Do attentional focus and partner gaze impact interpersonal coordination?

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Abstract

As a foundation for social interaction, interpersonal coordination is facilitated by positive social qualities (e.g., cooperation), but undermined in negative contexts (e.g., conflict). Exactly how social factors shape coordination is less clear. Previous literature notes that the way people attend to others impacts how interactions unfold. It is possible therefore, that patterns of social attention also govern coordination. We examined this proposition by using virtual reality to investigate how attentional focus (self vs. other) and partner gaze (direct vs. averted) influence the spontaneous emergence of coordination. The results indicated that: (i) coordination was enhanced in the other (cf. self) focus condition; (ii) coordination was diminished in the averted (cf. direct) gaze condition. These findings suggest that changes in social attention impact interpersonal coordination. More broadly, this work provides further evidence that the emergence of interpersonal coordination fluctuates as a function of social context.

Keywords: interpersonal coordination; gaze behaviour; social attention; virtual reality

Introduction

The dynamics of social interaction are tightly intertwined with how people attend to each other (Capozzi & Kingstone, 2023). A prolonged stare, or furtive glance, invite diverse interaction opportunities, affiliative and otherwise (Argyle & Cook, 1976). Chief among the social corollaries of attention is interpersonal coordination (Tognoli et al., 2020). As a foundation for social exchange, coordinating actions with others boosts prosocial behaviour and affiliation (Mogan et al., 2017; Rennung & Göritz, 2016). By contrast, contexts in which effective social connection is challenging are accompanied by marked reductions in coordination (e.g., conflict, Paxton & Dale, 2013; psychopathology, Macpherson et al., 2020) and associated interpersonal benefits. What is not known, however, is specifically *how* variation in social circumstances shapes the emergence of interpersonal coordination. Here we raise a novel proposition: social factors shape coordination through changes in how people attend to others.

Attention and Coordination

The notion that social attention shapes coordination dynamics is consistent with contemporary research. Guiding this work is an influential model of motor control, the Haken-Kelso-Bunz (HKB) equation (Haken et al., 1985). Having seen wide application as a framework for studying coordination in biological systems (Kelso, 1995; Schmidt & Richardson, 2008), the HKB equation specifies two key parameters, frequency matching and coupling strength, that govern the emergence of coordination. System components will coordinate to the extent that they are: i) moving at sufficiently similar rates and ii) are coupled – that is, there is potential for transfer of information between the components. Of note, such coupling can be attentional whereby a perceptual link between components[1] is sufficient to drive the emergence of spontaneous coordination (Cummins, 2009; Meschner et al., 2001; Schmidt et al., 1990). In this way, the HKB model indicates that factors that serve to strengthen, or weaken, the attentional coupling shape the stability of coordination.

Evidence for the link between attention and coordination is compelling (Repp & Su, 2013). A broad literature has documented systematic effects of variation in stimulus properties (e.g., amplitude, modality, velocity; Hajnal et al., 2009; Snapp-Childs et al., 2011; Varlet et al., 2012; Whitton & Jiang, 2023) and perceptual strategies (e.g., anchoring, gaze location, object tracking; Richardson et al., 2007; Roerdink et al., 2008; Schmidt et al., 2007) on coordinated behaviour. A key theme to emerge from this work is that actions which serve to amplify the information required to successfully coordinate (e.g., motion of the target), enhance coordination. Making such information available for perception strengthens coupling and bolsters coordination, providing robust empirical support for a key prediction of the HKB model. Given shifts in attention modulate coordination, it is feasible that the social factors that shape interpersonal coordination do so by driving shifts in attentional behaviour.

Empirical work exploring the link between attention and *interpersonal* coordination also provides robust evidence that the strength of the informational coupling between people supports the emergence of coordinated behaviour (Schmidt & Richardson, 2008). Everyday actions, such as looking toward (or away from) others strengthens (or weakens) coupling and resultant coordination (Richardson et al., 2007; Schmidt & O'Brien, 1997). On this basis it is viable that disruptions to coordination that accompany, for instance, argument (Paxton & Dale, 2013), norm violation (Miles et al., 2011), or impaired interpersonal functioning (Macpherson & Miles, 2023), result from individuals attentionally decoupling from others (e.g., by looking away or focusing attention inwardly) who are seen as quarrelsome,

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[1] Attentional coupling can be made to extrapersonal (e.g., entrainment to an external rhythm), intrapersonal (e.g., bimanual coordination), or interpersonal (e.g., interpersonal coordination) sources of information.

