The Five Senses: Assessing Non-verbal Communication in Multicultural Human–Robot Interaction

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ABSTRACT

As social robots move from research laboratories into everyday settings, they increasingly encounter users whose sensory expectations are shaped by different cultural worlds. This concept paper proposes a Five-Senses Framework for assessing nonverbal communication in multicultural human–robot interaction (HRI). Drawing on sensory anthropology and embodied cognition, we treat sensory perception as culturally mediated: what people see, hear, feel, smell, and taste in robot encounters is socially learned. We combine Urakami & Seaborn's five-senses taxonomy [1] with sensory anthropology to produce an assessment framework: for each sensory channel, we identify what the robot expresses, what users are likely to perceive, and how cultural norms shape the interpretation of that perception. We discuss the framework in the context of multilingual South Africa, where everyday interactions routinely cross linguistic and cultural boundaries, and where expectations about gaze, personal space, timing, and touch often differ in subtle but meaningful ways – making it the ideal environment for assessing nonverbal behaviour in multicultural HRI. We argue that the framework offers a practical way to detect culturally mediated sensory misalignment – when a robot's nonverbal cues are perceived or interpreted differently than intended – and to address it early, before it undermines trust and engagement and impairs interaction.

CCS CONCEPTS

• Human-centered computing • Human-robot interaction • Cross-cultural interaction

KEYWORDS

Human-robot interaction; nonverbal communication; cultural sensitivity; trust; social robotics; multisensory perception; multilingualism; South Africa

1 Introduction

The deployment of social robots now extends across healthcare [2], education [3], retail [4], hospitality [5], and eldercare [6], requiring them to operate in socially and culturally complex environments. These settings bring together users with different languages, social norms, and embodied expectations about gaze, distance, timing, and appropriate behaviour in interactions.

Yet much human–robot interaction (HRI) research continues to be conducted within Western, educated, industrialised, rich, and democratic (WEIRD) contexts [7,8]. As a result, the nonverbal behaviours designed into social robots - such as gaze patterns, response timing, interpersonal distance, movement dynamics, and touch - often reflect the sensory norms of their designers rather than those of the diverse users they are intended to serve. When these robots are deployed beyond the laboratory, their behaviour may be experienced as awkward, inappropriate, or subtly unsettling, despite the robot functioning as intended.

This mismatch arises because nonverbal communication is shaped by cultural norms rather than universal conventions. Expectations around gaze, silence, conversational rhythm, proximity, and touch vary across communities and play a central role in how social intentions are interpreted. Recent HRI research increasingly recognises that these nonverbal and contextual factors shape user comfort, engagement, and trust, particularly in open-ended or first-encounter interactions [9,1].

Multilingual South Africa offers a valuable context for examining these dynamics. With twelve official languages and ongoing migration from across the African continent [10,11], everyday social interaction frequently brings together people with different cultural norms and sensory expectations. As a result, interaction involves continual adjustment: people modulate gaze, conversational pace, interpersonal distance,

and silence depending on who they are speaking with and in what context, and norms for these behaviours vary across South African communities [12,13]. These adjustments are rarely explicit; instead, they are embodied, habitual, and learned through participation rather than formal instruction.

For social robots, this poses a fundamental challenge. Behaviours such as sustained eye contact, rapid responses, or standing in close proximity may signal attentiveness to some users while constituting norm violations for others, as expectations surrounding these cues vary significantly across cultural contexts [14,15].

In response to these challenges, this paper proposes a Five-Senses Framework for assessing nonverbal communication in multicultural human–robot interaction. Building on Urakami and Seaborn's sensory taxonomy [1] and grounding it in sensory anthropology and embodied cognition, the framework treats perception as culturally mediated rather than universal. For each sensory modality - visual, auditory, haptic, olfactory, and gustatory - it considers what the robot expresses, how users are likely to perceive that expression, and how cultural norms shape its interpretation. Developed through the case of multilingual South Africa, the framework provides a structured way to understand how small, often overlooked nonverbal mismatches can undermine trust before interaction meaningfully begins.

2 Related Work

A growing body of HRI research has examined how cultural background shapes user perceptions of and responses to social robots. Broadbent et al. [16] provided early evidence that cultural context shapes attitudes toward robots, reporting systematic differences in robot acceptance across East Asian and Western samples. Subsequent work has expanded on this, with Li et al. [17] showing that cultural norms shape preferences for robot appearance and behaviour, and Haring et al. [18] reporting that participants from different countries differ in their evaluations of robot animacy, intelligence, and perceived safety.

Cross-cultural studies of nonverbal cues in HRI have shown that culturally mediated expectations shape interaction outcomes. Eresha et al. [19] showed that participants from different cultures responded differently to robot gestures and spatial behaviour, while Evers et al. [20] demonstrated that relational self-construal (i.e., the extent to which people define themselves through close relationships) – shaped by national culture – predicted how users negotiated with a social robot. Salem et al. [21] showed that culturally congruent robot gestures improved user ratings of interaction quality compared to incongruent ones. Collectively, these studies show that nonverbal behaviour in HRI is not culturally neutral.

