The Greeting Machine: an Abstract Robotic Object in the Context of an Opening Encounter

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***Abstract*— Opening encounters are an integral element of everyday social interaction, and are essential for forming and maintaining social relationships between people. We present an abstract non-humanoid robotic object called the Greeting Machine, designed to communicate positive and negative social cues in the context of opening encounters. The design is of a small ball rolling on a larger dome, with a unique gear mechanism that supports a variety of subtle movements. Gestures were designed with movement experts, and were evaluated in the context of opening encounter, in a physical first-person qualitative study. Our findings reveal that an abstract non-humanoid robot designed with no metaphor to an everyday function, can be experienced as a positive or negative opening encounter. Furthermore, minimal movement, designed as Approach and Avoid gestures, may be enough to generate these positive and negative experiences. The potential in creating opening encounters with low Degree of Freedom (DoF) non-humanoid abstract robots is promising, due to the low complexity, low cost, and design flexibility of such devices.**

I. INTRODUCTION

During the first seconds of meeting a person when entering a space, one receives and evaluates non-verbal cues from the other person [1]. These first few seconds form an *opening encounter* that provides an immediate impression of the other person's willingness for interaction [2]. Research in human social interaction shows that opening encounters are a universal act [3], [4] which involves rapid exchange of non-verbal cues indicating if one is inviting or avoiding the arriving person [2], [5]. As such, opening encounters can be either positive or negative [6]. This "non-verbal signaling" has been found to affect the subsequent social interaction [4], for example a positive encounter can lead to prolonged social interaction, while a negative one to avoidance from interaction [4], [7].

Opening encounters were also shown to influence psychological aspects beyond the interaction. Increase in mood, motivation, compliance, and general wellbeing have been found following a positive opening encounter [4], [8]–[14]. The importance of opening encounters is also evident in industry, where employees are assigned to provide positive opening encounters to customers [11], [15]–[17]. In sum, opening encounters are an integral element of social interaction, essential for forming and maintaining social relationships.

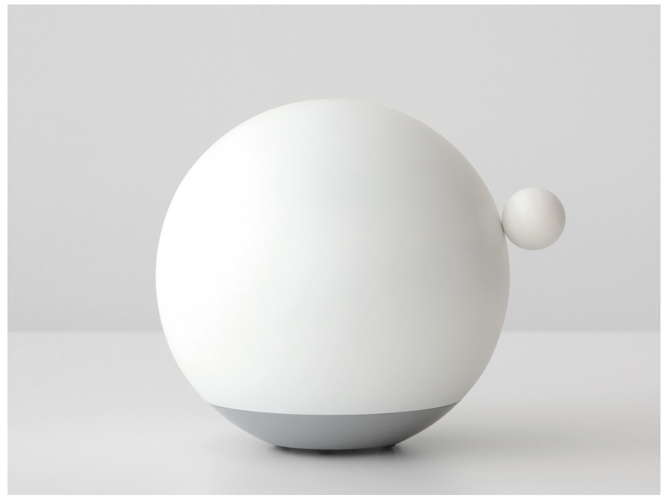

Fig. 1. The Greeting Machine, a low-DoF robotic object designed for opening encounters, in the form of an abstract ball rolling on a dome.

In this paper we present the design and evaluation of the "Greeting Machine", a robot intended to provide socially effective non-verbal opening encounters.

Recently, robots started to take a role of greeting or welcoming in a variety of service industries including retail, hotels, public transport and more [18]–[25]. Robots performing a greeting role are thought of as a way to promote services, attract new customers, and create a pleasant atmosphere [26]. These robots are commonly designed with humanoid appearance and communicate opening-encounter cues by mimicking human behavior. Most of them also include verbal greetings [18], [21]–[24], [27], [28]. Human Robot Interaction (HRI) researchers also studied a variety opening encounters with humanoid robots. Behaviors were usually human-like and included communication cues such as facial expressions, nodding, hand-waving, and eye gaze [29]–[31]. These human-like non-verbal behaviors were shown to be successfully interpreted as social cues [29], [32]. A few studies tested social interactions including opening encounters with non-humanoid robots designed as everyday devices, including an ottoman, a car seat, and automatic doors [33]–[35]. The non-verbal cues expressed by these non-humanoid robots were successfully interpreted as a social interaction related to greeting.