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rude, or threatening. However, the evidence for this conjecture is scant. Coordination research that has considered social factors has not typically manipulated or measured attentional behaviour, while work focused on attentional coupling has rarely done so outside of minimally social contexts. Evidence that interpersonal coordination is shaped by socially relevant changes to attentional behaviour is therefore needed in order to extend the extant literature.

Attention and Coordination in Social Contexts

Evaluating attention-coordination links during real-time social exchange is challenging. In everyday social encounters, attentional patterns are diverse and nuanced, serving numerous functions. Gaze patterns, for instance, serve dual perceptual (e.g., information gathering; Lev-Ari et al., 2022) and communicative (e.g., social signalling; Argyle & Cook, 1976) roles that guide key interpersonal processes and provide an avenue for information exchange (Gobel et al., 2015). Similarly, head movements orient perceivers towards salient information *and* provide important nonverbal cues to others (Hietanen, 1999; Langton et al., 2000; Livingstone & Palmer, 2016). To further complicate matters, attention may also be decoupled from the here-and-now and directed towards inner mental experience (e.g., mind wandering; Smallwood & Schooler, 2006). In this case, gaze direction loses utility as a means to understand the attentional focus or behavioural intentions of the individual. As such, isolating social attention to consider only a single aspect is unlikely to reflect naturalistic interpersonal exchange (Brunswik, 1956).

Consideration of the dual function of gaze in interpersonal coordination research has been limited. With respect to the perceptual (i.e., information gathering) role, it is clear that deliberately focusing gaze on, or away from, an interaction partner results in corresponding changes in coupling strength (e.g., Richardson et al., 2007). What researchers are less sure about is how the communicative functions of gaze direction impact interpersonal coordination. The gaze of others can have powerful influence, not only by capturing and directing an observer's attention but also as a social signal which, at its most basic level, specifies affiliative intent (Argyle & Cook, 1976). Direct gaze typically encourages approach and social engagement, while averted gaze signals disinterest and can lead to withdrawal (Capellini et al., 2019; Cui et al., 2019) – actions that may strengthen or weaken coordination. Indeed, preliminary evidence suggests this is the case. Macpherson et al. (2023) demonstrated a link between averted partner gaze (cf. direct gaze) and decreases in coordination using virtual reality (VR). Adopting the same methodology, the current research investigates the effects of attentional focus (self vs. other) and partner gaze (direct vs. averted) on the spontaneous emergence of interpersonal coordination.

The Current Research

The current study explored whether patterns of social attention modulate coordination dynamics. We used virtual reality (VR) to evaluate whether two core characteristics of attentional behaviour - focus and gaze – impact interpersonal coordination. To enhance naturalistic social exchange, the procedure feigned a real-time social interaction with a human-controlled avatar (i.e., another participant). In reality, the avatar was pre-programmed.

Employing VR affords the key advantages of precise control (e.g., when manipulating avatar gaze) and unobtrusive motion-tracking (e.g., for quantifying coordination), while preserving essential features of social interaction (Zhao et al., 2015). Here, we focus on coordination of two specific behaviours. First, following previous research we instructed participants to perform arm curls (e.g., Lumsden et al., 2014), and programmed the avatar to do the same (Macpherson et al., 2023). Second, taking a more exploratory stance we captured participants' spontaneous (i.e., uninstructed) head movements, patterns of which index key attentional and social factors (Foulsham, et al., 2019). For each target behaviour we estimated the extent to which participants coordinated with the avatar. Finally, via inbuilt eye-tracking we also captured participant gaze patterns during each interaction.[2]

In the context of a virtual social encounter, we instructed participants to direct their attention externally toward their interaction partner (other focus condition), or internally towards themselves (self focus condition). We also manipulated the attentional patterns of the interaction partner whereby the participant was either the focus of their attention (direct gaze condition) or not looked at (averted gaze condition).

Hypotheses

For the instructed arm movements, we expect:

H1. Lower levels of coordination when individuals are asked to focus on themselves versus the other person.

