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Dance, Dance, Dance With My Hands: Third-Party Human Robot-Human Interactions

Sorina-Silvia Cîrcu^{4,1*}, Bruno Yun², Abderrahmane Kheddar^{1,3}, Chu-Yin Chen⁴, and Madalina Croitoru¹

Abstract—A robot can affect its social environment beyond the person who is interacting with it. Within this context, we believe it is important to explore Human-Robot Interactions (HRI) in complex social settings. To this end we examine the effect of different robot shapes in a multi-person context during dance routines, to understand how the design of the robot enhances the artistic process and through which factors human preferences are being shaped within a novel third party setting human-robot-human interaction (HRHI).

I. INTRODUCTION

Questioning how knowledge gained through art practices “can relate to other forms of knowledge regarded by the public as more or less authoritative or trustworthy” [1], art is seen as a perfect frame for distributed knowledge.

Current research suggesting that people’s behaviors towards robots are influenced by the observation of third-party encounters between robots and other people [2], offers important insights. To the extent of our knowledge, we are the first to investigate third-party (i.e. robot - robot - human) interactions [3] within a dance imitation setting. Such interactions will become more and more common with the rise of the robot [4], [5], [6], [7]. In parallel, nonverbal behaviours [8], [9] prove their efficiency in collaborative processes between humans and robots. According to [10], a robot can affect its social environment beyond the person who is interacting with it. Within this context, we believe it is important to explore Human-Robot Interactions (HRI) in complex social settings. Our initial study was based on a collective HRI done with virtual avatars of robots during a dance workshop. The next step of our research, allows us to tackle new interaction possibilities and verify a new hypothesis about the human-robot social dynamics: *from the perspective of another human interacting with a human-robot dyad, our hypothesis is the embodiment type influences how the robot is being perceived and its impact on the creative environment.* Through our approach, we examine the effect of different robot shapes in a multi-person context during dance routines, to understand how the design of the robot enhances the artistic process and through which factors human preferences are being shaped within a third party setting human-robot-human.

In this paper, motivated by the flourishing perspective of staging robots in art performances, we introduce a novel third-party human-robot-human interaction (HRHI) setting as defined in [3]. Traditionally third-party interactions are notably less studied than their two-party counterparts (see for instance mediation studies with respect to negotiation studies etc). We restrict ourselves to the setting of collaborative dance routines involving upper body movements between a professional dancer, a robot, and a human. Through this setting, we are interested in the creative potential of such interaction partners that we propose to measure by the improvising capacity of the human spectator. As noted by [11], creativity in works of art involves skill defined as a certain “plasticity of the control”, i.e., being able to see beyond the specific problem with which one is dealing and having a real understanding of the methods and procedures of the discipline and the principles that lay behind them.

We propose to analyze the improvisation capacity induced by the third-party creative state from the following key points: substitutability [12], synchrony [13], [14], [15] and kinaesthetic awareness [16], [17] of the participants:

- In dance, remembering a phrase or a gesture involves a process of assimilation known as marking, where each dancer reproduces the movement material by activating different body parts. The observations of [12] propose the marking technique as a scaffold to mentally project a more detailed structure than one could otherwise be held in mind. Similar to an interactive strategy augmenting cognition, dancers mark with their bodies, dance sequences to remember and transmit them. One of the proprieties of the marking is substitutability, describing how a movement in one body part can represent the movement in another. Following Kirsh’s observations that “hand movements and head tilts regularly stand for the motion of different body parts”, we propose a “dance with the hands” experiment translated by robots, that encodes different body parts in the human partners. In robotics this can have equivalent implications with “the correspondence problem” as defined in [14].

- Synchrony refers to simultaneous actions in our study, playing an important role in collaborative practices [18]. As defined in [19], this process corresponds to “the dynamic and reciprocal adaptation of the temporal structure of behaviors between interactive partners”. Moreover, synchrony influences the interaction quality to a greater extent than imitation because “unlike mirroring or mimicry, it is dynamic in [...] the timing, rather than the nature of the behaviors [19].”