Non-humanoid robots have several advantages that make

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them leading candidates for social interaction in daily contexts [36]. From a design perspective, taking away the constraint of a human-like figure allows flexibility and freedom for the designer [37]. Moreover, non-humanoid robots are mechanically simpler, have fewer Degrees of Freedom (DoF), are more reliable and therefore are easier to control and cheaper to manufacture. Finally, in the context of social interaction, non-humanoid designs reduce unrealistic expectations, a known phenomenon with humanoid robots. These expectations include a desire for human-like behavior, that may result in frustration [36], [38]. From a broader perspective, animation studies on the relationship between appearance and acceptance indicate that abstract characters tend to be accepted more easily [39].

At the same time, non-humanoid robots also present challenges. Their limited movement capabilities restrict non-verbal communication modalities, which is usually a significant part of a non-humanoid robot's expressive arsenal [40]–[42]. A key research question is thus how people interpret the physical movements of such movement-restricted robots.

A relevant indication was offered by the seminal study of Heider and Simmel who showed that people interpret even geometrical shapes as presenting social cues based on their movement alone [43]. From an HRI perspective, this suggests that movement of non-humanoid robots may also be interpreted as social cues [44] even if the robot's design is abstract and does not resemble or serve as a known object, such as furniture or a door.

Designing and studying non-humanoid robots that are extremely abstract has several advantages. First, it can lead to simple mechanisms providing high reliability for use in user studies. Second, they can be studied independent of people's preconceptions about the object's abilities and purpose. But perhaps most importantly, abstract designs can help distill the fundamental characteristic of movement, which then can be mapped to a variety of morphologies.

Building on this motivation, we present the design of an abstract non-humanoid robotic object called the Greeting Machine. We present the design, implementation, and evaluation of its ability to communicate positive and negative opening encounter cues. The robot is designed as a small ball rolling on a larger dome, with a mechanical design that supports a variety of subtle movements. Gestures were designed with movement experts, and were evaluated in the context of an opening encounter. We found that people readily experience the machine's behavior as an opening encounter, and attributed social and emotional intention both in the positive and negative direction with minimal cues, such as Approach and Avoid gestures.

II. RELATED WORK

Relevant previous studies on non-humanoid robots can be classified according to the following domains: Research with robots designed as everyday devices in the context of opening encounters; Research with abstract robots in the context of emotional perception; and Research on minimal movement and perception of social cues.

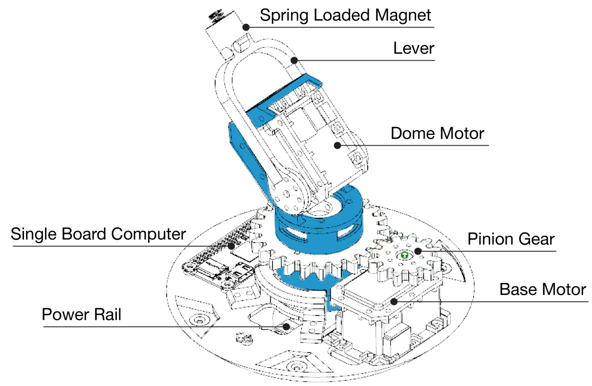

Fig. 2. The internal mechanism of the final prototype is structured around a base rotation linked to a tilting lever. The lever holds a rare earth magnet actuating the ball outside the shell.