H2. Higher levels of coordination when the avatar looks directly at the participant (cf. looks away).

H3. Higher levels of coordination in direct gaze (cf. averted gaze), predominantly where participants are instructed to focus on the other person.

For the uninstructed head movements, we take an exploratory stance, but expect to replicate the hypotheses above (**EH1-EH3**).

Further, for participant gaze, we expect:

H4. More time spent looking at or near the avatar will improve coordination, for both arm and head movements.

H5. More time spent looking around the room will reduce coordination, for both arm and head movements.

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[2] We included this measure as an indication of spontaneous participant attentional patterns. However, given attention can be decoupled from looking direction, we acknowledge that conclusions drawn must be tentative given our focus instruction manipulation.

Method

Participants and Design

One hundred and sixty-four participants took part in the experiment. Ninety-five were recruited from an undergraduate participant pool and took part in exchange for course credit. The remaining 69 participants were recruited from a community sample and received a small monetary reimbursement. Only individuals aged 18 and over with no injury or impairment that impacted their movements were eligible to take part. Data from 14 participants were excluded due to: technical error (*n* = 3), failure to follow task instructions (*n* = 2) or failure to believe the cover story (*n* = 9). This resulted in a final sample size of 150 participants (female = 96, male = 51, non-binary = 3; aged 18-53 years, *M* = 22.9 years, *SD* = 7.1 years). The experiment employed a 2 (focus instruction: self vs. other) x 2 (avatar gaze: direct vs. averted) mixed design with repeated measures on the first factor. Avatar gaze condition was randomly assigned. The research was reviewed and approved by the Human Research Ethics Committee at the University of Western Australia.

Procedure and Materials

Participants were recruited to a study examining how people attend to others in virtual reality (VR). They were told it involved interacting with another person, first in VR (represented as avatars) and then face-to-face. Upon arrival, participants were informed that the other person was completing the first part of the study in a nearby laboratory. In reality, there was no other person and therefore no face-to-face interaction. The cover story was included to give participants the belief they were engaging in a genuine social interaction (see Lumsden et al., 2012; Macpherson et al., 2023; Miles et al., 2011 for a similar procedure).

After providing consent, participants reported their age and gender in a free response format.[3] At this point, in order to enhance the believability of the cover story, the experimenter left the room to allegedly 'check on the other participant', returning a brief time later. Participants were then introduced to the VR system (Vive Pro Eye, HTC Corporation, Taiwan) and VR environment created using the Unity 3D Game Engine (v2018.4.8f1). To view the VR environment, participants were fitted with a head mounted display (HMD) equipped with dual OLED 3.5" screens (1440 x 1600 pixels per eye, 110° x 106° field of view) and on-board eye tracking. Eye tracking allowed estimates of the time participants spent looking at three pre-defined areas of interest (AOI): the avatar, near the avatar and the rest of the room (Figure 1). To track participants' arm movements, they were given two handheld controllers (Vive Pro, 2018). These recorded movement in 3 dimensions at a sampling rate of 50Hz. In the VR environment, the controllers were represented as hands.

Once in VR, participants completed a 5-point eye tracking calibration using the Super Reality (SR) runtime. They then completed a practice movement trial. Here, participants were placed in a generic grey environment, and instructed to perform arm curls (flexion-extension about the elbow) in time with a metronome (84 bpm) played through the HMD headphones. Participants moved in time with the metronome for 10 beats (approximately 7s) after which they performed the arm curls without the accompanying metronome for a further 45s. The practice trial was intended to familiarise the participant with the form and frequency of the movement required, as well as to give the experimenter an opportunity to make corrections if necessary (e.g., due to incorrect range of motion). Next, participants were placed in a VR room designed to closely resemble a standard research laboratory (5.34m x 4.34m), where task instructions presented visually in the HMD informed them to "wait for the other participant to connect".

During the short waiting period, participants were informed they would be completing two further VR arm curl trials and both themselves and the other person would be represented as avatars. They were instructed to perform the same movement at the same tempo as they did during the practice trial. Instructions for the focus manipulation (self vs. other) were presented before the commencement of each trial via the HMD headphones. The instructions were adapted from McManus et al. (2008) and directed participants to focus on themselves [the other person] throughout the interaction by attending to their own [the other person's] actions and monitoring how they [the other person] were coming across. Participants were reminded they would meet the other person in the next stage of the study. The order of instructions was counterbalanced across participants.