- Alternatively, the kinaesthetic awareness is a very important part of human physical education, involving inner

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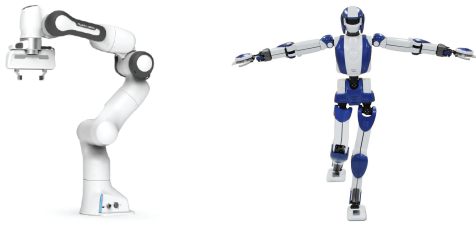


Fig. 1. Representation of the Franka (left) and the HRP-4 (right) robots.

physical sensations, among which the sense of balance and muscle tension. Seen as an ability to learn new things by understanding and controlling the position and movement of ones' body, it is a key factor in dance improvisation. According to [20] this type of awareness is related to embodiment [21] in human performers. Further on [16] introduces the concept of kinaesthetic empathy, "which explores the affective potential of movement and, with it, our innate capacity to kinaesthetically perceive other bodies." To tackle this hypothesis, the authors set up a study involving the BodyWeather dance training technique developed by choreographer and dancer Tess de Quincey. This technique's aim is to cultivate body's sensitivity and connectedness with its environment, while generating original movement material. In a similar approach, we focus on dance improvisation mixed with spontaneous gestures to determine how participants with little experience in dancing are relying on the robot to improvise.

Transposing these observations to human-robot interactions, allows us to determine the impact of robots on an overall artistic process and analyze how the embodiment type influences the spontaneous responses in humans.

II. THE HRHI EXPERIMENT

A. Preliminary experiment

In the first preliminary experiment, we recruited 25 French participants (24 females and 1 male) from a dance class at Lycee La Mercy in Montpellier. The experiment took place in November 2022. The mean age of the participants was 16.44 (SD=0.58, MD=16). The participants had a group experience of HRI, during a collective dance training session. We prepared three video sequences of one minute each where a series of gestures was executed, following the same order. The 25 participating students were instructed to imitate and then improvise with the virtual versions of an industrial (Franka) and a humanoid robot (HRP-4), see Figure 1. We asked them to collectively imitate each sequence in the following order: human, industrial robot and a humanoid robot. Once this imitation process occurred, we switched off the projection and asked the participants to collectively improvise using the gestures learnt during the video trials. The improvisation lasted for about 15 minutes and at their demand, we used recorded music to enhance expressive states. Videos of this experiment are available online (<https://vimeo.com/779347404> and <https://vimeo.com/779363288>). At the end of this process,



Fig. 2. Still from the HRP-4 experiments. Imitation phase above and improvisation phase below

we asked the participants to fill in a form with 23 questions. The feedback after the collective improvisation was that learning by imitation facilitates the emergence of a creative interaction type, improving the quality of movement.

Our goal was to understand how digital anthropomorphism triggers creativity and the experiment provided useful insights giving us the opportunity to tackle this concept in a broader context; but, more importantly, it put the basis for investigating the innovative HRHI setting introduced in this paper and described in the next section. Among our observations, we noted that the place the robot has within the experiment depends on the familiarity with the subject.

B. Participant recruitment

For investigating HRHI, we have recruited 21 French participants (7 females and 14 males) from Université de Montpellier. The experiment took place in March 2023 at the Laboratory of Computer Science, Robotics and Microelectronics of Montpellier. The mean age of the participants was 24.9 (SD=3.11, MD=24). The study was conducted under the ethical approval of the University of Montpellier.

C. Methodology

Each of our participants had to attend two sessions, one with the Franka robot and one with the HRP-4 robot (in this order). Those two sessions were split into an imitation phase (phase 1) and an improvisation phase (phase 2).

The third-party interactions used a minute-long movement sequence for each of the robots. We first programmed the humanoid robot, then adapted the sequence to the physical limitation (i.e., the number of degrees of freedom and joint order) of the industrial arm, having an identical time grid (i.e., a pause — freeze of motion — occurred at the same moment and lasted for about 5 seconds). The sequence order was identical for each interaction during the imitation phase, while the order of gestures was performed randomly during the improvisation phase. At the end of each session (after the two phases), the participants had to answer 29 questions, referred to as Q_i , $1 \leq i \leq 29$. The list of questions and

