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Picking Up Good Vibrations: Designing an Experimental Setup to Assess the Role of Vibrations in Human-Robot Interaction

Joffrey Becker¹, Samuel Bianchini², Hugo Scurto^{2,3,4}, Elena Tosi Brandi⁵

Abstract—Focusing on behavioral objects (considered as art and design objects which are not figurative nor utilitarian), this article describes a first step in the design of a research and creation project called *The Apprentices*. Conceived as an environment containing three behavioral objects which movements are amplified, *The Apprentices* constitutes an experimental platform which aims to contribute to a better understanding of the modalities by which humans and objects are in a situation of nonverbal communication. The project aims to contribute to the study of animism in human-robot interaction (HRI) but also to the study of analogical forms of communication generally prevailing in multi-species interaction. It therefore implies to pay a particular attention to the design of a shared space. Reviewing several works in the field of art and design where vibration plays a central role, we address a dimension of animism that is still poorly studied in HRI anthropology, based not on the idea that objects are considered as persons but rather that their collective activities can be considered by analogy with social life. We then identify vibration as a relevant modality for relating human and nonhuman collectives, which allows a frame for interaction within which vibratory signals can be exchanged and embodied. The article concludes with a description of the architecture of the shared vibratory space designed for the project.

I. INTRODUCTION

In the context of contemporary design, interaction with artifacts is evolving thanks to the richness of human-machine interaction and ubiquitous computing. The rise of artificial intelligence and the democratization of robotics impose new modalities of relation between humans and the artificial world. Communicating and connected objects capable of sharing data with their environment and with each other, sensory interfaces, social robots, conversational agents constitute a whole new typology of artifacts which, by their

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¹Joffrey Becker is with Laboratoire d'Anthropologie Sociale / Collège de France, 3 rue d'Ulm, 75005 Paris, France contact@joffreybecker.fr

²Samuel Bianchini is with Reflective Interaction Research Group / EnsadLab, École nationale supérieure des Arts Décoratifs, PSL University, 31 rue d'Ulm, 75005 Paris, France samuel.bianchini@ensad.fr

^{2,3,4}Hugo Scurto is with UMRS 1158, Inserm-Sorbonne Université, and Institut des Systèmes Intelligents et de Robotique (ISIR), UMR 7222, CNRS-Sorbonne Université, and Reflective Interaction Research Group / EnsadLab, École nationale supérieure des Arts Décoratifs, PSL University, 31 rue d'Ulm, 75005 Paris, France hugo.scurto@ensad.fr

⁵Elena Tosi Brandi is with Xdlab / Art Direction Nods, Orange, 46 Avenue de la République, 92320 Châtillon, France elena.tosibrandi@orange.com

expressiveness and their spontaneous or programmed behaviors, express intentions and therefore call for new forms of interaction with their audiences and their environments.

Since 2012, a multidisciplinary group of artists, designers, engineers, and researchers initiated a research project in the field of art and design to study and experiment with what we call Behavioral Objects. These non-anthropomorphic, non-zoomorphic objects and collective of objects are endowed with capacities for expressive movement, action and reactions and are also able to elicit observers' behavioral interpretations (intentional and emotional attributions) [1], [2], [3], [4].

Our ongoing research, *The Apprentices*, considers the agency of a collective of robotic objects. It pleads for a better awareness of the complex psycho-social dynamics involved when humans interact with a group of robotic agents, specifically by paying attention to the way vibration helps compose a shareable environment and thus gives a frame for communication between humans and robots. Indeed, vibrations, sounds and even rhythmic structures are perceived and produced by many different species. Vibration also plays an important role in situations where analog multi-species communication constitutes a common frame when humans exchange signals with other nonhuman types of existence across the globe. As we are going to see, this justifies to conceive a shared, embodied and composed vibratory space as a preliminary step in our work.

To which extent such a space leads humans to consider the animacy of a robot group, that is, on the one hand, the attribution/abduction of agency [5] and on the other the psycho-social effects resulting from the coordinated activity of a group of objects? Our paper questions how vibrations can constitute expressive means which give a context for spectators to elicit collective dynamics and social qualities from the objects' activity. What is at stake here is the conception of a shared vibratory space which enables new modalities for human-robot interaction. Leaning firstly on art and design practice and anthropological researches conducted within the fields of robotics and artificial intelligence, this paper describes the conception of a shared vibratory ecosystem in order to address the questions raised by embodied and ambient forms of communication with behavioral objects.

