Exploring Social Co-Presence through Movement in Human-Robot Encounters

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Abstract. This paper explores the social capacity of robots as an emergent phenomenon of the exchange between humans and robots, rather than an intrinsic property of robots as is often assumed in social robotics research. Using our Performative Body Mapping (PBM) approach, we have developed a robotic object for studying how social meaning is enacted when movement qualities meet kinesthetic empathy. In this paper we introduce PBM and how it harnesses performers' kinesthetic imagination and movement expertise for designing the movement potential and movement qualities of abstract, non-humanlike robots. We then present our recent study of how the social presence of our robotic object-in-motion emerges in an encounter, involving experts from performance and design. Preliminary results of this study show that our robotic object can successfully convey movement qualities and their intended expressions as embodied by a dancer as part of the PBM process. Finally, we discuss how our observations can shift our focus from attributing qualities to the object to an emergence of qualities, propelled by the encounter. We believe our study provides a glimpse into the dynamic enactment of agency and how it requires both sides to 'give' for the robotic object's characteristics and the participants' experience to evolve.

1 INTRODUCTION

Our desire to create artefacts and machines that are life-like and with whom we can connect on an emotional level is age-old [1]. Research in social robotics often strives to materialise human-machine relationships that are reminiscent of the human likeness of Maria in Fritz Lang's Metropolis [2], the companionship of Star War's metallic-shiny humanoid C-3PO and witty can-shaped droid R2-2D, or the cute demeanour of Pixar's WALL-E.

Pepper, for example, featuring soft feminine curves, a perky voice and an innocent cheekiness is marketed as an 'emotional' robot that "wants to be your friend" [3]. Much of current research favours human likeness over abstract, machinelike designs based on the belief that social agency can be 'given' to a robot by mimicking human appearance and behaviours [4, 5]. This technical view of social agents suggests that successful human-robot relationships should model human-human relationships [4]. Furthermore, it understands a robot's social capacity as a property that is a primarily intrinsic to the agent [5], without considering the social potential of the interactional exchange and situation [6].

But what if the relational dynamics unfolding in the encounter between a human and a robot play a significant role in rendering the latter a social agent? Locating social capacity not inside the machine but in the encounter or evolving relationship, shifts the design focus from the *representation* of agency to how agency is *enacted*. Such a distributed, enactive approach to social agency could open up a more diverse array of entry points into human-robot relationships, beyond simply mimicking the human. Instead of modelling humanlike appearance and behaviour, an enactive approach requires us to develop a deeper understanding of what happens in the encounter, i.e., how exchanges are negotiated, and how dialogical relationships are initiated and propelled. Importantly, these could be genuine human-machine relationships that embrace the differences of the mechanical.

From an aesthetic viewpoint, a non-humanlike and yet still expressive or affective robot, capable of initiating and/or propelling social exchanges with humans open up a much richer and less predetermined design space of possibilities. Also, robot designs that don't rely on the familiar organic bodies allow for encounters that are not constrained by "preconceptions, expectations or anthropomorphic projections … before any interactions have occurred" [7]. The challenge of this open playground is to find a starting point, from which to explore the social potential of machinelike agents.

Our project, Machine Movement Lab (MML), takes movement as a starting point to investigate the connection-making, relational potential of non-humanlike machines and how it can open up social situations. According to Erin Manning, movement *is* bodying or becoming-body, rather than "something the body *does*" [8]. Given this generative capacity of movement, we investigate whether movement can transform an abstract machine-object into an expressive performer. Bringing together creative robotics, dance/performance and machine learning, MML's enactive approach harnesses choreographic knowledge and kinesthetic expertise of performers to design a robot's movement mechanics and its capacity to learn to move in ways that support connection-making through movement qualities. To support this exploration we have conducted a series of workshops to design an autonomous robot with an abstract, non-organic form based on its ability to move expressively resulting in the development of a robot "costumes", enacted by performers, and an autonomous cube-shaped robot (see Section 3).