| Question | | X = Humanoid (HRP-4) | | | X = Industrial (Franka) | | | paired <i>t</i> -test |
|----------|---|----------------------|------|------|-------------------------|------|------|-----------------------|
| ID | Statement | AVG | MD | SD | AVG | MD | SD | <i>p</i> -value |
| Q1 | I have interacted with X robots. | 2.10 | 2.00 | 1.09 | 2.05 | 1.00 | 1.28 | 0.666 |
| Q2 | I could easily imitate the dance sequence performed by the dancer. | 2.71 | 3.00 | 1.35 | 3.05 | 3.00 | 1.07 | 0.339 |
| Q3 | I could easily imitate the dance sequence performed by the X robot. | 4.48 | 5.00 | 0.60 | 3.57 | 4.00 | 1.03 | 0.002 |
| Q4 | During the first session, I felt encouraged to do my own movements and improvise. | 1.90 | 2.00 | 0.94 | 2.33 | 2.00 | 1.06 | 0.071 |
| Q5 | After the first session, I felt encouraged to do my own movements and improvise. | 3.81 | 4.00 | 1.21 | 3.95 | 4.00 | 1.02 | 0.452 |
| Q6 | When improvising, I felt the need to touch the X robot. | 1.10 | 1.00 | 0.30 | 1.48 | 1.00 | 0.75 | 0.042 |
| Q7 | While improvising, I wanted to make the X robot react to my gestures. | 1.81 | 2.00 | 0.81 | 2.19 | 2.00 | 0.81 | 0.119 |
| Q8 | I could easily distinguish intentional from unintentional (or reflex movements like yawning) from the dancer. | 3.33 | 3.00 | 1.02 | 3.05 | 4.00 | 1.32 | 0.267 |
| Q9 | I could easily identify a movement equivalent to human reflex movement from the X robot. | 4.33 | 5.00 | 1.02 | 2.33 | 2.00 | 1.02 | 8.712e-06 |
| Q10 | I felt comfortable imitating the X robot movements. | 4.10 | 4.00 | 0.89 | 3.86 | 4.00 | 0.96 | 0.309 |
| Q11 | I felt comfortable imitating the dancer's movements. | 3.24 | 3.00 | 1.00 | 3.19 | 3.00 | 1.21 | 0.858 |
| Q12 | I felt more inspired by the dancer's movements. | 3.19 | 3.00 | 1.08 | 3.10 | 3.00 | 1.22 | 0.754 |
| Q13 | I felt uncomfortable while imitating the X robot's movements. | 2.10 | 2.00 | 1.14 | 1.95 | 2.00 | 0.97 | 0.614 |
| Q14 | Compared to humans, robots are generally strange creatures. | 2.29 | 2.00 | 1.23 | 2.29 | 2.00 | 1.31 | 1.000 |
| Q15 | Compared to the human dancer, it was more interesting for me to follow the movements of the X robot. | 3.71 | 4.00 | 0.96 | 3.48 | 4.00 | 1.08 | 0.437 |
| Q16 | During the first session, I imitated 100% of the X robot movements. | 4.05 | 4.00 | 1.16 | 3.10 | 3.00 | 1.58 | 0.006 |
| Q17 | During the first session, I felt in synchrony with the X robot while imitating it. | 3.33 | 4.00 | 1.39 | 3.52 | 4.00 | 1.17 | 0.592 |
| Q18 | During the second session, my improvisation was... | | | | | | | |
| Q19 | During the second session, I felt in synchrony with the X robot while improvising with it. | 2.48 | 2.00 | 1.21 | 2.48 | 2.00 | 0.93 | 1.000 |
| Q20 | I only improvised once I felt comfortable and understood what are the constraints. | 3.00 | 3.00 | 0.95 | 3.24 | 4.00 | 1.41 | 0.382 |
| Q21 | I felt the need to add other moves once the movement sequence got repetitive. | 3.00 | 3.00 | 1.22 | 3.00 | 3.00 | 1.38 | 1.000 |
| Q22 | The X robot movements are movements I usually do when I dance. | 1.95 | 2.00 | 1.12 | 1.71 | 2.00 | 0.78 | 0.329 |
| Q23 | Once I started improvising, I felt the X robot movements were reacting to my own movements. | 1.52 | 1.00 | 0.68 | 1.86 | 2.00 | 0.85 | 0.130 |
| Q24 | I can qualify the movement sequence of the X robot as "natural". | 2.29 | 2.00 | 1.10 | 2.76 | 3.00 | 0.94 | 0.086 |
| Q25 | I felt the human dancer communicated some emotions through dance. | 3.57 | 4.00 | 1.16 | 3.43 | 4.00 | 1.16 | 0.624 |
| Q26 | I felt the X robot communicated some emotions through dance. | 2.05 | 2.00 | 1.20 | 2.19 | 2.00 | 1.08 | 0.624 |
| Q27 | After this experience, I could spend more time engaging in artistic interactions with both humans and X robots. | 3.43 | 4.00 | 1.03 | 3.67 | 4.00 | 1.15 | 0.204 |
| Q28 | In my opinion, X robots should dance because... | | | | | | | |
| Q29 | In my opinion, X robots can be creative if their movements are... | | | | | | | |

