Extended Applications of Augmented Social Influence Through Imposed Synchrony

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Abstract

Extended Reality (XR) offers the unique potential to transcend the limitations of face-to-face interaction, moving beyond the mere replication of reality toward intentional "social augmentation." In this position paper, we explore "Social Leading," a novel paradigm of imposed behavioral synchrony designed to subtly restructure interpersonal dynamics. Unlike traditional mimicry, Social Leading imperceptibly blends a user's nonverbal movements into their partner's avatar, effectively "augmenting" the leader's social influence and reshaping perceptions of dominance and rapport. We review our initial findings on dyadic interaction and propose an expanded framework for evaluating these effects in triadic group settings, focusing on the legibility of augmented cues to third-party observers. Finally, we discuss the critical design and ethical implications of such "social super-powers," weighing the risks of covert manipulation against the pro-social potential for communication training and motor rehabilitation. This work contributes to the broader discussion on how designed social cues can fundamentally alter the nature of human connection in XR.

Keywords

Social VR, Augmented Sociality, Transformed Social Interaction, Social Leading, Behavioral Synchrony, Ethics in XR

1. Introduction

While immersive VR could be used simply to recreate people's natural nonverbal behaviors in face-to-face settings, there is reason to believe that this approach alone will not be sufficient to improve virtual teamwork. Even in face-to-face settings, people differ in how they produce and interpret nonverbal behaviors. For example, touch could be seen as a way to convey empathy or support or as a violation of personal space [1]. Similarly, continuous eye contact might indicate either interest or aggression (cf. [2]). Different conventions about appropriate speaking distances can lead to perceptions of others as encroaching on one's space or overly aloof [3, 4]. Thus, tools that simply try to recreate face-to-face nonverbal behavior are likely to perpetuate the sociocultural differences and biases found when people are collocated, but virtual reality can allow for "social super-powers" that can improve on face-to-face interactions [5].

In this paper, we explore the potential of one such super-power: "Social Leading," specifically within the context of group dynamics. While our prior work demonstrated that imposed behavioral synchrony can alter perceptions of dominance in dyads, the complexity of multi-party interaction remains unexplored. We contribute a novel triadic framework that introduces an "Observer" role alongside the "Leader" and "Follower." We further outline the design of this framework and propose a set of research questions to guide future investigations into the social and ethical dimensions of augmented sociality.

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2. Social Augmentation Techniques for VR, AR, and MR Environments

Immersive virtual reality (VR) is able to create scenes that can somewhat replicate real-life scenarios, and many commercial platforms (e.g. Meta Horizon World [6] and VR Chat [7]) offer people realistic experiences and activities similar to what they can do in reality. However, virtual reality can also transform experiences, changing both individuals' social perceptions and social dynamics.

Among all the transformations in immersive virtual reality, the transformation of nonverbal behavior is an arising area of investigation in social VR. Nonverbal synchrony, between both human-controlled avatars [8] or between avatars and agents, has been much explored for its effects on liking, affiliation, and trust. However (with some recent exceptions, see [9, 10]) most of this work has focused on either naturally emerging synchrony or simulated synchrony, in which participants perceive others (either other humans, or agents) as mimicking their movements [11].

Taking a step forward, we propose a novel concept that people's avatar movements are led, modulated or partially controlled by those of their conversational partners during social interactions. We call this "Social Leading." Below, we review some of the previous work which this type of nonverbal behavior transformation builds upon and further elaborate our work on the "Social Leading" effect.

2.1. Synchrony and Mimicry in Avatars

Extensive research in Virtual Reality (VR) has investigated how avatar embodiment—specifically appearance and behavioral cues—shapes social interaction within virtual environments. A focal point of this inquiry is nonverbal synchrony, particularly mimicry, defined as the imitation of specific gestures or motor patterns during interaction. While the "Chameleon Effect" is well-documented in human interaction, Bailenson and Yee were among the first to extend this phenomenon to the digital realm. Their work suggests that embodied agents mimicking a user's head movements are perceived as significantly more persuasive and likable than their non-mimicking counterparts [12]. Empirical evidence further indicates that users assign higher social evaluations to such agents [13] and report a heightened sense of social closeness under conditions of behavioral synchronization [14]. Remarkably, in simplified interaction modalities, agents mirroring human behavior—such as button-pushing—have demonstrated the capacity to pass Turing-style assessments [15].