II. INSIGHT FROM ART AND DESIGN PRACTICE

Some behavioral objects conceived in the field of arts and design address the role of sound in human-machine

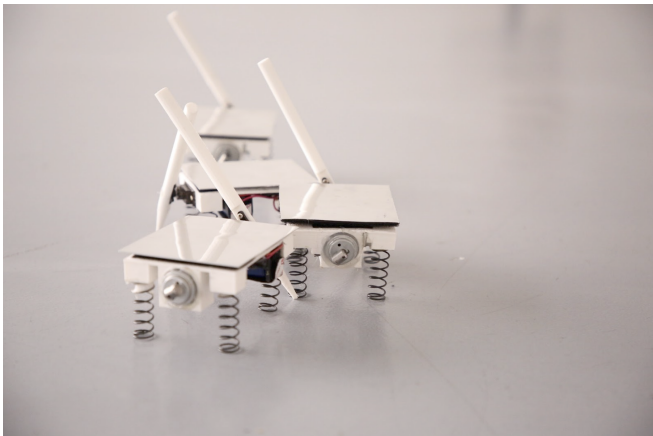


Fig. 1. *Tous ensemble chacun pour soi*. Olivain Porry, 2018. A project developed as part of the ICOC project (Collective Interface for Connected Objects) of the Reflective Interaction research group of EnsadLab conducted in partnership with the CHArt laboratory with the support of the Carnot Cognition Institute.

interaction. For instance, by displaying a metal container deforming noisily under what seems to be blows coming from the inside, Arcangelo Sassolino’s *Piccolo Animismo* (2011) confronts the spectators with a radical otherness that leads us to suspect that this box contains an eerie and threatening entity. In Rebecca Horn’s *Ballet of the Woodpeckers* (1986), motorized hammers hit the surface of mirrors while the spectators can see how their own movements create waves on the surface of two cones filled with water. These works of art are not only staging how important sound is in human-robot encounters. They sometimes use sound and vibration as a means to highlight a more collective dynamic.

Conducted at the EnsadLab, the works of Ianis Lallemand and Olivain Porry provide a first insight on the approach we adopt today on vibration. In *Tous ensemble, chacun pour soi* (“All together, each one for itself”), Olivain Porry explores the effects of synchrony and de-synchrony in a small swarm of robotic agents, showing the particular relations occurring between them (see Fig. 1). When one enters the room of the installation the first thing she perceives is small nasal whispers, soft and short that are repeated with regularity. Perched on springs and covered with a plate that reflects, in the same way a mirror does, the space around them, the robots shake and turn slightly with the movements of their rods. Scattered carelessly in the exhibition space, the robots appear to be very active and if the movements of the rods are first synchronized, they change after a few minutes. Indeed, one robot in particular stands out from the group. It shakes its rod in a fast motion and then stops. The five other robots then reproduce this same movement and thus draw a choreography which is guided by the first one. The robots vibrate in a loud noise and move on the ground for a few seconds, thus adopting new positions. The loop then resumes at its start and the choreography of the rods begins again.

In a cooperative work with Olivier Dauchot and the Collective Effects & Soft Matter team at ESPCI-Paris, Ianis Lallemand also worked on vibration but adopted a differ-

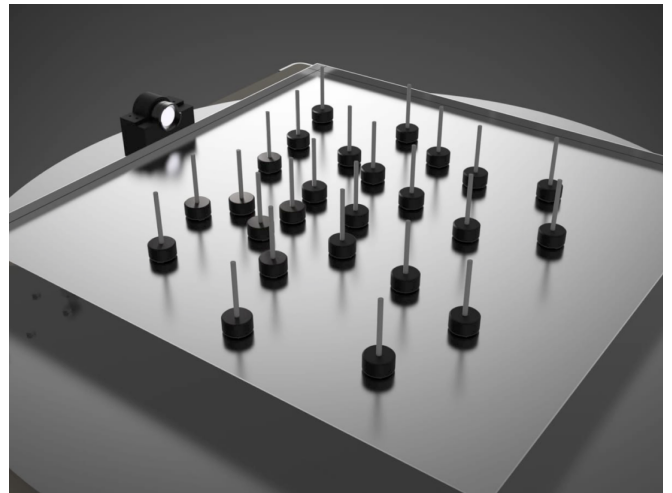


Fig. 2. *Manœuvres*, Ianis Lallemand, 2016. A project developed as part of EnsadLab’s Reflective Interaction research group in collaboration with Olivier Dauchot and the Collective Effects & Soft Matter team of the École supérieure de physique et de chimie industrielles de la ville de Paris (ESPCI) with the support of PSL University.