A. Opening encounters with Robots Designed as Everyday Devices

Opening encounters have been studied before with non-humanoid robots designed as everyday devices, such as an Ottoman, a car-seat, or a door. Tennet et al. (2017) designed and evaluated the expressiveness of car seat motion (2 DoF). Using the Laban effort features [45] the researchers assigned different vectors for each expressive movement (time, space, weight, flow). When the car seat movement pattern involved specific forward and backward movements of the backrest, participants perceived the seat as greeting them [34]. Another positive opening encounter experience was presented by Ju and Takayama (2009), who showed that extreme minimal movement (1 DoF) of an automatic door was perceived as a social cue. Door trajectory and speed influenced people's interpretation of the door's intentions. Specifically when the door opened (with or without a pause) in response to participants' proximity, participants perceived it as welcoming and inviting [35]. Another aspect of positive opening encounters was shown by Sirkin et al. (2015). They studied reactions to approach movements of a 'Mechanical Ottoman' and showed that participants viewed the ottoman's movements as "indicators of intention to interact". Specifically, a quick (but not too quick) movement towards the participant was interpreted as an offer to engage in interaction. The authors suggested path trajectory (indirect, curved) and a pause (at a meter distance from the participant) as additional factors to consider in movement design for social interaction [33]. These studies indicate that it is possible to communicate positive opening encounters with non-humanoid robots designed as everyday devices. Gestures and social cues conveyed by these robots are coupled with the robot's everyday function [46]. Our work extends this prior work by studying opening encounters with a robot designed as an abstract, unfamiliar object that does not have an everyday function.

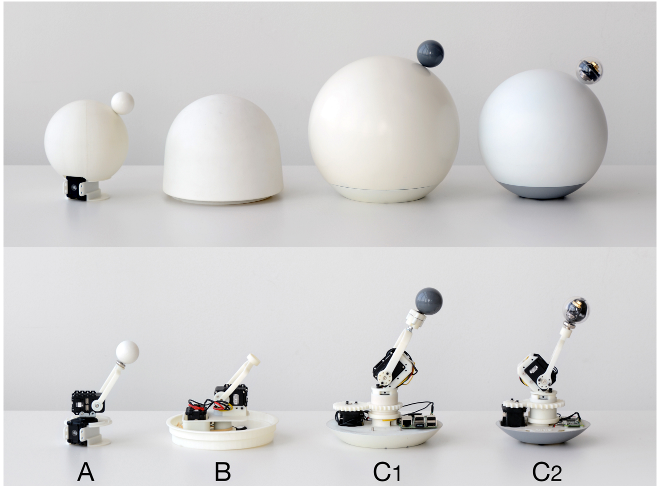

Fig. 3. The Greeting Machine iterative prototyping process.

Fig. 4. The various rolling balls designed and tested with the Greeting Machine, spanning a variety of external materials, internal rolling constraints, and ferromagnetic components.

B. Emotional Perception with Robots Designed as Abstract Objects

Another relevant class of studies evaluated people's emotional perception when interacting with abstract non-humanoid robots. For example, minimal movement of a robot designed as a stick [47] was consistently interpreted as representing the robot's inner state. A more recent study with a robotic speaker [48] found similar results. In some studies participants associated specific gestures with specific emotions (e.g. happiness, sadness, fear) [47], [48]. These studies imply that movement of an abstract non-humanoid robot has the potential to be interpreted as a positive or negative social cue. Our work extends this prior work by studying an abstract robot in the context of opening encounters, not emotional perception.

C. Minimal Movement and Social Cues

Based on indications from human-human interaction that people are able to perceive social cues from minimal human movements [49], HRI researchers tested if minimal gestures of non-humanoid robots can be perceived as social cues. For example, studies showed people interpret minimal posture changes as social cues [50]. Additional studies showed minimal posture changes of abstract robotic objects were perceived as an indication for the robot's engagement in a task, when synchronized with a human performing a task [41], [51]. Our work extends this prior work by studying minimal movement in the context of opening encounters.