However, the efficacy of this digital Chameleon effect appears to be context-dependent and potentially fragile. Literature suggests that mimicry may bolster calculative trust rather than genuine relational trust [16], and the replicability of these positive effects remains inconsistent [13]. Crucially, the effect can backfire: agents are often perceived as less trustworthy and friendly when users consciously detect the mimicry, compared to when it remains subtle [15].

While existing work establishes a robust framework for understanding how virtual agents mimicking humans influences interaction outcomes, there remains a notable paucity of research addressing the "inverse" dynamic. Specifically, limited attention has been directed toward scenarios where human behavior is unknowingly guided or led by an agent or another human, and the resulting social implications.

2.2. Avatar Embodiment

Substantial research regarding avatar embodiment in VR has examined how avatar representation—encompassing both visual appearance and behavioral dynamics—shapes user experience. Specifically, the Proteus Effect posits that users' digital self-representation significantly influences their behavior within virtual environments. Empirical studies have demonstrated this phenomenon: participants embodied in attractive avatars approached confederates with greater proximity, while those assigned taller avatars exhibited enhanced confidence during negotiation tasks [17]. Conversely, avatar appearance can also constrain engagement; for instance, participants embodying avatars dressed in business suits showed reduced involvement in a casual musical drumming task compared to those in casual attire [18].

Beyond static appearance, modifying the motor behavior of an embodied avatar can also unconsciously shape participants' physical movements. Research indicates that when an avatar is programmed to execute circular motions, users unintentionally deviate into elliptical hand movements, even when instructed to draw straight lines [19]. Similarly, users have been observed to unconsciously decelerate their physical actions to align with an avatar that has been artificially slowed down [20]. In reaching tasks, participants tend to adjust their physical hand positioning to accommodate their avatar's movements, even when the avatar is modulated to drift up to 30 degrees outward, regardless of whether the drift occurs gradually or instantaneously [21]. This phenomenon is described as the "self-avatar follower effect," suggesting that under the illusion of embodiment, the brain is driven by an implicit need to minimize the spatial discrepancy between the physical body and the self-avatar whenever the system permits.

While prior work has investigated agency within the context of virtual co-embodiment—where control over a single shared avatar is distributed between two users [22]—a specific research gap remains. Although these studies illustrate how nonverbal behavior can be tracked and rendered onto an external avatar, they have not yet explored the implications of transformed nonverbal behavior within dyadic social interactions, specifically scenarios where one user's nonverbal behavior is directly mapped onto the other user's virtual avatar.

2.3. Motor and Cognitive Influence

While the previously discussed self-avatar follower effect primarily examines how an individual's behavior is modulated by their own avatar, the "social leading effect" is distinct in its interpersonal nature. A critical attribute of this effect is its occurrence within a social context: participants not only experience movement modulation but also visually perceive their social partner's movements as a stimulus, potentially catalyzing further motor and cognitive shifts.

This also has something to do with motor contagion, a phenomenon where observing another individual's actions activates homologous motor representations in the observer's neural system [23, 24]. Predominantly involuntary, motor contagion manifests in common daily occurrences, such as the infectious nature of yawning [25]. Fundamentally, this effect reflects a natural human propensity for automatic behavioral entrainment, playing a significant role in domains such as motor learning [26] and the decoding of others' action intentions [23]. Furthermore, motor contagion extends into Virtual Reality environments. Empirical studies indicate that users subconsciously adjust their kinematics to mirror or mimic co-present avatars, demonstrating that the behavior of external avatars can significantly shape user actions and reshape interaction dynamics within VR [27, 28].

