Prototyping with Monkeys: Uncovering What Buttons for Monkeys Look Like

Vilma Kankaanpää
vilma.kankaanpaa@glasgow.ac.uk
The University of Glasgow
Glasgow, UK

Ilyena Hirskyj-Douglas
ilyena.hirskyj-douglas@glasgow.ac.uk
The University of Glasgow
Glasgow, UK

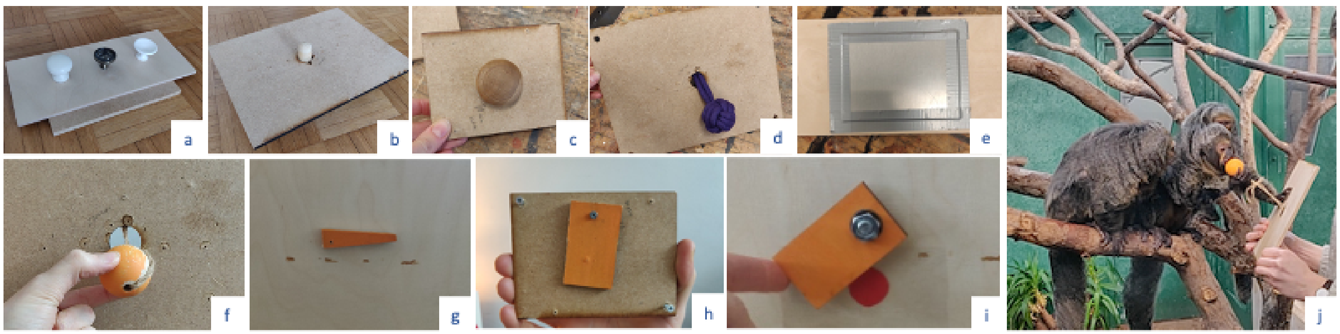

Figure 1: Prototyping buttons with white-faced sakis: (a) B1: doorknob touch button, (b) B2: push button, (c) B3: doorknob push button, (d) B4: pull-rope pull button, (e) B5: metal plate touch button, (f) B6: ball pull button, (g) B7: lever push button, (h) B8: swinging panel button, (i) B9: upgraded swinging panel button, (j) monkeys testing the ball pull button f.

ABSTRACT

Although much work has focused on designing touch interfaces for primates, little is known about how physical computer buttons for monkeys would look. Here, we employ the rapid prototyping method commonly used in human–computer interaction to design tangible buttons for monkeys allowing them to interact with computer enrichment. Our findings reflect on the process of altering rapid prototyping from humans to animals and how computer buttons for monkeys might look. On this basis, we make suggestions for monkey buttons, highlighting colour and pull/swing over push/touch interactions. We also reflect on lessons learned from transferring prototyping across species, such as the need to iterate on a few variables and for initial prototypes to be varied, and speculate on how to balance the designer (human) and user (animals) needs. More broadly, this paper builds upon HCI prototyping techniques for unconventional users, creating a method for rapid iterative prototyping with animals.

CCS CONCEPTS

• **Human-centred computing → User interface design**.

TEI '23, February 26-March 1, 2023, Warsaw, Poland

ACM ISBN 978-1-4503-9977-7/23/02…$15.00
https://doi.org/10.1145/3569009.3572735

KEYWORDS

animal–computer interaction, monkeys, prototyping, tangible, iterative design

ACM Reference Format:
Vilma Kankaanpää and Ilyena Hirskyj-Douglas. 2023. Prototyping with Monkeys: Uncovering What Buttons for Monkeys Look Like. In *TEI '23: Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '23), February 26-March 1, 2023, Warsaw, Poland.* ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3569009.3572735

1 INTRODUCTION

Non-human animals (hereafter animals) increasingly have access to computer systems. Animals can use computer systems directly as users manipulating the technology or as 'usees', where the technology is used on them, e.g. via worn monitors and trackers or by remote behaviour measurement without their awareness [1]. Traditionally, these animal-computing systems have been developed without considering animals as users, ignoring their needs and requirements [20]. This is partly due to the human tendency to anthropomorphise animals, which applies to the design of interactive elements, with animals often being expected to interact with computers as humans do (for instance, using fingers to press on touchscreens). However, animals tend to interact with devices in various ways more akin to their ordinary behaviours, such as through licking, gripping or leaning [17, 58]. With a call to develop computer systems with focus on the interfaces between animals and computers, similarly to human-computer interaction (HCI) [35], there is need to explore novel ways for animals to interact with technologies.