TABLE I
SUMMARY OF THE QUESTIONNAIRE STATISTICS

some statistics about their answers are detailed in Table I. Please note that Q28 and Q29 are open questions with free-text answers; in Q18, the participant had to choose between “did not respect the instruction to improvise”, “alternatively improvised a few times with the robot and a few times with the human”, “completely improvised by myself not giving attention to either human or robot”, “imitated the human who was improving with the robot”, “felt both improvising with the human and the robot at the same time”, “improvise only with the robot”, and “improvise only with the human”; in Q6/Q7, the participants had to choose between “No” (1), “Maybe” (2), and “Yes” (3). In all the other questions, the participants had to answer using a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree).

Questions Q2-4, Q10-11, Q13, and Q15-17 (light grey) analyze the imitation context through synchrony and substitutability, whereas Q5-7, Q18-20, and Q23 (dark grey) focus on kinaesthetic awareness during the improvisational part.

Working with real robots instead of their digital twins [22],

[23] is motivated by the fact that dancing sequences appearing smooth in simulations are altered by live noise, hazardous physical contingencies, and subject to mechanical constraints when enacted through robot bodies. As [21] states, “such unpredictability is related to a robot’s material embodiment, and part of their idiosyncratic charm as performers”. Additionally, the professional dancer used a combination of intentional, aesthetic gestures and reflexive and everyday gestures (like yawning) during the improvisation phase, adapting its behaviour to each participant. When the dance improvisation was less comfortable, she engaged in direct contact with the participant, changing place accordingly or performing fewer movements. When the participants expressed agency and autonomy during the improvisation, she deliberately imitated the participant, then performed a series of expressive motions to see if the participant continues the process further. These differences are addressed in Q8 and Q9 (green).

As the humanoid robot has gestures and movements that are easily recognized as everyday gestures by the partici-

pants, we added an extra movement type to the sequence, having the robot shake some body parts during the sequence. This movement type helped the participant distinguish intentional from unintentional (or reflex movements) in the humanoid. It also produced occasionally a loud noise. Alternatively, the industrial robot performed the sequence without symmetrical body parts and the equivalent of shaking expressed through jerk during some joint rotations. Our choice to develop an interaction involving only upper-body dance routines is influenced by the fact that working with constraints enlarges expression possibilities in humans and reduces the risks of robot malfunctioning. As the industrial arm is set on a fixed base, it seemed logical to get the humanoid robot immobile, on a chair. A second chair was available during the humanoid robot experiments, and participants were instructed to choose between using it or not at the beginning of each session. Depending on the choice of each participant, the dancer chose accordingly. As a result, the setting of each experience was different, having the participant and the humanoid sitting, the dancer and the humanoid sitting, or both humans standing and the humanoid sitting. The affordance characteristic [24] involving a chair requires adopting a reflexive, static position while the human has to compensate with the hands to generate expressive movements. The aspects of comfort and constraints were addressed in the Q10, Q20 and Q24 questions.

The rest of the questions are oriented towards the comprehension of creativity involving the three key points mentioned in Section I alongside subjective input expressed through questions oriented towards emotions.

III. RESULTS AND DISCUSSION

Considering creativity is a combination of skill and intention [25], [26], [11], [27], our methodology identifies the factors that differentiated a result from either non-creative or creative. Given these premises, we proposed a model of HRHI based on two phases (dance imitation and dance improvisation) to analyze the human expectations within. We analyzed through our questionnaire the kinaesthetic awareness, the substitutability as well as the synchrony potential of two robots operating in an identical laboratory setting. Although the motion algorithms were identical, the robots' moves elicited different reactions in the participants. Their feedback might be related to their familiarity with robots (i.e., participants less accustomed to robots were more enthusiastic about their creative potential in dance). We summarize our results and identify some of the challenges as follows. A detailed version of the data is available here: https://osf.io/rkqwt/?view_only=ac3cb3ca6e4b4da09052ef5ffeb4d1c2.

