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REPRESENTATION OF NONVERBAL COMMUNICATIVE SIGNALS IN AI-MEDIATED COMMUNICATION

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Abstract. This article examines the representation of nonverbal signals in AI-mediated communication, focusing on gaze, facial expression, gesture, posture, and body movement. It analyses how these signals are modelled and interpreted in conversational agents, virtual humans, avatars, and social robots. The study shows that effective nonverbal communication depends on contextual appropriateness, temporal coordination, behavioural consistency, and social presence.

Keywords: AI-mediated communication, nonverbal communication, embodied conversational agent, virtual human, social robot, gaze, gesture, social presence.

Introduction

The rapid development of artificial intelligence has changed the structure of mediated communication by introducing systems that do more than transmit verbal messages. Contemporary interaction increasingly involves embodied conversational agents, virtual humans, socially interactive robots and computational avatars that can display, transform or respond to visual and behavioural signals. In such environments, communication cannot be adequately described as a purely linguistic exchange because meaning is also organised through gaze, facial activity, gesture, posture, body orientation, movement and prosodic features.

In the present study, AI-mediated communication is understood broadly as interaction in which an artificial or computationally controlled system participates in generating, interpreting, modifying or displaying communicative behaviour. This formulation includes communication with embodied conversational agents and social robots as well as avatar-mediated interaction in which computational systems regulate or reconstruct aspects of nonverbal behaviour. Such a broad view is necessary because the technological representation of nonverbal signals has developed historically across virtual reality, conversational-agent research, social robotics and multimodal computer-mediated communication.

The relevance of nonverbal behaviour to artificial agents is explicitly recognised in T.W.Bickmore's doctoral dissertation, where relational agents are described as computational artefacts designed to maintain social-emotional relationships and where verbal and nonverbal conversational behaviours are treated as mechanisms for negotiating and maintaining those relationships. His analysis further distinguishes emotional, attitudinal, interactional, propositional and framing functions of nonverbal behaviour in face-to-face interaction and considers how these functions can be implemented in embodied agents (T.W.Bickmore, 2003, pp. 89–107). F.N.Zamani's doctoral work on communication strategies in the digital age likewise places computer-mediated communication, virtual environments and multimodality within the same research field, indicating that digital interaction requires attention to more than verbal content alone (F.N.Zamani, 2021).

The aim of this article is therefore to identify the principal forms in which nonverbal signals are represented in AI-mediated communication and to explain their pragmatic functions. Particular attention is given to gaze, facial and affective display, gesture, body movement, behavioural timing, embodiment and social presence. The discussion is based only on openly accessible theses and dissertations from official institutional repositories; journal and conference articles are not used as source items in the bibliography.

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1. Nonverbal communication as a multimodal meaning-making system. Nonverbal behaviour is not simply an ornamental layer added to language. It participates in the construction, regulation and interpretation of communicative action. J.J.Wilson's doctoral research on co-speech gesture demonstrates that gesture can influence both the production and comprehension of utterances and argues that it should be incorporated into pragmatic models of communication rather than treated as an optional supplement to speech (J.J.Wilson, 2016). This position is particularly important for AI-mediated communication because a system that reproduces words while omitting functionally relevant visual behaviour may preserve propositional content yet weaken interactional meaning.

In human communication, nonverbal signals frequently operate simultaneously. A speaker may direct gaze toward an interlocutor, change facial expression, shift posture, move the hands and modify vocal delivery within a single turn. These signals can indicate attention, regulate turn exchange, mark stance, highlight referential content, communicate affect, signal interpersonal distance or support social alignment. When communication is mediated by an artificial system, such signals must be converted into representable forms. They may be captured from a human user, encoded as behavioural parameters, generated algorithmically, displayed through an avatar or robot, or inferred from interactional context.

This transformation from embodied human behaviour to digital representation is pragmatically significant. Representation does not require exact physical duplication; rather, it requires the preservation of communicatively relevant relations between behaviour and context. A gaze movement that occurs at an inappropriate moment, a gesture that does not correspond to the spoken referent, or a facial display that conflicts with the conversational situation may be visually sophisticated but pragmatically misleading. Accordingly, the central problem is not merely whether an artificial agent can move its eyes, face or body, but whether those movements function coherently within the interaction.

2. Gaze as a represented communicative signal. Gaze is one of the most extensively investigated nonverbal resources in mediated interaction. W.A.H.Stepto's doctoral thesis specifically examines eye tracking in avatar-mediated communication and notes that avatar-mediated systems may fail to capture, transmit and display channels of nonverbal communication that are available in face-to-face or video-mediated interaction. His research treats gaze, blinking and other oculic behaviours as important social signals and shows that misleading avatar gaze can reduce the quality of communication, whereas eye-tracking-driven gaze can enrich the nonverbal information available to interlocutors (W.A.H.Stepto, 2010).