2.4. Social Leading Effect in Pairs

In our recent work, we introduced and evaluated the concept of "Social Leading"—a novel form of Transformed Social Interaction (TSI) where the movements of one user (the "leader") imperceptibly influence the avatar movements of their conversational partner (the "follower"). While previous research has focused on the "self-avatar follower effect" or agent-based mimicry, our work examined the "inverse" scenario: how an individual's social behaviors and perceptions change when they unknowingly control—or are controlled by—a partner's nonverbal behavior.

We developed a VR system to facilitate real-time behavioral modulation in dyads. The system applied a modulation ratio of 0.3 to two key nonverbal channels:

- Proxemics: When the leader moved physically, the follower's avatar position was transformed to move slightly in the same direction relative to the leader, subtly enforcing proximity.
- Gestures: The leader's upper-limb movements influenced the follower's avatar hands, causing the follower's avatar to mirror the leader's gestures slightly. Critically, this modulation was designed to remain below the threshold of conscious detection.

We conducted a user study with 42 participants (21 dyads) who were randomly assigned roles of "leader" or "follower." The pairs engaged in collaborative and competitive tasks, including self-introductions, a debate, and a money-splitting negotiation.

The results revealed that the "Social Leading" effect significantly altered social dynamics without participants detecting the manipulation. We observed some of the distinct behavioral and perceptual shifts:

- Behavioral Dominance: Leaders dominated the verbal interaction. They disclosed significantly more information during introductions and spoke for a greater percentage of time (56.2%) and used more words (54.4%) during the debate compared to followers. Leaders also contributed significantly more ideas than followers.
- Perceptual Shifts: While self-perceived dominance remained similar between roles, leaders perceived their follower partners as significantly more submissive (less dominant) than followers perceived their leader partners.

These findings suggest that implicit motor synchronization can fundamentally restructure social hierarchy and interaction patterns in VR, even when users retain a strong sense of embodiment and presence. This work lays the foundation for understanding how imposed synchrony can be utilized for pro-social outcomes, such as encouraging engagement in shy individuals or assisting in motor rehabilitation, while also highlighting ethical considerations regarding social manipulation.

Following our initial exploration, recent research has further validated the technical feasibility of blending user movements to mediate social interaction. For instance, Koseki et al. [29] introduced "Co-embodied Mirroring," a system that similarly fuses a partner's motion into an avatar to induce artificial synchrony. Their work offers valuable validation for our technical parameters, specifically finding that a 25% blending ratio remains undetectable to users—a threshold consistent with the 0.3 modulation ratio used in our system. However, distinct differences exist between our approaches. First, while Koseki et al. employed a between-groups design to compare the effects of different blending intensities (e.g., 0% vs. 25% vs. 50%) on mutual rapport, our Social Leading framework focuses on the asymmetric dynamics within a dyad, specifically examining the divergent perceptual and behavioral shifts between the "Leader" and the "Follower." Second, whereas their study primarily investigated non-verbal tasks (e.g., radio calisthenics and reaching) and found no significant increase in closeness or trust, our work mainly emphasizes the effect of motor modulation onto verbal communication, demonstrating how imposed synchrony can fundamentally alter complex social dynamics such as conversational dominance, self-disclosure, and argumentation.

3. Tools and Frameworks for Designing, Prototyping, and Deploying Social XR Applications

Building on our initial findings regarding the "Social Leading" effect in dyads, our current work focuses on expanding this framework to accommodate the complexity of ecological social networks. While pairwise interactions provide foundational insights—specifically that leaders dominate verbal channels and followers perceive leaders as less submissive—human social interaction frequently occurs in larger groups where observational perspectives play a critical role. To bridge the gap between dyadic experimental controls and realistic group dynamics, we are currently prototyping a framework to investigate the Social Leading effect in triads.