The goal of this study is to evaluate how people perceive minimal movement of the Greeting Machine in the specific context of an opening encounter. We explored whether people consistently attribute social meaning, both positive and negative, to the abstract non-humanoid robot gestures.

III. DESIGN PROCESS & IMPLEMENTATION

The design process of the Greeting Machine, a non-humanoid abstract robot was initially inspired by the Gestalt theory study of basic geometric shapes [52], [53]. We also drew inspiration from the classic studies by Heider & Simmel [43]. Another inspiration came from the Animation discipline, and the practice of reducing emotional expression to simple animated geometric shapes [54]. From the great variety of geometric shapes, we focused on a design language of spheres and curvilinear movement, informed by the studies of Arnoff *et al.*, who found that curvilinear forms are associated with emotions of pleasantness, happiness, and warmth [55], [56]. A series of initial sketches and low-fidelity prototypes converged to a two-part design: a larger static sphere (dome), and a smaller moving sphere that rolls around the larger sphere surface as a gesture mechanism (ball). The relation between the two spheres was intentionally designed to not resemble a human face feature such as a pupil or nose. One metaphor the design team was inspired by is an abstract spherical "creature" (the ball) navigating a spherical "planet" (the dome).

A few prototypes were explored to strike the right balance between the mechanical requirement of movement range and the overall aesthetics (shown in Figure 3). These prototypes included a small two-ball design (A), with the actuation underneath the robot; a dome-shaped ground body (B), and two versions of a spherical shape with cut-off bottom - (C1) and (C2), which was eventually chosen for its clean appearance and expressive movement range.

A. Technical Implementation

From a mechanical design perspective, the Greeting Machine consists of a 2-degree-of-freedom (DoF) polar coordinate mechanism mapped to the sphere's surface by actuating a base rotation of a tilt lever (see: Figure 2).

A rare-earth neodymium magnet is mounted at the end of the lever. The ball is placed on top of the dome's surface, and through magnetic force the ball moves in a rolling motion across the outer surface of the base sphere.

The design of the ball's internal mechanism required special attention, with two goals in mind: (1) The ball should roll and not drag across the shell surface, and (2) when the ball rapidly changes direction, a secondary motion should be clearly visible indicating the inertia of its movement in a cartoon-like fashion. Figure 4 shows a variety of ball designs we tested. The relevant factors were the material of the outer shell and the internal mechanism. Material exploration

Fig. 5. A choreographer and character animator discuss gesture design using a puppet version of the Greeting Machine.

included 3D printed plastics (PLA / ABS), injection molded plastic, steel, and rubber. Internal mechanism explorations included 1-DoF and 2-DoF motion constraints, as well as various shapes, sizes, quantities, and diameters of ferro-magnetic material. For example, 20mm round neodymium magnet, 15mm round ceramic magnet, 12.7mm steel bearing sphere, and multiple 5mm steel spheres. The final design included a non-magnetic 12.7mm steel bearing sphere inside an injection-molded exterior, with no motion constraints.

B. Electronics and Software Control

The hardware includes a Raspberry Pi model 3 control board and two Dynamixel MX-12w motors. The software is based on a custom-written robot control framework running on the Raspberry Pi and written in both Java and Python. The framework enables translation of gestures designed in 3D animation tools to motor commands, supporting complex gesture design by non-programmers.

IV. GESTURE DESIGN

Designing gestures for an opening encounter using an abstract non-humanoid robot is uncharted territory, as there is no direct mapping of human gestures to abstract non-humanoid robots. Prior work in the field focused on humanoid robots that mimic human greeting gestures, [57], [58], and on non-humanoid robots designed as everyday-devices that can leverage the device function to communicate an opening encounter [34], [35].