Participants interacted with an avatar that either looked directly at them (direct gaze condition, *n* = 79) or away from them (averted gaze condition, *n* = 71) for the duration of each trial. In the direct gaze condition, the avatar was programmed to maintain eye contact with the participant while performing arm curls, whereas in the averted gaze condition the avatar avoided eye contact, instead looking around the virtual laboratory. The avatar was created using Adobe Fuse CC (v 2017.1.0b) and rigged for movement using Adobe Mixamo (www.mixamo.com). The avatar was designed to resemble a typical university student in Australia (i.e., female, aged approximately 20-25 years, 1.64m tall, casual clothing) and animated using arm curl movements performed by an experimenter of similar stature and captured using a Rokoko Smartsuit Pro and Rokoko Studio (Rokoko, Copenhagen, Denmark). For the direct gaze condition, the pre-recorded head movements were overridden using the animator

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[3] As part of a separate project, participants also completed the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987) and the Social Behaviour Questionnaire (SBQ; Clark, 2005). These data are not reported here.

controller in Unity3D, such that the head of the avatar followed the participant's position. Each trial lasted for 45s.[4]

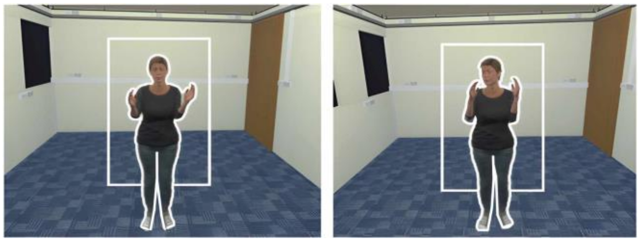

Figure 1: Participant's view of the direct (left panel) versus averted (right panel) avatar gaze during the interactive trials. The white outlines represent the AOIs (i.e., avatar, near avatar, around the room) used to categorise the participant gaze data.

After completing both trials participants were funnel debriefed to ascertain any suspicions they held regarding the cover story. Those who indicated that they did not believe the cover story (n = 9) were excluded from the analyses. Participants were then debriefed as to the true purpose of the experiment and dismissed. Each testing session took no longer than 30 minutes.

Data Reduction and Analysis

Consistent with previous work (e.g., Macpherson et al., 2020; Varlet et al., 2014), to prepare the data for analysis, the first 5 s of each trial was discarded to avoid analysing any transient movement that may have occurred during the initiation of the arm curls. The remainder of the trial was then standardised to a length of 40s. Next, each time series was centred around 0 and low pass filtered using a Butterworth filter with a 10Hz cut-off.

To estimate coordination between participant and avatar arm movements, we calculated the relative phase relationship between the right arm of the participant and the left arm of the avatar,[5] using a Hilbert transform. The resulting values were normalised to a range of 0° - 180° and the circular variance of the distribution of relative phase (rho) was then calculated for each trial separately and standardised using a Fisher transformation. Rho provides a linear index of coordination stability whereby higher numbers represent more stable coordination.

Cross-recurrence quantification analysis (CRQA) was used to estimate coordination between participant and avatar head movements. Estimation of the delay, embedding dimension, and radius parameters was performed using standard protocols (see Coey et al., 2014). The delay value was selected using the first minimum of the average mutual information of the avatar time series. The number of embedding dimensions was selected using the first minimum in a false nearest neighbour analysis. This resulted in a delay of 27 and an embedding dimension of 6. The radius was set to 10. As per previous literature (e.g., Macpherson & Miles, 2023; Romero et al., 2016), we then selected %REC as the outcome variable in our statistical analyses. Here, more stable coordination dynamics are indicated by higher values.