3.1. Expanding the Framework: The Triadic Model

We are extending our Unity-based system to support a three-person interaction topology. This framework introduces a third role—the "Observer"—alongside the established "Leader" and "Follower" roles. We maintain a 0.3 gesture modulation ratio between the leader and the follower, and we cancel the proxemics modulation as it would make people prone to motion sickness. This design allows us to isolate specific vectors of influence and perception within a group setting without alerting participants to their assigned roles. The framework creates a distinct flow of nonverbal influence:

- The Leader: Retains full motor autonomy. Their movements are mapped to their own avatar and simultaneously modulate the Follower's avatar. Leaders have no influence on the Observer.
- The Follower: Retains partial autonomy. Their avatar's movements are a blend of their physical motion and the imposed modulation driven by the Leader. They have no connection to the Observer's movement.
- The Observer: Retains full motor autonomy. They act as an independent node within the social graph; they neither exert influence on others nor are they influenced by others. However, they fully participate in the social tasks and visually observe the interaction between the Leader and Follower.

3.2. Research Questions and Deployment

This expanded framework allows us to move beyond self-other perception and investigate the "third-person perspective" in social XR. By deploying this tool in collaborative tasks, we aim to answer several critical questions regarding the legibility and impact of imposed behavioral synchrony.

- Stability of the Effect: Does the presence of a third party weaken or strengthen the dyadic power dynamic? We aim to verify if the Follower still perceives the Leader as more dominant (and vice versa) when an Observer is present.
- Perception of Influence (Leader's Perspective): By comparing how the Leader perceives the Follower (who partially mimics them) versus the Observer (who does not), we can isolate the specific social, psychological impact of imposing synchrony and exerting influence on one's behavior.
- Source Attribution (Follower's Perspective): By comparing the Follower's perception of the Leader versus the Observer, we are curious to see if the Follower can subconsciously detect the source of the influence, distinguishing between the person controlling them and the neutral participant.
- Objective Observation (Observer's Perspective): This framework allows us to analyze social leading from a third person's perspective who also participates in the interaction. Can a neutral Observer realize the implicit leading-following modulation and distinguish between leaders and followers? We will investigate if the Observer assigns different dominance or submissiveness ratings to the Leader and Follower, thereby determining if the "Social Leading" effect creates visible social signals that are legible to third parties.

4. Privacy, Ethics and Inclusivity Considerations in Socially Augmented Systems

There are perceived risks of manipulation in the transformation of nonverbal behaviors. For example, "Virtual-Physical Perceptual Manipulations" (VPPMs) could enhance a user's ability to interact with Virtual Reality (VR) in ways that exceed normal physical limitations, such as redirected walking and haptic feedback techniques [30]. However, there could be attacks on immersive VR systems that lead to potential physical harms to the users. Tseng and colleagues [30] summarized two main types of attacks: puppetry attacks and mismatching attacks. The former attacks exert control over the bodily actions of users engaged in immersive environments. For example, Casey and colleagues [31] demonstrated the feasibility of developing attacks capable of disorienting users, activating their Head-Mounted Display (HMD) camera without consent, superimposing visual content within their field of view, and altering virtual environmental conditions in ways that may cause collisions with physical objects or walls.

Additionally, manipulation of the nonverbal behaviors could break the behavioral realism of the social interactions in VR, characterized as the extent to which an avatar's behaviors resemble and align with those observed in the real world [32]. Herrera et al. [33] reported that when an avatar's body movements did not correspond to the user's physical movements, participants exhibited reduced movement in those body parts compared to individuals embodied in static avatars.

Gesture transformations in social VR should consider variations in nonverbal behavior associated with factors such as age, gender, culture, and social role. For example, Dong and colleagues [34] found there are age-related variations in upper limb motor performance in a virtual reality task. These findings indicate that the manipulation of individuals' nonverbal behavior should account for the diversity of participants' personal backgrounds.