A. Numerical analysis of results

During the imitation phase, 95.3% of the participants easily imitated the dance sequence for the humanoid robot, compared to 61.9% for the industrial arm. Moreover, 71.5% of the participants in the interaction with the humanoid robot and 61.9% for the industrial arm considered it not suitable

to use improvisation movements during this phase. These participants were engaged in what Dourish calls "absorbed coping" [21], or a full engagement in the interaction, with 47.6% of participants for the humanoid and 33.3% participants for the industrial arm, not imitating the professional dancer at all. A similar distribution of answers regarding comfort during the imitation: with 85.7% participants feeling comfortable while imitating the humanoid robot and 38.1% the dancer, compared to 66.7% for the robot and 42.85% for the dancer - for the industrial arm robot. This might be correlated with the fact that for the humanoid robot, 71.4% of the participants decided to sit on the chair during either the improvisation or the imitation phase. The feeling of being inspired by the human dancer's movements compared to the robot follows the same trend, with 42.8% of participants agreeing this is the case for the humanoid robot, compared to 38.9% for the industrial one. Overall, the participants found it more interesting to follow the movements of the robot, instead of the dancer- with 66.7% for both the industrial and the humanoid robots. Only a small minority- 19% for the industrial and 14.3% for the humanoid identified emotions in the robot's dance, compared to the human's - 61.9% for the industrial session and 57.1% for the humanoid one. According to [28] in bodily emotional expression modes, humans can recognize on average about 50% of a robot's emotions correctly. The lower score in our study can be explained by the fact that the robots were not reactive. This observation emphasizes our intuition that participants engaged in dance (either imitating or improvising) were less likely to contemplate the performative act and ascribe emotions to either human or robot. On another note, during the imitation phase, 66.7% of the participants felt in synchrony with the humanoid robot compared to 57.1% for the industrial robot. Comparing these results to the same question regarding the improvisation phase, we note a difference, as only 14.3% for the industrial robot and 23.8% for the humanoid robot responded positively. This finding proves that synchrony is less established through dance improvisation, regardless of the robot type or the dancer.

Another interesting fact to mention is that while improvising, the participants did not feel the need to engage in physical contact with the robot (66.7% for the industrial arm and 90.5% with the humanoid robot) with a slight indecision percentage for the industrial arm (19%), compared to (9.5%) for the humanoid robot. Alternatively, 14.3% of the participants in the experiment with the industrial arm responded affirmatively to this question, whereas none for the humanoid robot. This interest in physical contact, reinforcing the kinaesthetic awareness during the improvisation phase, can facilitate a dance creative state in HRHI dance.

While improvising, the majority of the participants (80.95% for the industrial robot and 90.4% for the humanoid) rejected the idea the robot was reactive, regardless of its shape. However, 42.85% of the participants for the industrial robot and 23.8% for the humanoid to make the robot react to their gestures.

Since we included in the dancer's sequence a set of

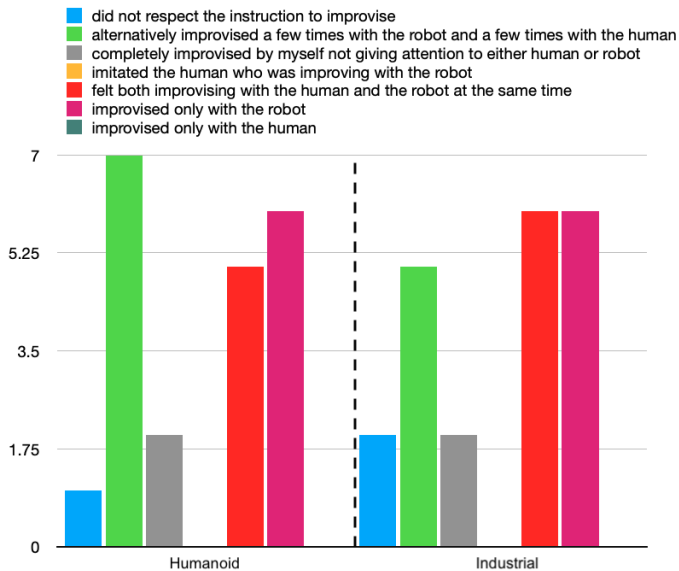


Fig. 3. Number of participants for each answer to Q18 in the two sessions (humanoid and industrial robots).

unintentional movements (type yawning and shaking) among the standard, aesthetic movements- we wanted to see if the participants made the distinction between them during the third-party interaction. In both cases, 52.4% for the industrial arm and 47.6% for the humanoid one, participants managed to identify them. For the robots, these movements were simulated during the improvisation phase sessions, where each sequence was performed in a random order compared to the imitation phase. For the humanoid robot, a state inspired by human shaking was added. Only 19% of the participants for the industrial arm identified these movements, compared to 85.7% for the humanoid robot. We explain this difference by the fact that the shaking movement was relatively different from the rest of the movements of the sequence, and also analogical to states of neurological dysfunctions in the human body. The occasional jerk from the industrial robot was less attributed to a human-like characteristic.