To address the hypothesised effects, we conducted a series of mixed effects models (MEMS) using the lme4 (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017) packages in R (v 4.3.0; R Core Team, 2019). For each model, coding for factorial variables was as follows: focus instruction [1 = self, 2 = other], avatar gaze [1 = direct, 2 = averted] and all continuous predictor variables were centred prior to inclusion. Degrees of freedom and p-values were estimated using Satterthwaite approximations. The random effects structure for each model comprised a by-participant random intercept as this was the maximal model that would converge. Interaction effects were decomposed by estimating Tukey-corrected post-hoc comparisons using the emmeans package (Lenth, 2021). After examining model fit, some of the models did not have normally distributed residuals. When this occurred, the relevant outcome variable was log-transformed.

For H1-H3 and EH1-EH3, the models examined the influence of avatar gaze (direct vs. averted) and focus instruction (self vs. other), on each coordination metric (arm movements: rho; head movements: %REC). For H4-H5, the percentage of time participants spent looking at each AOI (avatar, near avatar, room) was added separately as additional fixed effects.[6]

Results

Arm Movement Coordination (H1-H3)

We first examined the effects of the manipulated variables on the coordination (i.e., rho) of arm movements between the participant and the avatar (Figure 2). There was no main effect of focus instruction – coordination did not differ between the self and other-focus conditions, such that we found no support for **H1** (p = .52). We did however reveal a main effect of avatar gaze. In support of **H2,** arm movements were more coordinated when the avatar looked directly at the participant, than when gaze was averted (b = -0.38, SE = 0.11, t = -3.56, p < .001). There was no interaction between attention instruction and avatar gaze, and accordingly we found no support for **H3** (p = .56).

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[4] After each trial participants rated where their attention was focussed and how difficult they found the task. Analyses indicated the manipulation was successful in that participants were more focused on self (cf. other) in the self focus condition (b = 22.70, SE = 3.42, t = 6.63, p < .001). Further, difficulty ratings indicated that participants found the self (cf. other) focus condition more difficult (b = -12.80, SE = 3.46, t = -3.70, p < .001).

[5] The opposite configuration (right arm of the participant, left arm of the avatar) revealed identical patterns of results and is therefore not reported here.

[6] An additional 5 trials (from different participants) were excluded from the CRQA analyses (EH1-EH3) as the estimates for %REC were considered outliers (i.e., > 3 SD from the mean). Further, 4 participants were excluded from analyses that considered participant gaze patterns, due eye-tracking errors.

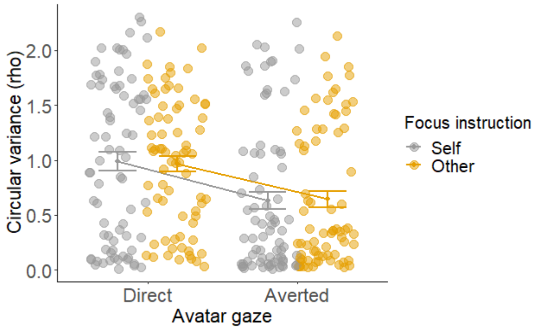

Figure 2*:* Rho as a function of avatar gaze (direct vs. averted) and focus instruction (self vs. other). The error bars represent ±1 SE.

Head Movement Coordination (EH1-EH3)

When considering head movement coordination (i.e., %REC), we found support for **EH1** in terms of a main effect of focus instruction (Figure 3). Here, greater coordination of head movements was observed in the other focus (cf. self focus) condition (b = 1.04, SE = 0.08, t = 12.68, p < .001). We did not find support for **EH2**, in that there was no main effect of avatar gaze (p = .44). There was, however, an interaction between these factors (b = 0.33, SE = 0.12, t = 2.72, p = .007). Post hoc contrasts revealed higher levels of %REC when avatar gaze was averted, but only in the other focused condition (self: b = 0.07, SE = 0.09, t = 0.78, p = .86; other: b = -.26, SE = 0.09, t = -2.96, p = .02). These results are counter to the effects predicted in **EH3**, whereby higher levels of %REC were observed when the avatar *looked away* from the participant.

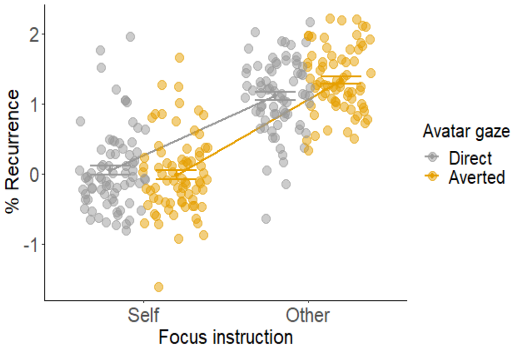

Figure 3*:* %REC as a function of focus instruction (self vs. other) and avatar gaze (direct vs. averted). The error bars represent ±1 SE.

