The Nudging Machine: Exploring Expressive Touch-Based Movement for Abstract Robots

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Abstract

A single tap from a robot can set off a cascade of interpretation. This study examines how people perceive affect, intent, and agency when a non-humanoid robot conveys meaning through contact-based nudging. Using a cube-shaped robot programmed with twenty animator-designed affect–intent variants, participants completed two tasks: a situated interaction in which the robot attempted to pass their arm, and an isolated gesture-recognition task. In the situated encounter, participants rapidly attributed motives such as attention-seeking, social contact, or boundary testing. Recognition of the robot's obstacle-passing goal was partial but participants consistently described the robot's movement qualities as shifting from cautious to more assertive, interpreting these changes as emotional and intentional. In the isolated task the expressive movement was far less legible: only neutral gestures were reliably recognised, with frequent confusions between comfort and attention. These findings support the position that nudging gains meaning in context: while a minimal robot can elicit rich social inference when its nudges unfold dynamically in interaction, affect and intent become opaque when the same motions are removed from their relational frame.

CCS Concepts

• **Human-centered computing → Human computer interaction (HCI)**; *Haptic devices*; • **Computer systems organization** → Robotics.

Keywords

robot-initiated touch, non-humanoid robot, expressive movement, affect and intent perception, movement design

ACM Reference Format:
Nataliia Kaminskaia, Rob Saunders, Kim Baraka, and Somaya Ben Allouch. 2026. The Nudging Machine: Exploring Expressive Touch-Based Movement for Abstract Robots. In *Companion Proceedings of the 21st ACM/IEEE International Conference on Human-Robot Interaction (HRI Companion '26), March 16–19, 2026, Edinburgh, Scotland, UK*. ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3776734.3794420

HRI Companion '26, Edinburgh, Scotland, UK

ACM ISBN 979-8-4007-2321-6/2026/03
https://doi.org/10.1145/3776734.3794420

1 Introduction

Touch is considered the most essential medium for interacting with the world [14, 8, 22]. It develops earlier than all other senses and plays a crucial role in shaping human cognition and emotion. Touch also plays a fundamental social role in primates, supporting cohesion, stress regulation, and communication [23], and has been linked to the emergence of complex social cognition [11].

In HRI, communication similarly goes beyond linguistic exchange. Social robots increasingly rely on non-verbal cues – gaze, posture, motion dynamics, proximity, and spatial behaviour – to engage users. Embodiment, understood as the robot's physical form and movement, determines how these cues are produced and interpreted. Even minimal or abstract forms can become socially expressive, supported by findings showing that non-verbal channels often communicate more than language [38, 20]. Within this context, touch represents an underexplored interface for interaction, especially when originating from the robot rather than the human.

While touch is gaining some attention in HRI, most studies still focus on human-initiated touch, haptic sensing, or tactile pattern recognition. Robot-initiated touch appears mainly in three areas – functional use, affective touch for behaviour shaping, and user perceptions of touch-capable robots – and largely relies on humanoid or zoomorphic forms and socially familiar gestures [9, 37, 56, 33, 54, 55, 19, 12, 49, 3].

Robot-initiated physical nudges remain largely unexplored in HRI. A nudge is a gentle, localized push that functions as a social cue in human interaction.

As a minimal physical gesture, it offers a way to examine how people attribute affect, intent and agency when cues are reduced to their simplest embodied form.

Non-humanoid robots provide an alternative for studying touch and non-verbal communication without anthropomorphic constraints. Prior work shows that abstract or instrumental platforms can convey socially meaningful cues [1, 48, 29, 51, 27, 25, 44, 16], reflecting classic evidence that people readily attribute intent to simple geometric motion [21]. These designs reduce anthropomorphic bias and make it possible to examine motion as a communicative resource in isolation [1].

This study investigates how an abstract, non-humanoid robot without screens or speech can use brief nudges to express variations in intent, affect, and social presence through motion, building on evidence that expressive movement shapes users' perceptions of robots [25], and examining how people interpret these same signals across different contexts. The research question is: *How are affect, intent and agency perceived in nudging gestures initiated by a non-humanoid robot?*

This work employs a custom-built cube-shaped robotic platform designed to produce brief, expressive nudges using a Stewart–Gough mechanism on an omnidirectional base. A set of animator-designed nudging gestures was created within a 5 (affect) × 4 (intent) design space and implemented on the platform. Interpretations of these movements were studied with 24 adult participants in two conditions. In the situated task, participants blocked the robot's path and experienced a three-stage nudging sequence that increased in assertiveness. In the isolated task, participants purely observed as the robot delivered five distinct nudges, rating its perceived intent and affect after each touch. This design allows a controlled comparison of how affect, intent, and agency are attributed to nudging behaviour during an interactive blocking scenario and during decontextualised presentation of the same movements.