However, as Lim et al. [22] and Schneiders et al. [23] have argued, much of this work relies on broad cultural comparisons - typically East Asia versus the West – using high-level dimensional models such as Hofstede's cultural dimensions framework. These approaches risk treating culture as a static, nation-level variable rather than as a set of embodied, contextually sensitive practices that vary within as well as between countries, and therefore offer limited guidance for assessing specific nonverbal behaviours in real-world settings. Seaborn et al. [8] further supports this concern, showing that the majority of HRI studies draw on WEIRD populations, which limits the extent to which these design assumptions can be generalised to other populations.

Building on this line of work, Urakami and Seaborn [1] proposed a five-senses taxonomy for nonverbal communication in HRI, organising nonverbal cues by the sensory channel through which they are perceived – vision, audition, touch, smell, and taste. While their framework provides a comprehensive mapping of the sensory dimensions relevant to HRI, it does not address how cultural background mediates the interpretation of those sensory cues as they are perceived in interaction.

We addresses this gap by integrating Urakami and Seaborn's sensory taxonomy with sensory anthropology and embodied cognition to produce a culturally grounded assessment framework. Rather than comparing cultures at the level of national dimensions, we focus on how specific sensory expectations – shaped by local linguistic and social practices – affect the interpretation of robot nonverbal behaviour. We develop this approach through the case of multilingual South Africa, offering a within-country perspective on cultural variation in HRI that complements the cross-national comparisons that prevail in the literature.

3 The Five-Senses Framework

The Five-Senses Framework examines nonverbal communication in HRI through the sensory channels in which people encounter robot behaviour - vision, hearing, touch, smell, and taste [1]. Grounded in sensory anthropology and embodied cognition, the framework treats perception as culturally shaped rather than universal.

For each sensory modality, the framework distinguishes between what the robot expresses, how that behaviour is perceived, and how it is interpreted within culturally specific expectations of appropriateness. Differences across these aspects can undermine comfort, trust, or engagement, even when a robot's behaviour is technically sound.

We apply the framework to multilingual South Africa to show how sensory cues function as context-sensitive resources rather than fixed signals, offering a concrete setting for examining nonverbal communication in multicultural HRI.

3.1 Visual modality

The visual channel includes appearance, facial expressions, gaze, gesture, posture, and spatial behaviour. Visual perception is culturally organised rather than universal: what counts as

appropriate eye contact, natural gesture, or comfortable interpersonal distance varies systematically across cultures [24–26].

In many Nguni-speaking contexts, including amongst isiZulu and isiXhosa speakers, *hlonipha* - a Nguni system of respect that prescribes restrained speech, lowered gaze, and deference toward elders and authority figures - emphasises bodily restraint and indirect or lowered gaze toward elders, with sustained direct eye contact often interpreted as confrontational [27]. In Sotho-Tswana-speaking contexts, respect is more commonly communicated through posture and spatial regulation, while in Tshivenda-speaking communities, visual restraint and reduced facial animation are associated with seriousness and dignity. For HRI, this means that fixed gaze strategies risk cultural misalignment, as visual behaviour is interpreted through culturally situated norms rather than universal ones.

3.2 Auditory modality

The auditory channel includes vocal quality, paralinguistic features such as tone, pitch, and rhythm, as well as response timing, silence, and non-speech sounds. Norms governing how people speak and listen are culturally specific rather than universal [28,29]. The pace of turn-taking, comfort with silence, and expectations around back-channeling differ across communities, with clear differences in what counts as an appropriate response time [30]. Together, these features shape what has been described as communicative musicality - the felt rhythm and flow of conversation [31].

Across linguistic groups in South Africa, silence and response timing carry different meanings. Among Tshivenda speakers, silence is often associated with reflection and dignity rather than disengagement [13], while in many isiZulu- and isiXhosa-speaking contexts silence can signal respect, particularly in interactions involving elders [27]. By contrast, Sotho-Tswana-speaking communities tend to place greater emphasis on smooth turn-taking, where attentiveness is conveyed through timely verbal responses [12]. For social robots, the same response speed may feel attentive to some users but rushed or intrusive to others, showing that silence and timing are culturally shaped rather than universal.

3.3 Haptic modality

The haptic channel refers to touch and bodily contact, including qualities such as texture, temperature, pressure, and physical proximity. Touch is not a neutral or universally positive form of communication; it is shaped by culturally specific norms that regulate who may touch whom, in what contexts, and in what ways [32]. These norms are learned through everyday social interaction and are closely tied to relationships, age, hierarchy, and setting. Empirical work further shows that the subjective experience of affective touch varies across cultural contexts, including within South Africa [33].