Participant Gaze and Coordination (H4-H5)

To examine the impact of participant gaze, we added each AOI (i.e., avatar, near avatar, room) separately to the models reported above and examined changes in model fit. For models with improved fit, we then examined the effects of participant gaze. For arm coordination, the addition of each AOI did not improve model fit (p = .19 - .88).

For head coordination the addition of time spent looking at and near the avatar improved model fit (looking at: $\chi^2(4)$ = 12.47, p = .01; looking near: $\chi^2(4)$ = 11.60, p = .02). Each model revealed a two-way interaction between focus instruction and looking time (looking at: b = 1.46, SE = 0.54, t = 2.70, p = .008; looking near: b = -1.88, SE = 0.65, t = -2.91, p = .004). Post hoc tests revealed a difference in the relationship between %REC and participant gaze as a function of focus instruction, for both time spent looking at the avatar (self focus: b = -0.51, SE = 0.27, t = -1.92, p = .06; other focus: b = 0.49, SE = 0.35, t = 1.41, p = .16; contrast: b = -1.00, SE = 0.43, t = -2.33, p = .02) and near the avatar (self focus: b = 0.68, SE = 0.37, t = 1.83, p = .07; other focus: b = -0.98, SE = 0.60, t = -1.64, p = .10; contrast: b = 1.65, SE = 0.69, t = 2.38, p = .02).

These results provide qualified support for **H4** – participant gaze patterns were *positively* associated with coordination, but only when considering the time participants spent looking near the avatar in the self-focus condition. However, time spent looking at the avatar *decreased* coordination in the self-focus condition. Inspection of Figure 4 suggests these effects are part of a broader pattern, whereby the impact of attentional focus on coordination may be dependent on subtle differences in participant gaze behaviour (e.g., at vs. near the avatar).

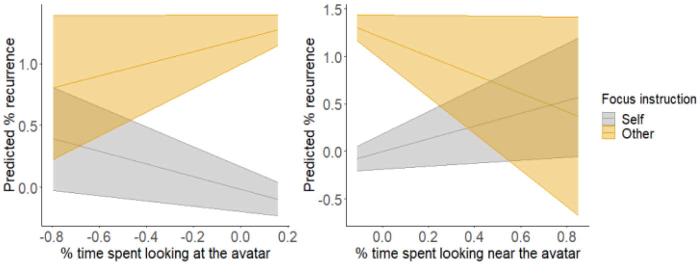

Figure 4*:* The relationship between predicted %REC and percent of time spent looking at (left panel), and near (right panel) the avatar, as a function of focus instruction (self vs. other). The shaded area around the regression line represents the 95% *CI*.

Finally, we did not uncover any effect of time spent looking around the room, therefore providing no support for **H5** (p = .46).

Discussion

This study investigated the influence of social attention on interpersonal coordination. In VR, participants performed a simple movement task with an avatar programmed to look toward (direct gaze) or away (averted gaze) from them. Participants were instructed to direct their attention externally toward the avatar (other focus) or internally toward themselves (self focus). Throughout the experiment, we captured participant movement and gaze patterns. We then quantified the degree to which participants coordinated their arm and head movements with those of the avatar. Several novel findings were revealed.

Attentional Focus and Interpersonal Coordination

Higher levels of head, but not arm, coordination were uncovered when participants were instructed to attend to the avatar. We suspect that focusing attention on an interaction partner increases coupling, akin to manipulations of stimulus properties or perceptual strategies (e.g., Richardson et al., 2007; Varlet et al., 2012). To explore this claim we examined patterns of participant gaze as a function of focus instruction. Indeed, when directed to focus on the avatar, participants spent more time looking at it.[7] This is a strong indication that shifting the focus of attention from self to other impacts coupling strength and resultant coordination. In this way, the attentional factors that constrain interpersonal coordination are not limited to changes in physical properties – but extend to the effects of one's mental experience.