To explore these animal-focused systems, animal-centred design [20, 35] has become the de facto method for developing novel interaction methods for animal interfaces. The animal-centric approach focuses on ways of designing *with* animals, which is thought to lead to better-designed products [37]. However, animal-centred design is not well defined either in theory or in practice when it comes to designing and building new animal interfaces. Given that most systems for primates repurpose human interfaces, such as touchscreens [26], there is a gap between the ideal of focusing on how animals actually interact with the world and the current technologies used by animals.

Tangible interfaces have been proposed as a means of providing an intuitive form of interaction for animals that are usually tactile, such as primates [48]. While there are some examples of tangible interfaces for apes beyond touchscreens (e.g. [14, 48]), very little work has focused on monkeys. Furthermore, there has been no investigation into the use of tangible interfaces for computers beyond the objects in the primates' enclosures (e.g. balls or hay [48, 59]). As such, it is unknown how tangible computer buttons for monkeys would look or how to design them.

To bridge the gap between theory and practice in developing novel interactive interfaces for animals, researchers frequently borrow and modify the models and concepts of HCI (e.g. [7, 13, 24, 49, 51, 53]). These methods, such as co-design and participatory design, aim to involve the user in the design process to shape the technologies around how the user behaves.

Using such methods for primates in zoo contexts is incredibly complex because multiple stakeholders are involved [18], including zoo visitors, the animals, the keepers, the research directors and so on. Regarding design with animals in zoos, researchers have employed methods such as participatory design and co-design with elephants [10] and orangutans [59]. While primates worldwide are the key users of computer systems in zoos, much attention has been focused on great apes species [59] and little on monkeys. As it currently stands, while there is a clear need for the animal-centric design of new interfaces to fit animals' needs, there is neither clear direction nor clarity regarding the methods for designing with monkeys as users beyond the testing of final designs [47]. Furthermore, the lack of a shared language between the designer and the animal poses difficulties in designing for and with animals, leading to issues in determining how animals can be involved in the design process when developing novel computer-based enrichment.

In HCI, rapid prototyping is an integral and commonplace design method that allows designers to refine the design using small quick steps, over many iterations, towards the users' requirements and needs that are updated on the go [16]. To meet the need for new interfaces for primates in zoos, iterative design has also been used to prototype these devices [14, 47, 59]. However, current prototyping with primates limits the feedback from the animals, often not involving them in multiple iterations or throughout the entire design process and instead testing a single experimental system (e.g., [14, 47, 59]). This contrasts with the practice in prototyping within HCI, where continuous feedback from the user to the prototypes is integral [16]. As such, rapid prototyping is underutilised and has been underexplored with monkeys and animals in general.

To discover what a tangible interface, which we refer to as a 'button', for monkeys could look like, this paper uses the HCI method for rapid prototyping with white-faced saki monkeys. Within our process, we pay attention to the emerging differences in prototyping between humans and monkeys. In particular, this research addresses the following research questions:

> **RQ1: What do tangible buttons look like for monkeys?**
> **RQ2: What can we learn from adapting HCI prototyping methods to monkeys?**

In prototyping tangible buttons with sakis, we provide insights into the monkeys' preferences regarding interaction methods and button features. We found tensions in prototyping with monkeys in terms of leveraging the monkeys' prior experiences and between individual, group and species needs. Furthermore, our study highlights the challenge of supporting discovery and functional prototypes for animals. Reflecting on the transfer of HCI methods to animal–computer interaction (ACI), we unpack the meaning of 'low-fidelity' when prototyping with animals, question how we share power with humans as proxies for animals and highlight the importance of prototyping a wide breadth of designs to unravel the human bias.

Contribution Statement. This study is the first to look at developing a tangible computer interface for monkeys that questions what buttons for primates might look like. No prior research has been undertaken applying standard rapid HCI prototyping to monkeys and reflecting on the process of transferring prototyping from HCI to ACI. As such, this work provides a framework for future research into monkey–computer interaction and the development of interfaces for animals using rapid prototyping. To the benefit of HCI, designing interfaces for other species can also expand our human methods to make them more inclusive and creative as a result of our better understanding of how to design for non-verbal users and users with minds and bodies very different from our own. Practicing this shift in perspective and attempting to assess the monkeys' experience shares similar challenges with previous more-than-human design pursuits [6, 39, 42]. We build on this foundation by questioning the design steps taken in prototyping to highlight commonly made assumptions, uniting islands of knowledge and strengthening ACI and HCI alike.