Importantly, our aim in working with choreographers and dancers is not to render the robot more human but rather to

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investigate the ecology of social relations and how they get activated through movement and kinesthetic experiences. Rather than understanding robots as mechanical artefacts that are 'implanted' with social qualities, our project looks at human-robot interaction as an enactment and how a robot contributes to this productive social performance through the transformative qualities of movement.

This focus on a built-in agency also shapes the ways in which we study humans interacting with robots. Typically, human-robot interaction studies bind participants' focus to a tightly orchestrated frame of interactive tasks [9]. Robots' social capacities are thus measured in terms of how well they perform existing human social tasks. While these studies produce useful results, they don't allow for much space to accommodate participants' imagination and experiences, let alone study them. Furthermore, this limited focus on how well a robot performs a social task promotes the idea that a machine's social agency can be predefined and programmed into it; and the more successfully so, the more the robot can replicate human qualities in performing the task. What is often missing is getting a better understanding of what makes a robot social in these scenarios, and what criteria and situations lead to rich or poor exchanges and strange, playful, creepy or emotive experiences. Granted, studying immeasurable and often difficult to articulate feelings of connectedness and sensations of resonance is a challenging task, and results are not nearly as decisive and comparable as more typical study outcomes. So far, we have completed two studies with participants with the aim of probing into their social experience of our delicately moving robotic object. We don't claim to have an answer to the challenging task of exploring the experiential and enacted between humans and machines. But if we keep dismissing these more ambiguous, difficult-to-capture constituents of social encounters, we are more likely to invest in humanlike robots simply because we lack the understanding of alternative social human-robot relations.

In this paper we will discuss related research, introduce our Performative Body-Mapping (PBM) methodology, and present preliminary results from a recent study with expert participants encountering our robot prototype.

2 RELATED WORK

Our project is situated in the emerging interdisciplinary research area of Creative Robotics, which explores human–robot relations from both a creative and a critical, socio-cultural perspective. The practice of Creative Robotics builds on a rich history of kinetic sculpture, robotic art, and machine performance.

Movement and its capacity to evoke affective responses has been central to a number of artists working with machine-driven agency. Edward Ihnatowicz's pioneering cybernetic work *The Senster* exhibited life-like movements to express its machine intelligence [10]. Simon Penny's *Petit Mal,* resembling a strange, responsive unicycle, according to the artist, takes on the role of "an actor in social space" [11]. *The Table* by Max Dean and Raffaello D'Andrea animates an ordinary looking wooden table that appears to choose visitors to develop a relationship with [12]. Louis-Philippe Demers' performance work *The Tiller Girls* features a troupe of up to 32 abstract, simple robots that generate their behaviours based on the specifics of their embodiment and interactions without using underlying computational models. These works materially manifest various forms of machine agency as it is enacted across the machine's performance and the audience's perception. Demers affirms this, stating that "the machine performer needs the co-presence of the audience to be fully materialised" [13].

Collaborations between robotics and performance domains have provided a testbed for evaluating robots' expressive capacity [14]. Many of these collaborative projects explore the theatrical value of machine performers, showing a tendency to integrate a robotic element within a conventional performance framework or event. Most relevant to our research are interdisciplinary projects that develop a performance-led methodology to investigate human-robot interaction, including Jochum et al's study of artistic strategies [15], including traditional puppetry methods, to inform robot motion design, Lu et al's approach for human actors to teach robots how to interact socially [16], and LaViers et al.'s somatic approach to robot motion design [17].