We therefore leveraged the guided improvisation technique [59], [60] together with movement experts. Since the robot is an abstract non-humanoid object, the experts could not use their body to demonstrate or enact the gestures. We therefore created a 1:1 low-fidelity prototype of the Greeting Machine as a passive puppet, on which the movement experts demonstrated the gestures they envision as most appropriate for opening encounters. The experts were four movement specialists: an animator, a puppeteer, a choreographer, and a comic artist (see Figure 5). The low fidelity prototype included a probe, a small ball connected to the end of a stick, enabling demonstration of gesture trajectories on the dome. We invited all movement experts to a four-hour joint brainstorm session. We explained the related theory on opening encounters and the challenge of mapping humanoid gestures to abstract non-humanoid object. The experts used the probe intensively, asked us to walk into the room and towards the Greeting Machine from various angles and in various behaviors, including change in pace, body orientation, with pauses or without. They demonstrated various gestures using the probe, engaged in active discussion about various artistic inspirations such as object theater, character animation, and puppetry. They discussed possible personalities for the Greeting Machine, and debated specific movement characteristics such as start position, pace, style of movement, end position, vertical vs. horizontal movement, straight vs. curved trajectories, and more.

Toward the end of the session they reached a consensus, recommending to focus on the start position and the ball's direction of movement. They specifically suggested that movement should start from a position that is hidden from the approaching person, so the ball will gradually reveal itself to the person. They called this movement an ”Approach” gesture. In addition, they suggested to focus on a reversed movement, with a start position in front of the approaching person, with gradual movement away from the person until the ball is hidden. They called this movement ”Avoid” gesture. They also recommended that in both Approach and Avoid gestures, the movement should not be designed as a direct point-to-point movement, but rather as a winding and animated movement, with curves and turns along the way.

Based on the experts' recommendations, we defined two main gesture directions: Approach (back-to-front) and Avoid (front-to-back). We also defined two types of movement characteristics: Straight (direct point-to-point) vs. Animated (indirect, with curves and turns); Visible (visible to participant before movement starts) vs. Hidden (hidden from participant before movement starts). The result was a set of four Approach and four Avoid gestures, see Figure 6.

V. EVALUATION STUDY

We conducted a physical first-person qualitative study with the Greeting Machine in the context of an opening encounter, to evaluate how participants perceive the minimal gestures of the abstract non-humanoid robot.

A. Method

1) Participants: 26 participants (undergraduate students, age ranging from 19-24 (88%) and 25-34 (12%); 19 females, 7 males) were recruited and received course credit for participation. All participants signed a consent form and filled a demographic questionnaire. The experiment was carried out in English.

2) Procedure: The experiment was conducted in a research lab, to evaluate participants' experience with no association to a specific environmental context (i.e. home or work). The robotic object was presented in a vacant carpeted room with a large partition initially blocking participants' view (see Figure 7). To create an opening encounter experience, participants were instructed to walk alongside the partition, stop at a specific position (marked by X on the floor) and then turn and face the center of the room, where the Greeting Machine was visible. When participants turned to face the Greeting Machine, a gesture was triggered. No other instructions or descriptions of the robotic object were given. The Greeting Machine was placed on a small desk (75cm high) at a distance of 1.5m in-front of the X mark. By using a fixed distance for all interactions we verified there are no proxemic influences. The researchers viewed the experience from a control room through a camera, and used a Wizard of Oz (WoZ) mobile app to trigger a desired gesture. When the gesture ended, a short 'beep' sound was played indicating the interaction was over and that the participant should leave the room. After a short break outside the room, the participant re-entered the room and experienced another opening encounter with a different gesture. Gestures were counterbalanced across participants. Upon completing eight interactions (one with each gesture) participants were asked to re-enter the room for a 10 minute semi-structured post-experimental interview. The interview included questions concerning participants' overall experience, their thoughts about the design of the robotic objects, and their suggestions for real-life applications of the Greeting Machine. Example questions included: 'what did you think the robotic object was doing when you entered the room?'; 'what was your general impression of the robotic object?'. During the interview the Greeting Machine did not perform any gestures. The experiment lasted approximately fifteen minutes and was documented by audio and video.