Studying abstract nudging contributes to HRI by showing how minimal, embodied cues can elicit social meaning without relying on human-like form or language. This perspective supports the design of socially intelligent systems that are materially simple yet communicatively expressive, expanding social robotics beyond anthropomorphic assumptions.

2 Background and Related Work

Touch involves sensory, affective, and interpersonal functions [42], making it difficult to isolate experimentally in HRI [22].

2.1 Philosophical and Ethical Context.

Touch is bound to bodily awareness and movement [13, 35], and its qualitative properties shape perception of the body itself [10]. Embodiment theories describe gesture as culturally shaped action that links bodily technique to meaning [34], while affect can arise from ambiguity in form and motion [2]. Work with deaf-blind children shows that touch alone can sustain intersubjective engagement [31]. These views frame touch as affective and situational, underscoring ethical concerns when robots elicit meanings that cannot be predicted.

2.2 Motion and Minimal Expressiveness.

Tactile interaction is always produced through movement, so motion qualities strongly influence how contact is interpreted. Prior HRI studies show that non-anthropomorphic robots can communicate affect or intention through small or well-timed motions [24, 48, 1]. Performative motion-mapping work further emphasizes rhythm and dynamic qualities as communicative elements [18, 17].

Spatial behaviour also shapes interpretation: maintaining or violating expected distances influences comfort and perceived social meaning [50, 30, 43, 32]. Robot form contributes as well. Studies show that people's expectations about non-verbal behaviour depend on appearance, and mismatches between appearance and motion can reduce comfort [53]. Abstract, object-like robots avoid such appearance–motion inconsistencies and instead rely primarily on movement to convey their behaviour [17].

2.3 Prior Work on Robot-Initiated Touch

Robot-initiated touch has received comparatively little attention. Existing studies fall into three areas. The first concerns instrumental touch, where robots use physical contact to guide or assist people. Examples include robotic nursing tasks involving forearm wiping [7] and ballbot platforms that provide directional cues through compliant arm contact [47]. The second concerns affective touch, where robots provide soothing interactions. Robotic hugs, warm tactile contact and gentle holding have been shown to influence trust, comfort and emotional responses [36, 46, 33, 54]. The third concerns perceptions of robots that initiate touch. Research shows that tactile qualities, duration and body location shape emotional interpretation and social evaluation, and that context significantly modulates how touch is understood [9, 56, 41].

3 Design and Implementation

A custom robotic platform was developed to deliver nudges with controlled variation in affect and intent. The design followed two requirements: (1) an abstract form suitable for touch-based interaction, and (2) motion capabilities to support expressive, affective nudging. A small cube form was selected to avoid unintended anthropomorphic cues; offering clear surfaces for contact, interpretive neutrality, and sufficient volume for the necessary mechanisms.

Software Development and Interface. Prior research on expressive non-humanoid motion [1, 48, 25, 44] indicates that expert motion knowledge cannot be captured through fixed primitives, therefore gestures needed to be authored through continuous, expert-driven manipulation. The robot's size and morphology made previous embodied exploration methods [44] impractical, so expressive motion had to be designed through direct manipulation of a physical proxy at the robot's own scale. The control system was designed to allow natural and continuous manipulation while ensuring precise reproduction of each gesture. The custom interface mirrored the animator's movements in real time, allowing iterative rehearsal based on the robot's physical output. The animator interacted with a physical model (local movement) while an operator controlled the mobile base using a joystick (global movement), providing control of posture and trajectory during contact (see Figure 1). A technical description of the robotic platform and its control code is available in the supplementary materials.[1]

Gesture Design. Gestures were created to embed specific affective and intentional qualities. Intents (getting attention, taking space, seeking comfort, and no-intent) were chosen for their relevance to nudging [45]. Affect states were selected using a valence–arousal structure (excited, content, angry, sad, neutral) consistent with prior work [4]. Across multiple design sessions, the animator manipulated the model within defined motion boundaries, refining the movements until their tactile qualities matched the intended affect–intent pairing. Emotionally neutral gestures used global translation only via joystick, while no-intent gestures involved minimal contact. The resulting 20 gestures (5 affects × 4 intents) represent the outputs of this direct-manipulation animation pipeline, captured as precise pose trajectories for repeatable playback. The full gesture database is available online.[2]

[1]https://github.com/kaminatic/Cub-e
[2]https://doi.org/10.6084/m9.figshare.30625013

4 Evaluation

To study how people perceive and interpret robot-initiated touch we used a two-part design that balances ecological realism with analytic control. A situated interaction explored how participants negotiate space with the robot and how they attribute affect, intent, and agency during an unfolding nudging sequence. Agency is defined here as perceived autonomy. A complementary isolated gesture assessment examined how accurately participants recognised the intended affect and intent of individual gestures and how confidence and individual factors relate to interpretation. Combining behavioural observation, structured ratings, and qualitative reflection allowed measurable comparison and insight into the subjective experience of touch-based interaction.