3 METHODOLOGY: MAPPING BETWEEN DANCERS AND MACHINE OBJECTS

This section introduces our methodology for exploring how non-humanlike robotic agents can look, learn and affect us, and take on a social presence. To investigate the potential of movement for expression and the enactment of agency without a humanlike veneer, our project develops an embodied approach to social interaction for designing a robot's mechanical structure and its capacity to learn how to move. From the outset, our aim was to expand the envelope of what we consider 'machinic' through the generative potential of movement qualities, rather than teaching the robot a set of specific gestures. At the heart of our methodology is a new embodied mapping method, called Performative Body Mapping (PBM), that harnesses performers' kinesthetic imagination and movement expertise. The purpose of PBM, in a nutshell, is the design of (1) an autonomous robot with an abstract, non-organic form and (2) a capacity to learn how to move in ways that are unique to its own machine body, shaped by the movement qualities it acquires from human dancers [18].

The underlying conceptual premise is based on social interaction being grounded in embodiment and, with it, the bodies' kinesthetic experiences [19]. In this notion of embodiment, our thoughts, feelings, and behaviours are grounded in our bodily interaction with other bodies and the environment [20]. Vice-versa, these thoughts, feelings and behaviours manifest in embodied ways in what Froese and Fuchs have termed "intra-bodily resonance" [21]. As they manifest, they also express themselves to others, who interpret them based on their own intra-bodily resonance. The resulting "inter-bodily resonance" [21] between bodies in motion is referred to by researchers in dance and dance studies as kinesthetic empathy [22]. The latter is a concept that facilitates our understanding of social interaction and embodied communication [23]. Importantly, from a performance perspective, inter-bodily resonance doesn't only 'translate' feelings but also a bodily processing of forces and tensions expressed in movement qualities and variations of energy, e.g. relations between tension and relaxation, degrees of intensification, weight or sudden stillness. These more ambiguous signals as a basis for initiating or sustaining social interaction, e.g., by communicating degrees of attention or relatedness are of interest to us because they avoid stereotypical emotional categories such as 'sad' or 'happy'.

Figure 1. Early PBM workshop, showing two tube-like costumes inhabited by performers.

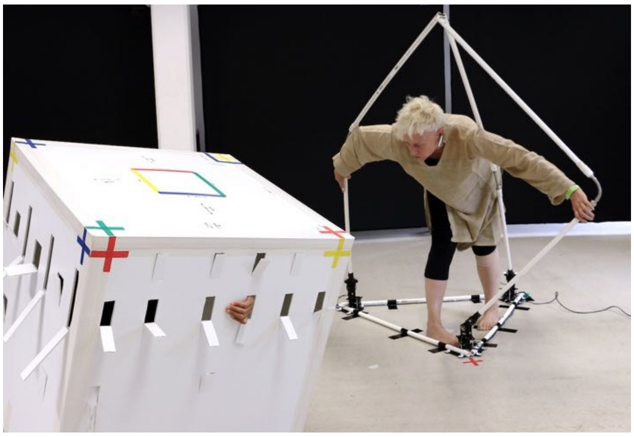

Figure 2. PBM workshop, showing a dialogue between two costumes inhabited by dancers (Tess de Quincey, on the right).

PBM relies on dancers' kinesthetic abilities to embody another, nonhuman body to develop movement qualities and kinesthetic expressions for *and with* this 'other' body. At its core, PBM deploys a 'costume', which stands in for a possible robot body and can be inhabited and bodily activated by a dancer/performer. It is a wearable object that extends the performer's body and constrains their habitual human movement. The PBM costume becomes thus the instrument for mapping between the different embodiments of the human dancer and the becoming-robot and, with it, their different movement capacities. It allows (1) for dancers to 'feel into' the machinic form and learn to embody it, and, later, (2) for a robot, resembling the costume, to learn from the dancer-costume entanglement by imitating its recorded movements. Importantly, this entanglement offers more than an aesthetically interesting movement repertoire. The performers' enactment with the machine's material body and the kinesthetic experience it produces is inseparable from their body's enactment with their social and cultural context [19]. We believe that the robot's movement qualities shaped through this enactment show visceral traces of this social and cultural embeddedness, without anthropomorphizing the robot. The PBM approach as a novel form of demonstration learning and the role of the costume as an instrument for mapping between different embodiments has been explored in more detail in [18].