ent perspective by conceiving a shared vibratory space (a vibrating surface) which animate the objects it contains (see Fig. 2). In *Manœuvres* (2016), Lallemand conceived an experimental setup which allows the spectators to create intricate light images, by contributing to the self-organization of a physical multi-agent system moved by a vibration plate converting energy into movements that are then translated into visual patterns thanks to light projection. Using vibration is a well known method employed to make robots move. It is a core feature used in machines such as Hexbugs or Kilobots. The difference here, however, is that Ianis Lallemand’s objects are moved by their very own ecosystem. The origin of their movement is thus external, embodying vibration in a given and composed situation which directly works the perception we have of their collective dynamics.

These behavioral objects invite us to wonder whether their perceived behavior is the result of a collective organized pattern or not. They put us in a situation where we, as spectators, are facing a society made of behavioral objects, working the notion of animism in a particular way. Indeed, anthropologists have shown that animism is not only about feeling that an object is behaving as a person would, but also about considering the activity of nonhuman groups as the index of a human-like social life [6], [7], [8]. How does vibration contribute to create a shared space where human and nonhuman agents can exchange information or even meaningful signs?

III. AN ANTHROPOLOGICAL ISSUE

While “face-to-face” interactions with robotic agents are holding the attention of many researchers in the field of human-robot interaction, the issue of interacting with multiple robots has gained interest only recently. A growing number of researches address today the many issues raised by human multi-robot interaction, whether they consist of

experimenting communication based on language, gestures and social cues, interfaces which enable mediation or a combination of all these [9], [10], [11], [12]. Still, little is known about how we perceive the collective behavior of a swarm of robots [13]. Yet pioneering experiments, such as the work of Fritz Heider and Marianne Simmel on the perceived social features of moving objects [14], or other works about the role of motor coordination on the emergence of a feeling of identity conducted in the field of humanities and social sciences [15], [16], [17], remind us how important such a subject is.

HRI experiments occasionally investigated the means by which robots are able to communicate with each other, focusing on the modes of communication which could appear as the more natural according to human. For instance, Williams et al. showed that, in task-oriented human-robots experimental setups, verbal communication between robots is preferable to silence [18]. Language is a good way to avoid the creepiness felt by human users when they have to deal with silent robots. Our goal is to help enrich these researches by addressing a nonsymbolic type of communication based on vibration. As we shall see, anthropomorphism (whether it concerns forms or language) is perhaps not the most suited way to engage humans to consider robots as potential social partners.

Anthropologists such as Emmanuel Grimaud or Denis Vidal have shown that robots are good candidates for studying the cognitive processes involved in anthropomorphic thinking and the perceived agency of these objects [19], [20], [21], [22], [23]. Experimenting human-machine interactions with the Berenson robot at the Quai Branly Museum, Vidal has shown that the main issue when encountering an anthropomorphic robot is about assessing its autonomy and limitations. This measure aims to verify that the machine is indeed one. However, once the mechanical nature of the robot is confirmed during the interaction, this does not prevent humans from behaving as if it was a "person" [23]. As Vidal suggests, by establishing continuities between human and machine inner processes and simultaneously noting that a discontinuity exists between our appearance and theirs, do human-robot interactions reveal that a renewed form of animism is at work? Philippe Descola has clearly shown that animism implies such a relationship of continuity and discontinuity [6]. In animist societies, if the whole of the existing nonhumans is thought to be crossed by an interiority identical to that of humans, it is mainly on the basis of a morphological difference that the relations of identity and otherness will be established. One can imagine that relations with robots could easily be compared to those occurring in animist worlds. In fact, anthropologists do not address another, yet fundamental, aspect of the notion of animism.