S.Dalzel-Job similarly investigates mutual gaze, task performance and social presence in virtual environments. Her dissertation begins from the problem that computer- and video-mediated interaction can lose important nonverbal cues and tests how patterns of looking affect mediated interaction. In the human-agent experiment, the virtual agent's degree of looking was manipulated, and the strongest effects were associated with the condition in which the agent looked toward the participant for a substantial but non-continuous portion of the interaction. Her findings also indicate that constant staring is not equivalent to effective gaze behaviour and can suppress mutual gaze (S.Dalzel-Job, 2014, pp. ii-v; pp. 2-4).

These findings support a pragmatic interpretation of gaze representation. In AI-mediated communication, gaze can perform at least four interrelated functions. First, it can indicate attentional orientation by showing what or whom the agent is attending to. Second, it can regulate participation by signalling availability for interaction or supporting turn exchange. Third, it can contribute to social presence by making the artificial interlocutor appear contingently responsive rather than visually disconnected. Fourth, it can guide reference by linking spoken content to objects, spaces or participants within a shared environment.

The important point is that represented gaze must be relational and temporally appropriate. Simply directing the agent's eyes toward the user is insufficient. Gaze acquires pragmatic value through its timing, duration, target and coordination with speech and other bodily behaviour.

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This explains why both excessive staring and randomly generated eye movement can weaken interaction even when the visual animation itself is technically accurate.

3. Facial expression and affective representation. Facial behaviour provides another major channel through which artificial agents can represent social and affective information. X.Pan's doctoral dissertation examines interaction between people and virtual humans and includes detailed treatment of facial expression, social blushing and body movement. Her experiments demonstrate that relatively subtle facial cues can influence how participants respond to a virtual character, including cases in which participants do not explicitly report noticing the cue. The thesis therefore provides evidence that digitally represented facial behaviour may affect interpersonal interpretation at behavioural and evaluative levels (X.Pan, 2009/2010, pp. 17–25; pp. 93–107).

For AI-mediated communication, the pragmatic function of facial representation should not be reduced to assigning a fixed emotion label to a particular facial configuration. The same visual movement can receive different interpretations depending on conversational context, previous interaction and accompanying signals. More importantly, facial behaviour can indicate stance toward the interlocutor, display responsiveness, soften or intensify an utterance, mark uncertainty, signal affiliation or contribute to the perceived personality of an artificial agent.

N.Churamani's doctoral research on affective robotics extends this problem from static expression to adaptive interaction. The dissertation argues that affective robots operating in human-centred environments must sense and interpret socio-emotional behaviour while learning to respond in context-appropriate ways. It develops continual and personalised learning approaches for facial affect perception and behaviour adaptation, including interaction with the Pepper robot (N.Churamani, 2022). This work is important for the representation of nonverbal signals because it shifts the focus from pre-programmed expression to context-sensitive and user-sensitive behaviour.

Thus, facial representation in AI-mediated communication has both expressive and interpretive dimensions. Artificial systems may display facial movements to communicate stance or affect, while AI components may also analyse users' visible behaviour in order to adapt subsequent responses. The resulting interaction is reciprocal: nonverbal behaviour becomes both an output channel and an input for interaction management.

4. Gesture, body movement and embodied reference. Gesture is particularly important when verbal meaning depends on spatial or referential context. J.J.Wilson shows that co-speech gesture can contribute directly to utterance interpretation and interactional organisation. In AI-mediated contexts, this means that gesture cannot always be replaced by verbal redundancy. Deictic gestures may identify an object or direction; iconic gestures can represent properties of an action or object; beat gestures can organise discourse rhythm or emphasis. Their effectiveness depends on semantic and temporal alignment with speech.

F.N.Moorlag's postgraduate thesis on a social robot's gestures offers an applied example. The robot was programmed to accompany verbal mathematical explanations with deictic, beat and iconic gestures. Although the experiment did not find differences in all learning outcomes between gesture conditions, participants rated supportive gestures as more helpful than random gestures, indicating that users were sensitive to whether bodily movements were communicatively aligned with the verbal explanation (F.N.Moorlag, 2021). The pragmatic implication is clear: gesture representation is not valuable merely because movement occurs; it is valuable when the movement is relevant to the ongoing communicative action.