Early movement workshops focused on exploring and challenging our assumptions and preconceptions with regards to possible machinic forms and movements (Figure 1). Later workshops focused on finding movement 'identities' with specific costumes, and the costumes' movements were continuously recorded (Figure 2). A detailed account of this earlier form-finding stages and movement studies can be found in [24]. So far we realised one of the costume bodies as robotic prototypes: Cube Performer #1 and Cube Performer #2 (see Figures 5 and 6). The movement requirements for the mechanical design of these prototypes were derived from an analysis of over five hours of motion capture recordings to determine the needed velocity, acceleration and ranges of movements—vertically, horizontally and rotationally.

But why a cube-shaped machine performer? A cube or a box presents a highly abstract, familiar geometric form, which, on its own, is not usually considered to be expressive or having a social presence. But our movement studies quickly showed the potential for movement qualities to transform the simple cube, for example, a sudden tilt, gentle sway or nervous teetering allow for the box to lose its stability and, with it, its 'boxiness' (Figure 3). It is this apparent schism between a cube's shape and its transformation through expressive motion that has motivated us to realize a cube-shaped machine performer.

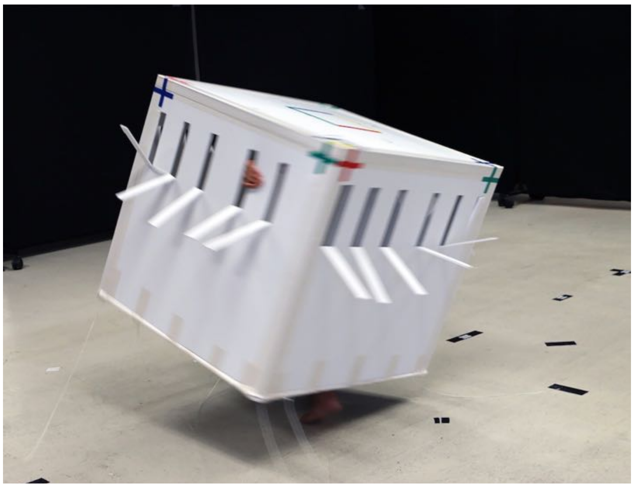

Figure 3. Cube costume activated by a dancer.

Our movement studies unfolded around a three way conversation between (1) a dancer inhabiting (2) a costume and (3) a choreographer, who directed the performer from an outside perspective onto this entanglement and its movements. Transparent costume components offer a window into the specifics of the dancer-costume entanglement and allow the choreographer to directly address body alignments, etc. in relation to the costume's transformation (Figure 4).

Figure 4. Cube costume with transparent sides, activated by Audrey Rochette.

Our process of developing the movement repertoire for the cube performer evolved dramatically over the course of this 3-year research. Earlier movement workshops were primarily exploratory and focused on developing a diverse set of movement characteristics with the cube costume. This resulted in motion capture recordings of about 10-minute-long movement phrases, in each of which the dancer-inside-the-costume explored a specific image or character, e.g., balancing the cube on one corner and raising the opposite corner with varying velocity, rhythm and weight, guided by the image of breath and how it changed according to different bodily states. Naturally, the cube didn't 'breathe' as a result, but the rhythm and dynamics of the motion brought about by this image, performed by a cube, exemplify the kind of transformations and connection-making abilities that we are interested in. *It has the effect of rendering the object in motion at once more strange and more familiar.*

4 RESEARCH DESIGN

In the following we present some preliminary observations from a recent study we conducted with expert participants who had a first-time encounter with our robot prototype.