In animist worlds, people don't only consider nonhuman beings as persons. They also consider the sociability which is established between members of the same species, of different species, or between living beings and artifacts [7], [8], [24], [25]. While it is easy to think that machine have a perceptual world of their own [22], [26], an *umwelt*

[27], experiments conducted in the field of human-robot interaction show that attributing the quality of a subject to a machine does not necessarily imply that we infer that robots have, between themselves, social relations analogous to ours, as this would be the case in the type of animist ontological inference described by Philippe Descola [6]. Would we spontaneously infer social qualities about groups of objects acting synchronously or collectively imitating certain human actions? Far from only considering the face-to-face interactions between a human and a machine that looks like him (as it is still too often the case in human-robot interaction experiments), the coordinated actions of groups of robots invite us to address the question of animism not only for the imputation of the quality of subject that is associated to it, but also through the inferred "social life" associated to behavioral objects. This dimension incites us to explore other modalities of communication which are weakly considered by researchers as they don't contribute to the conception of universal relational interfaces whose functioning would be thought as a kind of transfer of the human communication behaviors into machines.

Indeed, experiments made by anthropologists on social robots [19], [20], [21], [22], [23] show that interacting with a robot almost systematically implies that the human interactant mobilizes resources which are different from those daily used to interact with members of our species [20], [22]. With robots, the principles of an analog type of communication are at work [28], which can for instance be compared to that we establish with our pets. What prevails in such cases is the establishment of a framework which does not focus on the messages contents but whose function is to open and maintain a channel for communication. Where digital communication depends on the content of the messages exchanged, analog communication is about the very possibility of communicating; the creation of a shared, jointly habitable and meaningful world, despite the extremely rudimentary nature of the means used to communicate.

IV. VIBRATIONS: A CONTEXT FOR SOCIAL BONDING

Our work follows the perspective opened by this form of communication in HRI. It aims to explore nonverbal forms of communication based on the way vibrations are the cause of movements, sound and rhythm and thus appear as a first source which give access to more complex sensory dimensions. Analog communication can be seen in situations that are very distant both geographically or culturally and is addressed in a growing number of studies conducted in the field of anthropology [29], [30], [31], [32].

However, when it comes to interspecific communication, few anthropologists focus on direct information exchange. The ethnography of the modes of intersubjectivity between species remain poor though the subject gained progressively interest in anthropology during the last decade. Although their work adopts an interspecific perspective, many anthropologists consider the human-animal relationship to better grasp the networks and dynamics of human social agency