Across linguistic groups in South Africa, expectations around touch differ in meaningful ways. In many isiZulu- and isiXhosa-speaking contexts, physical contact forms part of everyday interaction but is carefully shaped by respect and relational roles, particularly in interactions involving elders [27]. By contrast, Sotho-Tswana- and Tshivenda-speaking communities tend to place stronger limits on touch outside close or care-related relationships, with uninvited physical contact more likely to be experienced as intrusive or inappropriate [12,13].

3.4 Olfactory and gustatory modality

Olfactory and gustatory cues have been shown to shape how human–robot interactions are experienced. In HRI research, added scents influence users' mood, comfort, and engagement during interaction [34,35]. Gustatory cues are also relevant in contexts where robots serve or assist with food, such as restaurants, hospitals, or care facilities, where taste expectations and food-related associations shape trust, acceptance, and perceived appropriateness [4,5].

Sensory anthropology shows that both smell and taste are culturally learned rather than universal [36,37]. While there is currently limited research on how olfactory and gustatory cues are experienced in South Africa specifically, the country's cultural and linguistic diversity suggests that food- and scent-related cues may be interpreted differently across contexts.

4 Discussion

The Five-Senses Framework contributes to the HRI community in three ways that extend beyond the South African context. First, the framework provides a structured method for identifying culturally mediated sensory mismatches early – before they manifest as breakdowns in trust or engagement. Existing approaches to cultural variation in HRI often rely on broad cultural dimensions or country-level comparisons [16–18,22]. These approaches can show that cultures differ in general, but they rarely tell designers what to do with a specific cue – such as gaze, response timing, or interpersonal distance – in a particular setting. By assessing each sensory channel separately - and by separating what the robot does, what users actually notice, and how they interpret it in their cultural context – the framework makes it easier to pinpoint where a misunderstanding is coming from. Designers and evaluators can use the framework to systematically review nonverbal behaviour across sensory modalities, rather than assessing single cues in isolation. This matters because meta-analytic evidence shows that robot attributes – including nonverbal design features – are among the strongest predictors of user trust [38]. A framework that supports structured, cross-cultural assessment therefore has clear practical value.

Second, the framework highlights within-country cultural variation as a design consideration for HRI. Most cross-cultural HRI research compares participants across national boundaries – typically East Asian versus Western populations

[16,18,23] - implicitly treating each country as culturally homogeneous. By developing the framework through multilingual South Africa, where twelve official languages and diverse migration patterns produce routine within-country variation in sensory expectations [10–13], we demonstrate that cultural mediation of nonverbal cues operates at a more local level than national comparisons typically capture. This perspective is relevant for any deployment context where users from different cultural backgrounds share the same physical space, including hospitals, airports, retail environments, and educational institutions worldwide.

Third, the integration of sensory anthropology with Urakami and Seaborn's taxonomy [1] offers a theoretical bridge between the HRI literature on nonverbal communication and the anthropological understanding of perception as culturally constituted. Where Urakami and Seaborn's taxonomy maps the sensory channels involved in HRI nonverbal communication, our framework adds the question of *for whom* and *under what cultural conditions* those channels carry meaning. This positions nonverbal robot behaviour not as a set of universal signals to be optimised, but as culturally situated expressions that require contextual assessment.

We acknowledge several limitations. The framework is currently conceptual and requires empirical validation. The South African examples, while grounded in existing ethnographic and linguistic research [12,13,27], have not yet been tested in controlled HRI studies. Additionally, the framework does not yet specify how robots might adapt their nonverbal behaviour in real time when interacting with users from different cultural backgrounds. Existing work on culturally adaptive robots has demonstrated the feasibility of adjusting greeting gestures and verbal style based on detected cultural cues [39], but extending this to the full range of sensory modalities identified by the framework – particularly haptic, olfactory, and gustatory channels – will require both technical and ethical consideration. Future work will address these limitations through empirical studies with South African participants interacting with social robots across the sensory modalities identified by this framework.

5 Conclusion

As social robots move into every day, culturally diverse settings, the question is no longer whether nonverbal behaviour matters, but how it is perceived, interpreted, and lived through the senses. This paper has argued that trust and engagement in human–robot interaction are often shaped before a robot performs any task, through culturally mediated sensory expectations about how it looks, sounds, moves, pauses, approaches, or touches. By bringing together Urakami and Seaborn's five-senses taxonomy [1] with sensory anthropology and embodied cognition, the Five-Senses Framework offers a structured way to assess nonverbal communication as it unfolds across vision, audition, touch, smell, and taste - linking what robots express to what users perceive and how those perceptions are interpreted within specific cultural contexts. By reframing nonverbal behaviour as a culturally mediated sensory experience, the Five-Senses Framework offers the HRI community a practical way to design, evaluate, and deploy robots that can earn trust in the global, culturally diverse, multilingual settings where they increasingly operate.

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