To support this two-part structure, a mixed methodological approach was adopted. Quantitative ratings provided a structured measure of how well affect and intent could be recognised, while qualitative accounts and video-based reflection captured the nuances of how participants made sense of robot-initiated touch, including reactions that are difficult to quantify. Using both perspectives allowed us to examine interpretation at the level of signal recognition as well as lived experience.

Procedure. Twenty-four adults (14 female, 10 male; ages 20–44) provided informed consent, including for video recording. The setup included the robot, a defined arm-placement area on a tabletop (see Figure 2), a camera to record the interaction, and a tablet for questionnaires and gesture ratings. In the situated interaction, participants placed their forearm on the table while the robot approached and performed a sequence of escalating nudges designed to convey varying intent and affect. A Wizard-of-Oz method was used to control the robot's behaviour. The interaction was video-recorded and followed by a retrospective think-aloud and a semi-structured interview addressing what participants believed the robot was trying to do, and how they experienced the interaction. Short pre- and post-interaction questionnaires measured affective shift and social perception. In the isolated gesture assessment, each participant observed five gestures randomly sampled from the full set of 20 affect–intent combinations, yielding a balanced distribution across the sample. After each gesture, participants selected the perceived

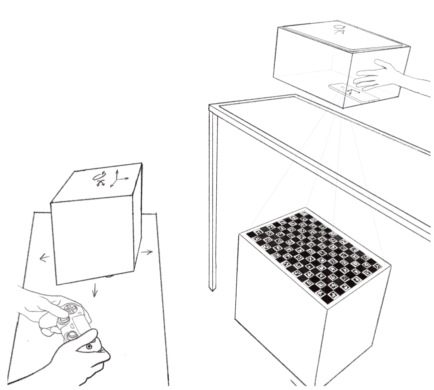

Figure 1: **System Architecture for Animation-Based Gesture Design.** The cube-shaped robot is controlled via joystick (left) and a proxy using a ChArUco board (right).

Figure 2: **Experiment setup.** A participant blocks the cube-shaped robot's movement with their arm.

intent from multiple-choice options, rated the robot's affect using an adapted SAM scale [5], and indicated their confidence. Distractor options were included to prevent recognition by elimination.

5 Results

The findings from the situated and isolated tasks describe how participants interpreted the robot's expressive, contact-based nudging movement in the situated and isolated nudge conditions.

Situated nudge. Participants offered recurring interpretations of the robot's nudging behaviour. Most described the robot as attempting to pass their arm or to maintain contact, while a smaller group framed the behaviour as testing boundaries. Recognition of the designed obstacle-passing goal was partial: about one third identified it in written responses and about half did so in interviews. Participants also attributed emotion to the robot. Early movements were described as careful or exploratory and later ones as more insistent, with descriptors including awkward, playful, and occasionally mildly aggressive, though generally viewed as non-threatening. Participants also described tactile qualities of the contact, adopting strategies such as keeping the arm still, observing the robot's adjustments, or lightly mirroring its movements.

On the Robotic Social Attributes Scale (range 9–63 per subscale), the robot was rated in the upper mid-range for warmth ($M = 36$) and competence ($M = 34.7$) and in the lower range for discomfort ($M = 18.5$). Neurodivergent participants rated the robot as warmer than neurotypical participants ($p = .0317$). Agency attribution varied: one participant reported low agency, most reported moderate levels, and nearly half reported high agency.

Interaction influenced participants' emotional state. Overall, PANAS scores increased following the task ($t(22) = 3.08$, $p = .005$), driven by a reduction in negative affect ($p = .0014$). Participants with more prior robotic experience showed greater improvement ($p = .022$).

Isolated nudge. When gestures were presented without context, accuracy for jointly recognising intent, valence, and arousal was low. Strict intent accuracy reached 22.5%, while grouping intents by broad functional goal increased accuracy to 43.3%. "No-intent" nudges were rarely identified as such. Emotion recognition was also weak: exact accuracy remained below chance, and even with a ±1 tolerance, valence and arousal were recognised at roughly 40%.