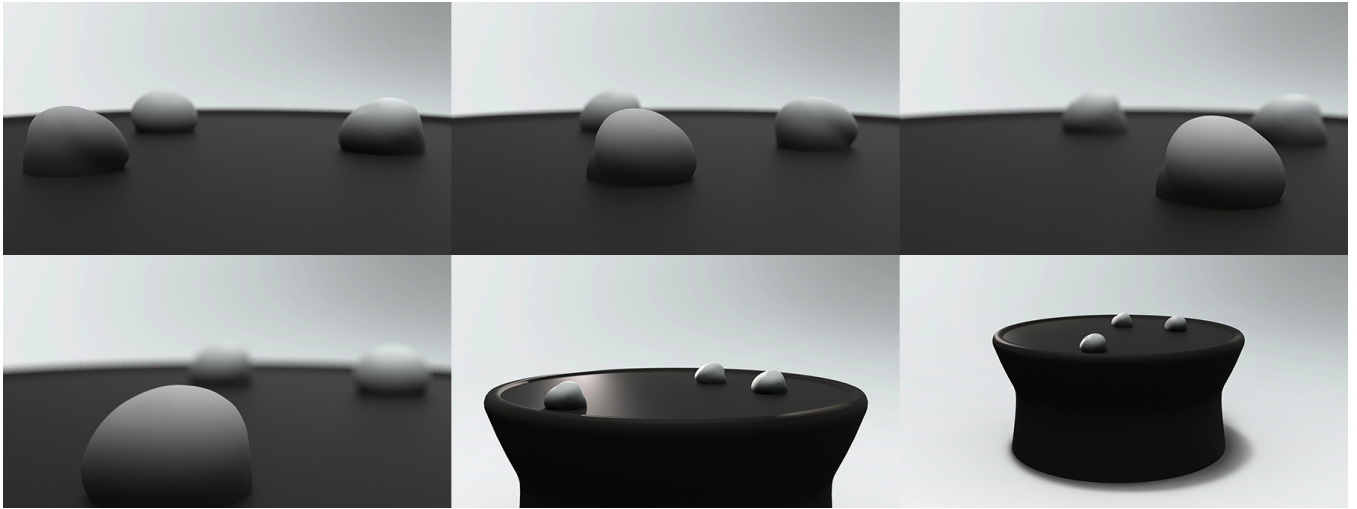


Fig. 3. Preview images of the project *The Apprentices*, conceived by Samuel Bianchini, Elena Tosi Brandi and Hugo Scurto with the collaboration of Joffrey Becker and Franck Weens as part of a research partnership between Orange’s Art Direction Nods Team (Xdlab) and EnsadLab’s Reflective Interaction research group, February 2020.

[33], [24], thus still centering the work on humans and their institutions.

The shared world between humans and nonhumans, what it is made of and crossed by, is not always considered for the questions of communication it raises, for instance by addressing what element could be relevant when species meet and exchange information [34]. Interspecific modalities of communication in HRI and the common world at the interface of which signals and signs can potentially be exchanged (the semiosphere, as called by Yuri Lotman, for example) should receive special attention.

Anthropologists such as Stéphane Rennesson, Nicolas Césard, and Emmanuel Grimaud have noted, for example, that rhinoceros beetle fights in Thailand [35] depend on a technique that involves establishing common ground between the human player and the insect relying primarily on vibrations and tactile means. Although human players do not share any cognitive or perceptual abilities with the insect, producing vibrations on the bamboo trunk used as a battle area is an attempt to affect the beetle’s behavior. The vibratory space appears as an interactional space where energy is transferred from a body to another at a preverbal level in a shared material environment. Vibration is thus a mediation means which can have deep consequences on the relation one can have with a nonhuman agent. This is even more the case when sounds are or seems organized and structured into rhythm. The notion of rhythm is, however, fraught with a certain ambiguity as it confuses the rhythms of life (calendar cycles, synchronization of activities, the question of repetition in relation to learning practices over a long period of time, etc.) and a more musical and situated definition which anthropology does not always manage to grasp, especially in ritual situations. In such a situation, rhythm is not a trigger for anything specific, even if it appears as a context accompanying practices [36]. Nevertheless, despite this ambiguity, what is at stake is that – whether

they are of a musical kind or not – vibrations appear as a particular context which gives a frame for social activities and bonding.

Our approach aims at exploring this last modality without necessarily trying to transpose the universe of signs specific to verbal language to an interactional situation based firstly on vibration, then sound and the imitation of rhythmic patterns. It is thus different from the work on vibratory communication conducted in the field of human-computer interaction, which seeks mainly to design techniques in order to convey strong meaning for human users [37], [38], [39], [40]. The experimental perspective we adopt is different from such an iconic approach. It relies on vibration as an embodied feature for communication in order to create an experimental context whose purpose is to assess how humans think about the activity of a collective of robotic agents by analogy with our own social activities.

V. DESIGNING A COMMON VIBRATORY ECOSYSTEM: THE APPRENTICES

How to compose a shared vibratory space? While in *Tous ensemble, chacun pour soi*, vibration emerges through the sound coming from the physical movements of the objects, including their motorization, *Manœuvres* rely on a vibration plate to animate the set of agents. In both cases the vibratory space naturally transposes material activities to our auditory perception, thus reinforcing our attention. Why not have recourse to such material actions—to this vibratory space—to interact with these objects, for example by inviting an audience who have become users to knock on the common support of these objects? How can we design a material environment for these objects that is not simply a stage, but also a kind of instrument, an environment calling for communication with these objects through a percussive gesture as a source of vibration? How to compose the whole set of this vibratory space of interaction which requires

to prevent or, on the contrary, to foster the propagation of the vibrations through the various "materials" implied (metal, wood, plastics, rubber, human body, air, etc.)? How to think the continuities and the discontinuities of this space of communication thus thought as a sensitive embodied space?

Thought to experience a trio of behavioral objects within a vibratory space to be shared, *The Apprentices* will remind an orientation table (see Fig. 3). It will consist of a large circular anthracite base, which stands in the middle of an interior space. Three objects will move irregularly on its surface. All of the same shape, these objects look like pebbles whose gray base merges with the scene while their lighter top offers enough contrast to distinguish them well.