B. Qualitative Analysis Process

Interviews were transcribed and read several times to develop a general understanding of the data before the coding process began. We followed the Thematic Analysis approach [61] including three stages. First, the primary rater reviewed all transcripts and identified initial emerging themes. The initial themes were presented to a second researcher and discussed in depth, inconsistencies were discussed until resolved and a list of mutually-agreed themes was defined. Second, the primary rater and an additional rater analyzed a selection of the data independently, inter-rater reliability was checked and found to be high (Kappa = 84%). Third, following inter-rater reliability validation, the two raters analyzed the rest of the data.

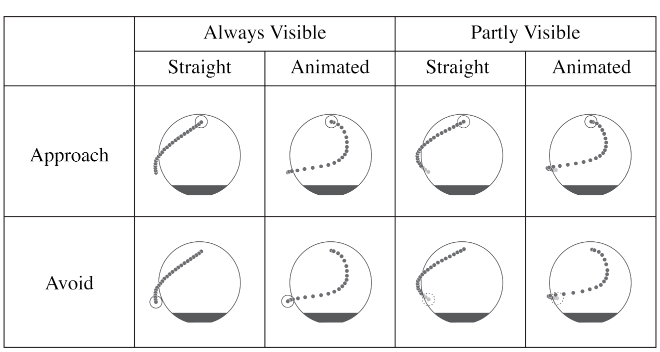

Fig. 6. Eight gestures according to three binary variables were a result of the movement expert workshop, and were used in the interaction study.

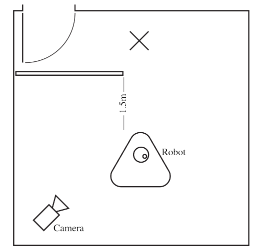

Fig. 7. Evaluation study setting, participants walked along the partition, stopped and turned to watch the Greeting Machine's gestures.

VI. FINDINGS

The 750 quotes were analyzed, leading to the following three themes: *Emotion-Related Expressions*; *Context of Use*; and *Design Aspects*.

A. Emotion-Related Expressions

Most participants perceived the interaction with the Greeting Machine as an opening encounter, reporting on a social and emotional experience. They perceived the minimal gestures of the abstract non-humanoid robot as social cues. Participants described the Approach and Avoid gestures as indication for the Greeting Machine's willingness or unwillingness for social interaction: *"When it was turning and facing me then I thought it was really welcoming [...] when it was facing the other side I had the feeling that he doesn't want to see me, that I should leave him alone, that I should leave the room."* (P6).

Participants often perceived the Greeting Machine's intent as loaded with judgment *about the participants*. When an Approach gesture was triggered, most participants perceived it as signaling that they were acceptable for social interaction (i.e. a positive opening encounter cue): *"when he moves he was like "I just want to interact with you""* (P20). Participants described varying levels of acceptance from the opening encounter: *"[...] he would be like "oh I'm super excited," or he would be like "I just need to know who she is[...] when he was moving a little bit more maybe he was excited to see me."* (P20). One participant diverged from this trend and perceived the Approach gesture as an aggressive cue signaling that he was not acceptable for social interaction: *"I felt it was just looking at me, staring at me, the same way you pass by the street and there is an aggressive dog at the gate and it looks at you in an unpleasant way."* (P8).