The main aim of our study was to gain expert insights and feedback on the possibility of experiencing kinds of 'inter-bodily resonance' in an encounter with our Cube Performer (#2). The study is part of our evaluation process and builds on a previous study, set in a public exhibition, where we asked audiences to provide feedback on their perception of the robot and its affective qualities [18]. In this study, we wanted to dig deeper into the question of how PBM's wearable costume captures the dancers' movement qualities and allows the robot to mediate them back to affect peoples' experience. In particular, we wanted to get a better sense of what "gets across" in terms of these qualities, and how they are transcribed through the PBM process. We previously described this form of human-machine communication as *human-robot kinesthetics* [18], proposing that the dancers' "distinctive spatio-temporal-energic dynamics" [25] are transcribed into the costume's (external) kinetic dynamics that in the audiences' "kinetically-sensitive eyes" [25] register as kinesthetic empathy.

Of course, as with all translation, this is not a loss-free process, and PBM is not about translating between humans and machines. Rather, it is about seeding our machine learning with the aesthetic, social and cultural dimensions that shape the dancers' movement qualities. Since, as we mentioned earlier, the movements that the robot performs are not composed of specific, easily identifiable gestures and are further abstracted by the robot's shape, evaluating the robot's ineffable connection-making capacity is not a straightforward task.

To explore this capacity, we developed an encounter scenario and involved five experts from performance and five experts from design (including three experience/interaction designers), recruited by email, to reflect on and share their experience of encountering our Cube Performer. Designed as a three-stage encounter, we were particularly interested if of our participants could recognise specific changes in the robot's behaviour, not only in terms of changes in the movement but also with regards to how it affected them. To develop the encounter, we asked choreographer Tess de Quincey and dancer/performer Linda Luke to develop a short (3-minute) movement sequence with the cube costume and to explore this movement trajectory in three different qualities. As per the choreographer's and dancer's descriptions, one had a light and airy quality, another one a boisterous, 'chunky' quality and the third movement was dynamically situated between the first two, with a playful and less predictable quality.

In an attempt to describe the three movement qualities in a uniform manner, we have applied descriptors from Laban Movement Analysis (LMA). LMA has been applied to analyse human movements in a wide range of domains, from dance and theatre to everyday actions and, in recent years, robot motion design [26]. Given the non-anthropomorphic nature of our robot, we used only the 'effort' qualities of Space, Time, Weight and Flow to describe the movement qualities recorded (see Table 1).

Movement	Space	Time	Weight	Flow
1	Direct	Sustained	Light	Free
2	Direct	Sudden	Strong	Bound
3	Indirect	Sustained or Sudden	Light or Strong	Bound

Table 1. LMA 'effort' descriptions of the prevailing qualities of the three movement sequences developed for the robot.

Cube Performer #2 was then trained to move with these three qualities. The robot's responsive capacities were very limited, only put in place to make the encounter safe. We chose this largely pre-scripted path for our study scenario for two reasons: (1) to compare participants' responses, we wanted them to experience a very similar composition of movement qualities, and (2) the robot's capabilities to adapt its movements *in situ* are still in development. Adapting movement qualities and choreographic structures in response to peoples' behaviours in ways that don't compromise their integrity poses a significant challenge and we have yet to develop these embodied improvisation skills.

The study was setup in a large, empty performance space (Figure 5); we didn't use any special lighting as the encounter was not about "putting a spotlight" onto the robot. Importantly, the robot was only referred to as a "robotic object". While we didn't provide any further details of the object, we deliberately chose to bypass any expectations of this being an encounter with a human-or animal-like robot. The robot itself was only revealed in the encounter and presented as a simple wooden box, with an outer skin made of unpainted plywood. Participants were instructed to enter the space three times to experience a different stage of the encounter. In each stage, the participants experienced the robot performing one of the three movement sequences. The order of the sequences was randomised for each participant to minimise priming effects. Participants were instructed that they could move around in space and make use of the chairs on offer. With regards to providing feedback, we asked participants to reflect of what they had noticed after each stage by making brief notes and subsequently fill in a more detailed questionnaire at the end of all three stages. This final questionnaire was followed by a brief interview, which allowed us to further explore some of the participant responses. Including the three 10-minute encounters with the robot, each study session took about 40 minutes.