J.Xu's doctoral dissertation, *Affective Body Language of Humanoid Robots*, approaches bodily expression from the perspective of human-robot interaction. The study explicitly addresses artificial intelligence, nonverbal cues, bodily expression and affective expression in humanoid robots (J.Xu, 2015). This line of research demonstrates that the robot's body can operate as a communicative surface through which stance, affective orientation and interactional intention become perceptible.

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Body movement also contributes to perceived character and interpersonal interpretation in virtual humans. X.Pan's work includes the representation of shyness through motion-captured bodily behaviour, showing how posture and movement can be used to construct socially interpretable behavioural patterns in an avatar (X.Pan, 2009/2010, pp. 50–58). In pragmatic terms, embodied movement can therefore index social disposition, regulate interpersonal distance and provide cues about how an utterance should be understood.

5. Temporal coordination and the synthetic representation of interaction. The representation of nonverbal communication requires coordination across time. A signal that is semantically appropriate but poorly timed may fail to perform its intended function. V.Devin's doctoral dissertation on an interactive talking head addresses this issue by developing a synthetic head that responds in real time to simple greetings with coordinated facial expression and intonation. The system models interactive behaviour across visual and auditory channels and emphasises appropriate response timing (V.Devin, 2002).

Timing is pragmatically important because conversational meaning unfolds sequentially. Nods, gaze shifts, facial reactions and gestures can function as feedback only when they occur in relation to another participant's action. A delayed acknowledgement may appear inattentive; an anticipatory gesture may reveal information before the verbal message; a facial response that persists too long may be interpreted as unnatural or socially inappropriate. For artificial agents, therefore, nonverbal behaviour generation must involve scheduling as well as form.

T.W.Bickmore's dissertation provides a systematic account of this problem in the generation of nonverbal behaviour for relational dialogue. The work distinguishes different communicative functions of nonverbal behaviour and describes selection, scheduling and animation processes for embodied conversational agents (T.W.Bickmore, 2003, pp. 89–107). This model supports the view that representation in AI-mediated interaction is a process of pragmatic orchestration: the system must determine what behaviour is appropriate, when it should occur, how long it should last and how it should relate to speech and discourse structure.

6. Embodiment, behavioural fidelity and social presence. The communicative value of nonverbal representation is closely connected with embodiment. M.Garau's doctoral research investigates avatar fidelity and social interaction in virtual environments and shows that behavioural realism can affect users' experience of interaction. In particular, gaze behaviour influenced evaluations of avatars, and the thesis concludes that even relatively minimal behavioural cues can enhance the perceived quality of social interaction when they are consistent with the avatar's appearance and communicative role (M.Garau, 2003).

This finding challenges the assumption that the most visually realistic avatar will automatically produce the most effective communication. Pragmatic success depends on coherence between appearance, behaviour and context. A visually simple agent whose gaze and gesture are responsive may be experienced as more communicatively competent than a photorealistic agent whose behaviour is random or poorly synchronised. Behavioural fidelity is therefore functional rather than purely graphical.

Social presence provides a useful concept for explaining this relationship. S.Dalzel-Job treats social presence as the extent to which a mediated interaction resembles face-to-face interaction in users' perceptions and behaviour. Her work indicates that mutual gaze can contribute to social presence, but that the relationship is not linear: more looking is not always better, and inappropriate staring may be counterproductive (S.Dalzel-Job, 2014). W.A.H.Steptoel likewise demonstrates that eye-tracking-driven avatar behaviour can enrich avatar-mediated communication and that users respond to the technical and behavioural characteristics of the medium (W.A.H.Steptoel, 2010).

Embodied conversational agents also need to remain perceptually available within the interface. C.B.Simmons' thesis on embodied conversational agents on handheld devices examines how the agent should be presented and how its visibility, accompanying text and interaction design affect usability. The study reports that text can be incorporated without

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removing the agent from the interaction, provided that the embodied agent remains appropriately visible (C.B.Simmons, 2014). This reinforces the idea that embodiment is part of the communicative organisation of the interface rather than merely a decorative graphic.

7. Pragmatic functions of represented nonverbal signal. The reviewed sources allow the pragmatic functions of nonverbal representation in AI-mediated communication to be grouped into several interrelated categories.

First, nonverbal signals perform an interaction-management function. Gaze, nodding, body orientation and timing can indicate attention, readiness to participate, turn continuation or turn completion. In AI-mediated systems these signals help users determine whether the artificial interlocutor is attending to them and whether a response is expected.