Emotionally neutral gestures were identified most consistently; among the non-neutral emotions, sadness showed somewhat clearer patterns. Responses were concentrated near the neutral region

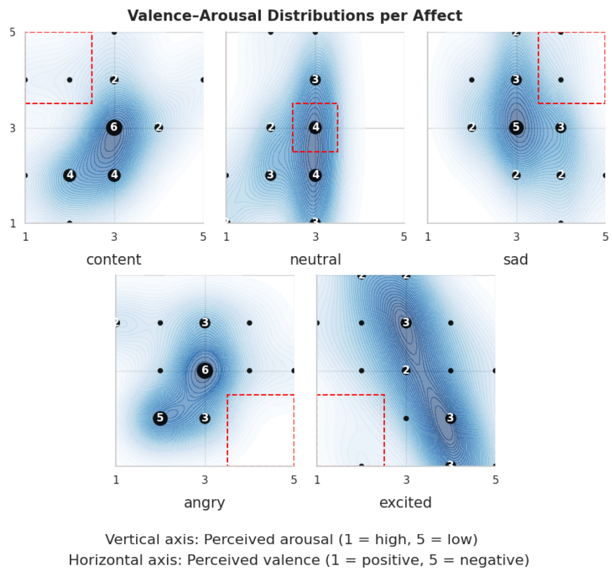

Figure 3: **Valence–Arousal distributions per affect.** Contours represent KDE density; dots indicate individual ratings; rectangles mark intended target regions.

(Figure 3). Gestures combining functional goals with incongruent emotional profiles were recognised less accurately. Responses integrated emotional and functional cues rather than treating them as independent dimensions.

6 Discussion

This study examined how affect, intent, and agency are perceived when a non-humanoid robot initiates nudging gestures. The situated condition revealed that meaning in robotic touch emerges relationally and depends strongly on context rather than on design alone, aligning with embodied perspectives in HRI where impressions develop dynamically through interaction [15]. In contrast, isolated nudges did not elicit consistent interpretations.

Participants attributed substantial agency to the robot. RoSAS ratings indicated warmth, competence, and sociality, and qualitative accounts described the robot as responsive, sometimes awkward, and occasionally mildly aggressive. All but one participant attributed autonomy to the robot, aligning with longstanding observations that even minimal motion cues can evoke animacy attribution [21]. Neurodivergent participants rated the robot warmer than neurotypical ones, suggesting that individual differences shape perceptions of robotic touch, consistent with heterogeneous patterns reported across psychological profiles [39, 40, 6].

Intent attribution depended on context. In the situated task, about half of participants identified the robot's obstacle – passing goal in interviews and one third did so in writing, while many initially interpreted the gesture as social contact. In the isolated gesture task, intent recognition was low, and participants distinguished intentional from accidental nudges rarely. Affect interpretations followed the designed behavioral progression; however, isolated recognition was weak, with neutrality being clearest, followed by sadness. Mismatched pairings hindered clarity, confirming holistic interpretation over functional-emotional separation.

Interaction with the robot reliably improved emotional state. Negative affect decreased significantly and overall PANAS scores increased, with the strongest improvement among participants with prior experience with robots. Touch played a central role: participants described even brief contact as communicative, and sometimes attachment-forming. Strategies ranged from keeping the arm still, observing robot responses, to actively mirroring or testing its movements; highlighting how people negotiate uncertainty and explore interactional dynamics in tactile encounters.

Taken together, these findings demonstrate that an abstract, minimal robot can elicit rich attributions of affect, intent, and agency through brief nudging gestures. Context strongly shapes interpretation, affect and intent are perceived jointly, and individual differences influence emotional and perceptual outcomes. The study contributes an animator-led movement design process and a dual-task structure that contrasts situated and isolated nudges.

This work builds on prior minimal embodiment research, which shows that minimal behaviors can convey social intent [28]. We extend this grounding into the tactile domain, highlighting the unique communicative role of touch. Future research should compare tactile versus non-contact gestures, investigate perception in neurodivergent populations, and integrate touch-sensing to automate robot behavior. Additionally, studies should compare touch with context-only or reduced-sensory conditions, examine how agent identity and material properties influence interpretation [26, 52], and vary affect independently of intent.

7 Conclusions

This study shows that an abstract, non-humanoid robot can convey affect, intent, and agency through minimal touch, demonstrating that nudging gestures carry expressive potential independent of anthropomorphic features. The two-part design – which contrasted situated with isolated nudges – revealed how meaning emerges differently under contextual interaction versus stripped-down observation, highlighting that social interpretations arise immediately while pragmatic intent requires reflective elaboration. By incorporating self-reported neurodiversity, the study also points toward the importance of individual differences in shaping touch-based HRI, an aspect rarely addressed in existing work. Although the sample was small and culturally narrow, and isolating touch reduced interpretability in the absence of contextual cues, these constraints sharpen future directions rather than diminishing the core contribution. They indicate the need for future work to investigate the roles of context, agent identity, and material properties in tactile interpretation. Overall, the findings demonstrate that a simple nudge can become a meaningful communicative resource in human–robot interaction, offering a foundation for future work on touch as an expressive modality in abstract robotic forms.

Acknowledgments

We gratefully acknowledge the animator, Ana Grinfeld, who contributed to the design of the robot's gestures and provided valuable movement expertise.

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Received 2025-12-08; accepted 2026-01-12