When an Avoid gesture was triggered, most participants perceived it as signaling that they are not acceptable for social interaction (i.e. a negative opening encounter cue): *"I had the feeling he, it, is avoiding me, like it feels uncomfortable. That's why it wants to turn away."* (P6). They described the Greeting Machine as intentionally ignoring them: *"When it was turning away, it was trying to shut me down and pretend that I'm not here."* (P17). One participant felt that the Greeting Machine was judging her: *"It was pretty* *judgmental, it looks at you, it detects that you're here, and then decides whether it wants to face you or don't want to face you."* (P10). Others mentioned that the Greeting Machine does not want to interact with them because of the robot's internal state, not because of them. They attributed emotions to the Greeting Machine that would explain the avoid gesture such as "shy" or "scared": *"I felt it was actually hiding [...] like he was scared. I thought maybe he doesn't know me but if I start being nice to him, he will turn and look at me."* (P1); *"When he looked away he was shy, maybe he doesn't know who I am, maybe I'm a new owner who hasn't used him before."* (P16). One participant hypothesized that the Greeting Machine's internal state was a result of his own behavior *"Maybe he was scared of me, because he sensed that I was angry at him."* (P14).

Participants also described their own response to the Greeting Machine's willingness or unwillingness for social interaction. When they felt that the Greeting Machine found them acceptable for interaction, responses were positive: *"When it stared at me, I was happier than when it wasn't. When it turned to me, it made me smile a little."* (P15); *"When it looked straight at you then you knew the situation was fine, because it was greeting you and everything was okay."* (P26). When they felt that the Greeting Machine found them unacceptable for interaction, they felt rejected *"I was a little annoyed: Why is he not looking at me again?"* (P1). Some of them even became angry: *"when he was facing the wall, it was really not nice. I was standing right there looking at him. I was thinking: Why are you doing that? It's not nice, not polite."* (P6). Participants were also intrigued by the fact that this abstract object could make them feel emotional: *"When I would walk in and it would face away from me, it was like "I don't want to talk to you". It's weird, because it's an object and it shouldn't make me feel anything, but it did. It's the same as if a person wouldn't want to talk to you."* (P10).

B. Context of Use

Participants envisioned themselves using the Greeting Machine in a variety of use cases, almost all in context of opening encounters. Most participants described it in a home setting: *"I would put it in my house by the entrance, so when I walk in this robot is greeting me. It's similar to when you come home and a person greets you. It may be a robot but it feels similar to a person greeting you."* (P10). Others described it as a greeting robot for guests: *"Maybe I could use it as a device to greet house guests when they come by the door. It could make them feel more at home."* (P21). Few participants explained why a workplace setting is more appropriate: *"It would make more sense in my office, because at home most of the time I have people who are welcoming me, and in the office I work late nights, so it would be nice [...] giving me a feeling that I am not alone. Clearly I realize that I am alone, but it's still something that is there [...] I don't know how to explain it."* (P13). Other participants associated it with dispelling loneliness or a bad mood: *"It would be really cool if you're living alone or you're far away from everyone you love, you come in and it's excited to see you"* (P20); *"When someone is having a bad day and comes back home, and suddenly they turn around and: Hello!"* (P14).

C. Design Aspects

Participants described the Greeting Machine in abstract terms with no association to a specific function. They mentioned form, color, visual aesthetics, visual metaphor, and movement. Participants did not have a consistent metaphor for the Greeting Machine: *"It was different.. it's just a thing."* (P10), *"It looks futuristic, like nothing from this real world or from this decade, like something from the distant future"* P(17). Some participants related directly to the spherical aesthetic language: *"Its spherical form makes it kind of calm."* (P3), *"very clean, white, and circle, and a little ball"* (P19). Several participants thought the design is too limited. Some of them stated a robot should resemble humans: *"The interface is so extremely simple, that you don't feel like it's an actual robot [...] If it's about interaction with other people it should look more human."* (P23). Interestingly, participants' desire to have more human features did not prevent them from perceiving the gestures as opening encounters. For example, P5 criticized the design and suggested it should resemble humans: *"It's very simple. It looks more like an object and less like a person [...] just like a thing that's there, and doesn't make it look friendly or welcoming or warm."*. However the same participant described the interaction as: *"It turned to me and turned away and then turned to me again. It set off this whole scenario in my head, when I come back from work. I felt it's similar to someone waiting for me at home, a person I live with, who can be mad at me or happy to see me."*.