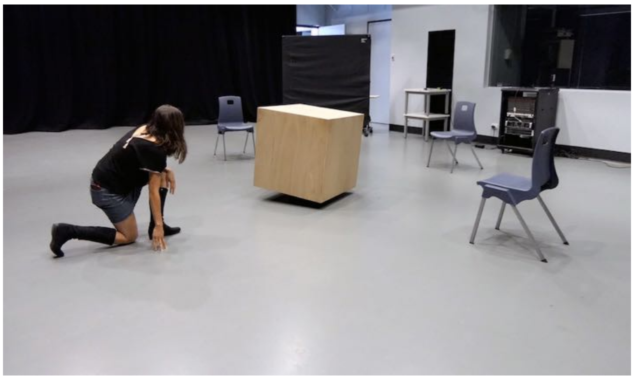

Figure 5. A study participant engaging with robotic object.

5 PRELIMINARY RESULTS

We are still in the process of analysing recordings of the participants' experiences and responses and can only provide preliminary results and observations here.

All ten participants perceived qualitative differences across the three stages, and nine participants described them in terms that align with the choreographer's and dancer's intended qualities, independent of the order they experienced them in (see Table 2). Having previously discussed the communicative potential of human-robot kinesthetics, this result suggests that there is a clear link between the images inscribed into the object by the dancer, the images' expression when externalized through the object's movements, and the participants' kinesthetic perception and interpretation. Seven of our ten participants described the robot's movement qualities as 'emotive' or 'visceral', an eighth participant referred to them as 'being in relation'.

Perhaps not surprisingly, there was a consistent difference in the way in which movement practitioners and interaction designers approached the robotic object, particularly in terms of meaning-making. Performance practitioners were significantly less occupied by a desire to "decipher" the meaning of movements and gestures. They focused more on how they felt connected to the object. For example, one comment was "I was surprised how intimate it was", another participant said: "We were just together". In general, design practitioners were more interested in exploring how they could evoke responses, for example, one participant rearranged the provided chairs to reconfigure the space and test the robot's response.

One of the most surprising results was that all participants perceived the robot as curious or responsive, behaving in relation to their presence. "We are in relation; it is working hard", as one participant commented. Even though from a technical perspective, the robot had very limited adaptive capacities. It is worth saying here that we had no interest in misleading our participants in that regard; we never referred to an 'interactive' or 'responsive' object during our recruitment, introduction, or in the questionnaire. Our survey responses consistently show that participants experienced a sense of co-presence despite its abstract appearance and limited interactivity. One participant commented: "I like its non-humanness … there is a companionability to it. Wow". Asked to reflect on their experience, other participants said: "When I'm still, it moves more, like it wants to play"; and another: "It comes across as playful with an 'honest curiosity', like a wild animal". From an experiential viewpoint, this suggests that the object-in-motion could trigger the participants' curiosity, sustain their interest and affect their own behaviour and evolving impression, despite the largely rehearsed performance of Cube Performer #2. To understand more about how much delicate, decisive or dynamic movement qualities contribute to an object taking on a social presence, we will need to undertake a study in which our Cube Performer also moves like a vacuum cleaner, that is, like we expect a machinelike agent to move.

Stage	Choreographer's & Dancer's Description	Participants' Own Descriptors
1	light and airy	sensitive, tender, tentative, gentle, delicate, timid, less dynamic than other two stages
2	boisterous, chunky	aggressive, more violent, agitated, sharp, competitive, purposeful, show-off, decisive
3	playful, dynamic, unpredictable	playful, dynamic, attention seeking, intense, animal-like, broader repertoire, moved with attitude

Table 2. Participants' descriptions of different movement qualities perceived in encounter stages 1–3.