Second, nonverbal signals perform a referential and propositional function. Gestures can identify objects, illustrate spatial relations or visually elaborate verbal content. J.J.Wilson's analysis is especially relevant here because it treats gesture as part of pragmatic meaning construction, while F.N.Moorlag's robot-gesture study demonstrates the difference between communicatively supportive and random gestures.

Third, nonverbal behaviour performs an affective and attitudinal function. Facial activity, posture and movement can display affiliation, uncertainty, confidence, shyness, warmth or other socially interpretable orientations. X.Pan's and J.Xu's dissertations show how facial and bodily behaviour can be represented in virtual humans and humanoid robots, while N.Churamani's work addresses how an affective robot can adapt its behaviour to individual socio-emotional patterns.

Fourth, nonverbal representation contributes to relational communication. T.W.Bickmore's relational-agent framework is based on the premise that long-term human-computer interaction requires social and emotional mechanisms, including nonverbal behaviours that support rapport and relationship maintenance. The pragmatic value of such behaviour lies not in conveying a separate proposition but in shaping how the relationship between user and artificial agent is interpreted.

Fifth, represented nonverbal behaviour contributes to social presence and behavioural credibility. M.Garau, W.A.H.Stepto and S.Dalzel-Job demonstrate from different perspectives that the quality of virtual interaction depends on whether avatar behaviour is socially plausible and appropriately coordinated. An agent's nonverbal behaviour therefore influences not only the interpretation of individual utterances but the perceived status of the agent as an interactive social participant.

8. Limits of representation in AI-mediated communication. Despite its communicative potential, nonverbal representation in AI-mediated environments remains subject to significant limitations. One limitation is signal loss. W.A.H.Stepto explicitly identifies the loss of nonverbal channels as a problem in avatar-mediated communication. Technical systems may fail to capture subtle gaze shifts, body tension, micro-movements or the full timing structure of face-to-face interaction. Even when a signal is captured, compression, tracking error or animation constraints may alter its form.

A second limitation is signal distortion. If the system generates a gaze direction or gesture that does not correspond to the user's actual behaviour or the conversational context, the mediated signal may create a false pragmatic inference. The problem is particularly important in AI systems that infer internal states from observable behaviour and then generate adaptive responses. N.Churamani's work on personalised affective robotics highlights the need for adaptive systems that learn from individual socio-emotional behaviour rather than relying exclusively on static general models.

A third limitation concerns over-realism and behavioural inconsistency. M.Garau's findings show that appearance and behaviour interact: increasing graphical realism without increasing behavioural coherence can produce a mismatch. This means that design should prioritise communicative consistency over visual complexity.

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A fourth limitation is contextual variability. A nonverbal signal does not have one invariant meaning. Gaze can indicate attention, dominance, hesitation, turn allocation or reference depending on the situation. Gestures may be semantically integrated with speech in one context but merely rhythmic in another. Facial movement may express affect, interpersonal stance or conversational feedback. Consequently, AI-mediated representation should be interpreted probabilistically and contextually rather than as a direct one-to-one code.

Finally, platform conditions shape what can be represented. F.N.Zamani's research on digital communication strategies and C.B.Simmons' work on handheld embodied agents demonstrate that communication practices are influenced by virtual environments, mobile devices and interface constraints. The design of nonverbal representation must therefore consider not only the behaviour of the artificial agent but also the affordances and limitations of the medium.

Conclusion. The representation of nonverbal communicative signals in AI-mediated communication is a multimodal and pragmatic problem rather than a purely graphical one. Artificial agents, avatars and social robots may represent gaze, facial expression, gesture, posture, body movement and prosodic behaviour, but the communicative value of these signals depends on their relation to discourse, timing, context and the interlocutor's actions.

The analysed theses show that gaze can regulate attention and social presence; gesture can contribute to referential and pragmatic meaning; facial and bodily behaviour can communicate affective and interpersonal stance; and coordinated nonverbal behaviour can support relational alignment and perceived communicative competence. At the same time, misleading gaze, random gesture, behavioural inconsistency or loss of nonverbal channels can reduce interaction quality. This demonstrates that the central objective of AI-mediated nonverbal representation should be functional appropriateness rather than maximal visual realism.

From a pragmatic perspective, nonverbal signals in AI-mediated communication operate as resources for managing interaction, constructing meaning, indicating stance, regulating interpersonal relations and creating a sense of social presence. Future systems should therefore integrate nonverbal generation and interpretation with discourse structure, user-specific behavioural patterns and situational context. Such an approach makes it possible to treat artificial agents not as interfaces that merely display animated movement, but as multimodal communicative systems in which nonverbal behaviour participates directly in the organisation of meaning.

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