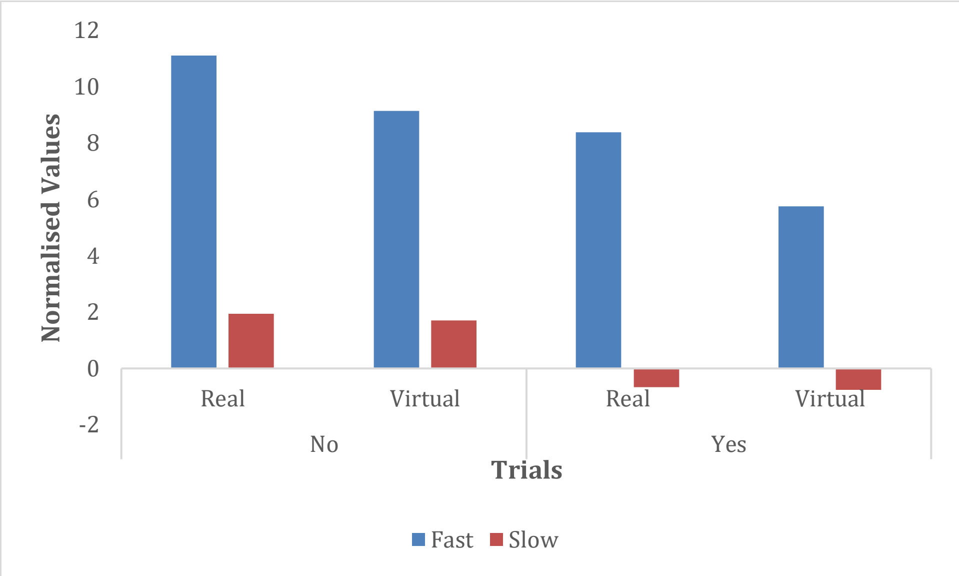
Normalised Stride Length Values



Note. Normalised cadence values across trials.

Figure 4

Normalised Stride Velocity Values



Note. Normalised cadence values across trials

Table 1

Results from Condition × Environment × Speed ANOVA on Stride Velocity Asynchrony

Independent Variable	$F_{1, 6}$	p	η_p^2
Condition	**20.55**	**.004**	**.77**
Environment	**17.79**	**.006**	**.75**
Speed	**146.99**	**< .001**	**.96**
Condition × Environment	**14.41**	**.009**	**.71**
Condition × Speed	**138.06**	**< .001**	**.96**
Environment × Speed	**15.68**	**.007**	**.72**
Condition × Environment × Speed	5.57	.056	.48

Note. Statistically significant values ($p < 0.05$) are shown in bold font.

Table 2

Results from Condition × Environment × Speed ANOVA on Cadence

Independent Variable	$F_{1, 6}$	p	η_p^2
Condition	.35	.574	.06
Environment	.002	0.966	3.38×10^{-4}
Speed	**43.83**	**< .001**	**.88**
Condition × Environment	1.31	.295	.18
Condition × Speed	2.08	.199	.26
Environment × Speed	**7.29**	**.036**	**.55**
Condition × Environment × Speed	**9.75**	**.021**	**.62**

Note. Statistically significant values are shown in bold font.

Table 3

Results from Condition × Environment × Speed ANOVA on Stride Length

Independent Variable	$F_{1, 6}$	p	η_p^2
Condition	.02	.887	.004
Environment	1.87	.221	.24
Speed	**20.66**	**.004**	**.78**
Condition × Environment	.06	.810	.01
Condition × Speed	4.13	.088	.41
Environment × Speed	1.23	.310	.17
Condition × Environment × Speed	3.19	.124	.35

Note. Statistically significant values are shown in bold font.

Table 4

Results from Condition × Environment × Speed ANOVA on Stride Velocity

Independent Variable	$F_{1, 6}$	p	η_p^2
Condition	**12.35**	**.013**	**.67**
Environment	1.46	.272	.20
Speed	**81.57**	**< .001**	**.93**
Condition × Environment	.06	.809	.01
Condition × Speed	.29	.608	.05
Environment × Speed	**6.97**	**.039**	**.54**
Condition × Environment × Speed	.12	.741	.02

Note. Statistically significant values are shown in bold font.