Contrary to expectations, manipulating attentional focus did not impact arm coordination. We suspect this is due to the dynamic stability of the task. The coordination of simple movements like arm curls provides a highly stable system, resistant to perturbation, reducing the capacity for disruption to coordination (e.g., by social factors; see Macpherson et al., 2023). For instance, psychopathology is more likely to impact coordination when system dynamics are less stable (Macpherson & Miles, 2023). Notably, in the current research, it is likely head coordination was easier to perturb (i.e., less stable), due to the variable nature of the behaviour.

Partner Gaze and Interpersonal Coordination

Arm movement coordination was more stable when the avatar looked at, compared to away from, participants. Replicating preliminary findings (Macpherson et al., 2023), this confirms that the gaze behaviour of others modulates the emergence of interpersonal coordination. This effect may stem from the fact that gaze direction specifies affiliative intent (Argyle & Cook, 1976). In the present study, direct gaze may have bolstered coordination by inviting engagement (Cui et al., 2019), while, as a signal of disinterest (Capellini et al., 2019), averted gaze may have encouraged disengagement (cf. Paxton & Dale, 2013). Insight as to how approach-withdrawal behaviour shapes access to information required for coordination is needed to confirm this account.

Of note, in one condition only, partner gaze showed a contrary effect. When participants focused on the avatar, averted gaze led to *higher* levels of *head* coordination. While social exclusion (e.g., being ignored) often encourages withdrawal behaviour, it can also trigger the opposite effect whereby people exhibit ingratiating behaviour in an attempt to (re)connect (Williams, 2009). Here, participants who felt excluded may have been faced with mixed implicit goals, needing to balance withdrawal following exclusion, with the loss of social connection (Kashdan et al., 2008). We speculate that, when directed to attend to the avatar, participants may have simultaneously fulfilled approach *and* avoidance goals, withdrawing via decreased (arm) coordination, but remaining socially connected via increased (head) coordination. This possibility awaits further investigation.

Participant Gaze and Interpersonal Coordination

We found no evidence for a relationship between participant gaze and arm coordination. Again, we suspect that the simplicity of the arm curl task may play a role. Here coordination is easily maintained via intermittent coupling, precluding the need for participants to consistently look at the avatar for stable coordination to emerge. We did however uncover a relationship between participant gaze and head coordination. In the self focus condition, recurrent activity correlated with time spent looking at, as well as near, the avatar. However, the direction of these relationships differed. Although time spent looking near the avatar *improved* coordination, time spent looking at the avatar *decreased* coordination. Interpretation of this complex interaction is challenging given gaze direction can be decoupled from attentional focus (Smallwood & Schooler, 2006). Future work should aim to disambiguate these effects.

Limitations and Future Directions

The current study examined coordination within a unidirectional context (i.e., participants coordinating with the avatar). However, coupling is frequently bidirectional, with coordination emerging via mutual information exchange between individuals. Extending the current work to consider dyadic interaction will not only allow for bidirectional coupling, but would also permit coordination of naturalistic interpersonal gaze patterns to be quantified. Further, as noted, the dynamic stability of arm curl coordination may have limited the capacity for disruption to this dynamic. Stability-related boundary conditions that constrain the influence of psychopathology on coordination have been identified (e.g., Macpherson & Miles, 2023), and may also apply here. Future work should explore this possibility by scaling task stability (e.g., detuning methods; Varlet et al., 2014) while examining the effects of social attention. Finally, despite strong parallels between social behaviour in and out of VR (Zhao et al., 2015), the contrivances of virtual environments mean it is important to explore the current effects in everyday contexts.

Conclusion

Interpersonal coordination supports social exchange. Here, we demonstrated that directing attention towards an interaction partner, as opposed to the self, can enhance the coordination of head movements. Further, we replicated previous research by demonstrating that the averted (cf. direct) gaze of an interaction partner decreased arm movement coordination. Contrary to expectations however, averted gaze also increased head coordination, but only in the other focus condition. These findings add weight to the claim that meaningful patterns of social attention shape the emergence of interpersonal coordination.

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[7] Effect of focus instruction (self vs. other) on time spent looking at the avatar: $b = 0.05$, SE = 0.02, $t = 3.03$, $p = .003$.

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