VII. DISCUSSION

In this work we showed that an abstract non-humanoid robot designed with no metaphor to an everyday function, can effectively take part in an opening encounter. The Approach and Avoid gestures, designed based on movement experts recommendations, indeed formed the basis for an opening encounter experience. By evaluating participants' interaction with the Greeting Machine we verified that minimal gestures of an abstract robotic object can be perceived by people as both positive and negative opening encounters. Specifically, the participants perceived the interaction with the Greeting Machine as an emotional and social experience.

The difference between the Approach and Avoid gestures contributed greatly to the perception of the opening encounter, and in most cases led to opposite emotions. Approach gestures were associated with a wide range of positive emotions perceived as willingness for social interaction, including *acknowledging, welcoming, happy to see me, wanting to interact with me, excited to see me, etc.*. Avoid gestures, however, were associated with a wide range of negative emotions, perceived as unwillingness for social interaction, including *being shy, ignoring, avoiding, wanting me to leave the room, wanting me to leave him* *alone, rejecting me, etc.*. These rich descriptions validate that an extremely abstract non-humanoid robot, performing minimal Approach and Avoid gestures, can signal to participants whether they are acceptable or unacceptable for social interaction. Hence, the minimal gestures provide a sufficient amount of nonverbal cues allowing for consistent interpretation of the opening encounter.

Interestingly, participants' reactions to the Avoid gestures seemed to have a stronger intensity than reactions to the Approach gestures. For example, a typical description of an Approach gestures is: *"It was really welcoming, like 'look at me', very friendly"*, while a typical description of an Avoid gesture is: *"It doesn't want to see me, like, it wants me to leave him alone, that I should leave the room for him or it to be back to normal."*. This imbalance in the response intensity corresponds with human human social interaction were negative emotions are more common and persistent than positive emotions. This common phenomenon is attributed to negative emotions having the potential to evoke useful responses to a threat or a loss [62].

Participants' suggested use cases were very relevant for opening encounters, including welcoming guests at the entrance of a house, and using it a solution for loneliness. The object was even associated with a mother welcoming children when they come back from school (P23). Such use cases imply that despite its abstract design and minimal movement, participants were able to envision the Greeting Machine as an appropriate entity for an opening encounter.

When specifically asked about the Greeting Machine's design, some participants appreciated the abstract design while others thought that a robot *should* resemble humans, and that the abstract design is too simple. However, the same participants that stated they prefer a more humanoid design had no reservation when envisioning the Greeting Machine as a meaningful entity in an opening encounter. This finding points to an interesting duality. On one hand, participants expected robots to have human-like features. On the other hand, the same participants perceived the abstract Greeting Machine as a relevant entity for social interaction. Finally, participants' reactions included a range of both positive expressions (e.g. excitement, happiness, compassion, interest, surprise) and negative expressions (e.g. anger, shame, disappointment, rejection, scared). This finding show that even minimal movement of an abstract robotic object can generate a wide range of reactions.

We conclude that interaction with an abstract non-humanoid robot can be experienced as a positive or negative opening encounter. Furthermore, minimal movement, designed as Approach and Avoid gestures, may be enough to generate these positive and negative emotions. The potential in creating opening encounters with low DoF non-humanoid abstract robots is promising, due to the low complexity, low cost, and design flexibility of such devices.

A. Limitations

The present study has several limitations. First, there was a larger representation of females in our sample. We acknowledge this limitation, however our findings demonstrate that both male and female participants used a variety of emotional expressions for the interaction. Future work should explore gender effects in this context. An additional limitation is a possible "novelty effect" due to the unfamiliarity of the robotic object. While this effect may account for positive responses, our findings show a wide range of both positive and negative responses. Lastly, as our findings are based on a specific group of university students, the generalizability of our findings to different age groups and cultures should be further studied.

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