When asked whom they have improvised with during the second session, the answers had a similar distribution for both robots. For the humanoid robot, 33.3% of the participants improvised alternatively with both human and robot, 28.6% only with the robot, 23.8% improvised with both at the same time, while 9.5% completely improvised by themselves and 4.8% did not respect the instruction to improvise. For the industrial arm, 28.6% of the participants improvised with both human and robot at the same time, another 28.57% improvised only with the robot, 23.8% improvised alternatively with both human and robot, while 9.5% completely improvised by themselves and others 9.5% did not respect the instruction to improvise. An explanation of these dynamics is illustrated in Fig. 3. We note that none of our participants responded they improvised with or imitated the dancer exclusively, regardless of the robot shape, proving the focus in an HRHI remains on the robot.

B. Limitations and future work

One shortcoming of our experiment is the order in which the trials occurred. Most of the participants started with the industrial arm experiment and then in the humanoid one. Our intention would have been to have the participants interact in random order with the two robots, but for logistic reasons, it was not possible. The imitation phase and its incidence in the participants regarding the humanoid robot might be explained by the fact that seeing the context of the experiments before, got the participants more accustomed to the constraints. Alternatively, these participants were less engaged in the need for a physical contact with the robot, challenging the idea of creativity emerging from collaborative practices like dance contact. Overall, the number of participants might also be a limitation for our analysis, as the data set is small compared to other studies.

As for our key factors, if substitutability and synchrony are verifiable (i.e through video analysis or direct observation), working with kinaesthetic awareness has a dual nature and is more difficult to measure. According to [17]: “sensorimotor processes can be characterized as both opaque and transparent. The apparent contradiction is resolved when considering that in both cases there is an issue of not seeing: opacity prevents us from seeing what we try to see, transparency is not seeing that through which we see.” To understand its incidence in the improvisation process we rely on our participants’ feedback but hope that for our future studies, some sensor measurements could complement our analysis. Furthermore getting both robots to react to participant’s movements (i.e., similarly to the human dancer) could also positively affect the overall feedback regarding creativity.

IV. CONCLUSION

Unlike other art forms, dance co-exists with traditions involving common, everyday gestures that later inspire aesthetic processes. Throughout its history, post-modern dance has renewed its expression by mixing these everyday gestures with aesthetical ones on stage, through a process of imitation and improvisation. Imitation in human-robot interactive dance has been long researched in the literature [29], [30], [31], especially in an embodiment setting [32], [33], [34]. While improvisation was mostly used to improve robots’ reactivity and social acceptance [21], [35], [36], [37] artists get robots to improvise on stage whether it is for dancing [38], [21], [16] or playing music [39]. It is important to specify that in our current study, rather than improvising, the robots are emulating improvisation according to pre-programmed algorithms. Originally a tool for composition, HRI dance improvisation is becoming a live performance technique enhancing creativity in the performers. Inspired by the work of [21], we used improvisation as a bottom-up approach for analyzing embodied interaction in dance. As [40] states, robot design changes rapidly while models become obsolete once companies stop developing them further. Consequently, the robotic community has difficulties in sharing common ground on what the term “robot” currently implies, including a large spectrum of shapes like “android, humanoid,

mechanoid, machine-like, zoomorphic or anthropomorphic”. Within such categories, understanding the interaction possibilities between humans and robots is a complex challenge, at the core of several disciplines involving robotics, neuroscience, psychology, ethology, philosophy of mind, and possibly arts. Recycling current practices, technologies, and protocols is less investigated than innovative models, leading to an oversimplified view of HRI. Consequently, we expanded the original settings of HRI to a third-party interaction model, in order to develop further emergent concepts related to arts and creativity that could increase social acceptance of robots. The authors in [41], [17], [21], cite the computer scientist Paul Dourish for whom “embodiment is not a property of systems, technologies, or artefacts; it is a property of interaction”. The type of embodied interaction we studied aims at “the creation and sharing of meaning” as defined by Dourish. In conclusion, the concept of embodiment is not limited to the physical manifestation of people and objects, being expanded to collaborative relationships between people and things. Through our study, we highlighted the importance of third party interactions in art experiments involving robots, hoping these models would increase the quality of exchange between them and humans in different social contexts.

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