6 DISCUSSION

The participants' social perceptions in this encounter could simply be dismissed as mere projections by the participants onto the object. After all, their respective areas of expertise brought a set of sensitivities to the encounter that was useful for providing explicit feedback but that may have also primed their experience. But projections here are more than attributions elicited by specific behaviours. According to Goffman, they play a significant role in shaping any social encounter, whether they are about maintaining projections of a self-image or negotiating projected definitions of the situation [27]. Also, the Cube Performer contributes its own projections—kinetically. Encounters with our cube-shaped robot during public events, as well as in this study, often unfold in surprisingly parallel ways to Goffman's dramaturgical observations about social interactions. Our motivation, however, is for the machine to not actively 'project' human qualities. "I was surprised how intimate it was. I responded to it like another species and increasingly so", said one participant. Due to the robot's familiar but highly abstract shape, it could be argued that the evolving social experience can be entirely accredited to its intricately choreographed movement qualities. However, the specificities of the object's shape come into play with regards to the movements' capacity to transform the object. For instance, the cube seems to 'take on' a face-like front on any of its four sides, along its edges or, suggesting a nose-like feature, by one of its four top corners, depending on one's position in relation to the object's movement dynamics (Figure 6). Some of our participants confirmed this previously observed dynamic, expressive effect.

Our approach and participants' responses raise questions regarding movement and its effect of 'animating' objects. Giving on-screen characters the appearance of movement is, as the word 'animation' suggests equated with 'bringing to life'. With this in mind, it could be argued that the animation of machines blurs the boundary between the organic and mechanical. Even though 'giving life' was not what we aimed for with our methodology, the effects of a simple object moving in delicate or playful ways undoubtedly opens up an ambiguous and possibly uneasy zone between subject and object. Animation also commonly presumes a life-like force or quality bestowed onto the object [28]. Looked at from this perspective, animated objects support traditional notions of agency, aligned with a view that agential capacities can be 'given' to an object—a view that underlies many current approaches in social robotics, that as we pointed out earlier are problematic (see Section 1). On the other side of the argument, our studies so far seem to support that a less mimicking approach that offers visceral encounters with machines complicates the simplistic pathway of programming social agency into machines by giving them life-like properties. In our study, five participants from both performance and design compared their experiences to the kinds of responses they have towards animals, while being clear that this analogy is as much about their approach to the object as it is about what the object projected. This mutual recognition clearly points to a shift in focus from attributing qualities to the object to an emergence of qualities, propelled by the participant and the object, embedded in a specific situation.

Even at this preliminary stage of analysis, our study has given us a glimpse into a dynamic enactment of agency that requires a dance between the two, where both sides need to 'give' for the object's characteristics and the participants' experience to evolve. We believe our embodied, machine-embracing approach and the "disjunction of form and movement" [29] can open up new and interesting human-machine relationships based on kinesthetic empathy rather than mimicry. More studies are required, however, to better understand the transformation of objects/machines through movement, including its potential for deception.

6 FUTURE WORK

Future work will include more studies with both expert and non-expert participants. Our assumption is that the latter will show a preference for less ambiguous, intensity-driven movement qualities in favour of more readily accessible communication signals to connect to the Cube Performer, but this remains to be tested. Important future work also includes expanding our machine learning system to learn to delicately adapt to changes in the environment and behaviours of other agents. Our goal is for the robot and its underlying AI to learn how to improvise based on what it has learned to imitate, grounded in its own unique mechanical embodiment. Will such improvisational skills open up dialogical experiences between participants and the robot, and how will they shape this social enactment, compared to the encounter we discussed here? We are keen to contribute to developing a better, empirical understanding of the aesthetic, social and cultural potential of machinelike agents and how they can participate in enactments of rich social exchanges beyond human mimicry.

Figure 6. *Cube Performer #1* exhibiting a fleeting face-like front in the interaction.

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