Our project leads us to design an "instrument-stage" which consists in a vibratory space which can be shared by human and objects. This common human-robot apparatus should make it possible to stage this collective of objects while stimulating interactions by means of an instrumental form favoring affordances, such as a large drum that has become a stage, and paving the way to interactions with a collective of objects by a collective of humans. Just like the beetle fighting studied by S. Rennesson, E. Grimaud and N. Césard involves an unusual form of partnership between humans and insects that shed a new light on the notion of communication [35], we conceived a vibratory space as a privileged environment for interspecific cooperation between humans and objects.

Beyond aesthetics, the whole apparatus—including robotic objects and stage—was designed to compose a vibration space (seen as both a space for communication and a shared material space) (see Fig. 4). Structure-borne vibrations made by robots' movements are converted into electronic signals by piezoelectric sensors placed under a metal plate. We chose metal as material for the plate due to its high impedance, which enables to soothe air-borne vibrations produced by a speaking audience, while strengthening structure-borne vibrations produced by robots' movements over the stage.

After going through some audio processing, the robots' vibratory signals are converted into structure-borne vibrations and diffused air-borne using piezoelectric speakers placed on a wooden box. As such, the audience can hear vibrations produced by robots through sounds diffused by the vibrating box, but also touch it, through haptic feedback produced by the box.

Crucially, we placed a rubber insulator between the metal plate and the wooden box, as well as an acoustic foam inside the wooden box, to respectively avoid structure- and air-borne vibratory feedback between piezoelectric sensors and speakers. Similarly, we placed a rubber insulator between the wooden box and the ground to soothe structure-borne vibrations produced by a walking audience and other entities moving around the exhibition space. Lastly, we equipped the stage's edge with piezoelectric sensors to sense the audience's structure-borne tappings, thus designing distinct communication channels between robots and the audience within a shared vibratory ecosystem.

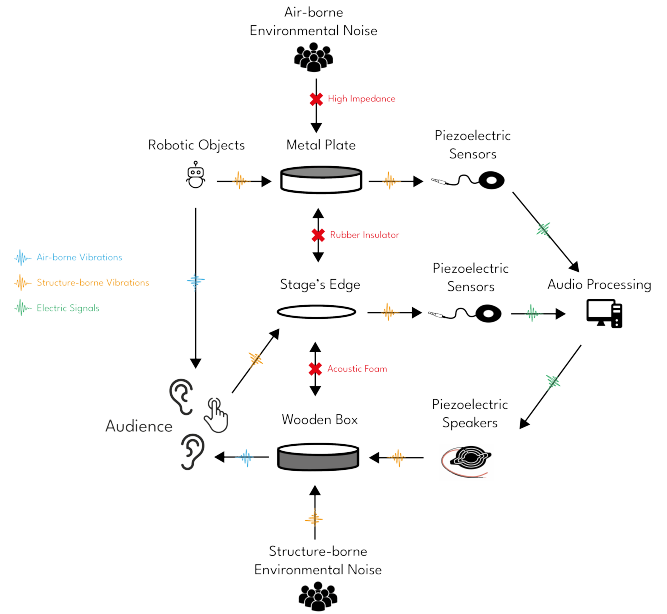


Fig. 4. Description of the vibratory space designed for *The Apprentices*.

VI. CONCLUSION

Our current research and creation project aims to question the behaviors of objects from the artificial world and, on the other hand, to identify methods and tools in order to define an approach in designing the agency of artifacts and thus creating experimental condition to receive them, materialize and assess them [41], [42]. Inspired by several works involving Behavioral Objects collectives, our ongoing efforts plead for extending the research on the expressiveness of machines but also on the communication uncertainties and the inferences emerging from the interaction.

Recognizing that vibration is a fundamental component in animal behavior and communication processes [43], [44], [45], [46], [47], [35], *The Apprentices* aim to experiment the semiosphere opened by the shared vibratory space described above. In contrast to a merely symbolic approach to vibratory communication, *The Apprentices* aims to contribute to the study of human-robot interaction by relying on an analogical modality of communication [28].

This particular form of communication is at work in multi-species relations in very different human societies around the world [29], [30], [35], [31], [32]. Our goal is to better understand the role of vibration, sound and rhythm in the perception of animacy in a group of robotic agents and thus to tackle the links between robotics and animism from a new perspective.

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