To address the above challenges and mitigate the risks of covert manipulation, a series of design and ethical safeguards need to be further developed. For example, developers should establish strict thresholds for modulation ratios to ensure that movement adjustments remain within safe limits that preserve the user's ultimate physical agency and prevent spatial disorientation. If behavior transformation has broader application in future commercial systems, it should also provide the option of allowing individuals to dynamically opt-out or scale down the degree to which their nonverbal behaviors could be influenced by, or used to influence, others. Other than these, a lot more safeguards could be further embedded to better balance between the pro-social potential of augmented sociality and the rigorous protection of user autonomy.

5. Domain Specific Applications

Social Leading introduces a structured leader–follower dynamic: during interaction, one person's movements subtly guide another's avatar, such that the follower partially aligns with the leader. This relational modulation creates a focused design space for reshaping social experience in VR. Below we outline several feasible application directions.

5.1. Motor Rehabilitation and Parkinson's Disease

Motor rehabilitation is a strong application area for Social Leading. For Parkinson's disease patients, symptoms often show up most clearly at the moment of starting a movement. Clinicians commonly address this with demonstration and external cueing to help patients initiate and time goal-directed actions [35]. Prior research also suggests that users unconsciously adapt their real movements to reduce mismatch with their avatar's movements [21]. Social Leading can connect these two ideas. Instead of taking over a patient's body, it can provide continuous, embodied cueing by blending a partner's demonstrated motion into the patient's avatar at a tunable strength.

We have designed a shared VR boxing task where a clinician acts as the leader and the patient as the follower. The leader's arm trajectory subtly pulls the follower's avatar toward more timely execution, while the patient still physically initiates the action. For individuals with Parkinson's disease who experience gait freezing or delayed initiation, such leader–follower coupling may lower the threshold to start moving and help scaffold smoother execution of intended movements.

This approach differs from systems that directly alter an individual's avatar without a human partner. We hypothesize that embedding movement guidance within a social relationship may introduce motivational and social facilitation effects (e.g. encouragement, shared goals) that extend beyond purely mechanical training. Whether such social coupling provides measurable therapeutic benefits remains an open empirical question.

5.2. Shaping Agency and Equity in Group Interaction

Prior work suggests that behavioral synchrony increases perceived social closeness [14, 36], and that avatar mimicry can enhance social evaluation [12]. Building on these findings, in group social interactions, leader–follower assignment may provide a more explicit way to modulate perceived agency and power dynamics.

In group settings, individuals experiencing social anxiety, when positioned as temporary leaders whose movements are followed by others' avatars, may experience reduced perceived anxiety by increasing perceived social closeness and social evaluation. Conversely, serving as followers to socially confident partners may allow subtle rehearsal of more open or assertive nonverbal patterns within a controlled environment.

Nonverbal dominance often reinforces existing power asymmetries in collaborative contexts. Temporarily assigning leadership roles to lower-status participants—such that others' avatars align with their orientation or posture shifts—may influence perceived authority and inclusion. While such modulation would require careful ethical consideration, Social Leading offers a minimally invasive mechanism for experimentally exploring how structured movement alignment shapes agency and equity in group interaction.

5.3. Communication Training

Avatar mimicry has been shown to enhance perceived persuasiveness in virtual interactions [12]. Building on this insight, a structured leader–follower dynamic may be explored in communication training contexts.

For instance, trainees could act as leaders whose movements are subtly followed by virtual audiences while practicing negotiation or public speaking. Such follower alignment may reinforce perceived influence and support confidence in delivery. The system could further parameterize the number of followers or the degree of movement alignment, allowing dynamic adjustment of how strongly the audience appears responsive. Varying these parameters may influence perceived persuasiveness and provide a controlled way to examine how nonverbal alignment contributes to communicative impact.

By explicitly structuring who leads and who follows, VR with Social Leading technique could serve as a programmable environment for studying and training interactional influence.

Overall, Social Leading suggests that immersive VR can selectively structure relational movement dynamics rather than merely replicate real-world behavior. These applications remain predictive, but they illustrate feasible directions for future investigation.

Declaration on Generative AI

The authors have not used any Generative AI tools.

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