2 RELATED WORK

A variety of approaches to animal-centred design have been proposed [7, 13, 24, 49, 51, 53]. However, these lack agreement and consistency and mostly involve applying HCI models directly to animal–computer contexts. For example, researchers have used user personas [7, 24] to centre design concepts before constructing technology, and different aspects of user experience have been used to centre animal feedback on designs [13, 51, 53]. Bridging these approaches, most researchers propose the definition that animal-centred design, as a body of theory, should focus on designing computer systems around the animal user by allowing the animal to maintain its natural behaviour [21, 36]. In line with this, many studies advocate for the importance of offering animals a form of consent, allowing the animal user to freely engage or disengage with any process or interaction with a device [5, 11, 17, 23, 32, 38, 43, 47]. This notion of consent in animal computing allows animals to provide feedback on the user experience via the agency that choice gives them.

For animals to use computer devices of their own volition, the user interface design must be such that they are capable of manipulating it and instinctively seek to interact with it without training [21, 61]. However, designing affordances for animal users that we cannot wholly understand and empathise with is a difficult process. In HCI, designers can take advantage of existing forms and their specific affordances that humans are familiar with, directly or through association, to design intuitive tangible interactions [45]. With animals, however, we are typically unable to take for granted either the form or the function. In computer enrichment for animals, a large part of this process is still missing, and we have yet to discover the ideal interface form for computer interaction. As such, a large part of ACI is dedicated to methods and theories that support animal feedback in the design process, aiming to nudge the design in the right direction.

In HCI, involving users in an iterative design process has been found to be essential to forming an understanding between stakeholders [40]. Similarly, it has been proposed that including animal users in design activities allows them to influence and shape the design process [47]. A number of studies have explored the involvement of animals in design activities [10, 22, 37, 59, 60]. Such shared design practices allow researchers to learn about animals' needs and requirements. In particular, prototyping has been proposed as a method that can help designers explore the affordances of tangibles through iterative testing with animals [47, 59], allowing the designers to discover and test features to validate their efficacy.

2.1 Prototyping with Animals

Prototyping is an early-stage design activity in which a sample version of a product is built to test a concept or process with a user. It is knitted into the design process of all services, products and systems for humans [4]. A cyclic process of prototyping, testing, analysing and refining a product or process is typically undertaken as part of an iterative design process.

Prototyping for animals inevitably differs from prototyping for humans due to differences in verbal feedback, sample sizes and the ability to involve the user in the stages of the process. Arguably, prototyping has yet to be integrated into the design process for animals using computers. When implementing an iterative design process with animals, the design is continually reshaped, and aspects of the prototype are refined based on what the experts looking after the animal, or interpreting its behaviour, can infer from its experience and feedback. Prototyping has also been proposed as a means of centring the design process on animals at an early stage [47]. However, while some studies have involved animals in prototyping [12, 14, 29, 47, 52, 59, 60], the methods employed vary, and no clear guidelines or best practices follow. Furthermore, the key challenges remain as to how to enable animals to give direct feedback on the user experience of the proposed designs and determining what can be learned from transferring HCI prototyping to animals.

The implementation of most iterative designs when building computers for animals often involves offering animals different options and changing and redefining the design based on the choices made. These options include how to interact, which interface to use and when/if to engage or disengage. It has been proposed that providing these options gives power to animals in the design process by eliciting their instinctive responses to a computer interface [37]. The affordances of computer interfaces for animals have been studied through iterative design and informed by observation of how animals instinctively interact with interfaces [12, 14, 29, 47, 52, 59]. However, only two studies among the examples cited allowed the animals to discover the interactivity for themselves and thereby influence the final design [12, 47]. In most studies, the animals' interactions with the prototypes were externally initiated, i.e., the animals were prompted in some way, such as by training [52], food rewards [12, 14, 60] or via gestures [12]. Furthermore, only one study [47] explicitly compared animals' responses to two distinct prototypes. Thus, while it is proposed that, to obtain direct input from animals, they should be given more autonomy and control in the design process through the facilitation of choice, little is known about how to elicit an animal's perspective in an unbiased fashion as part of prototyping in an iterative design process.

In HCI, rapid prototyping is a widely used prototyping style. In this style of prototyping, the construction of prototypes is accelerated to obtain the users' feedback on design concepts as early and quickly as possible, and this is repeated over many versions of the design. Quickly testing many versions of the concept allows for fine-tuning to the needs of the user [16]. Many examples of prototyping in animal computing have tested only one iteration before implementing the final device [29, 47] or have bypassed the iterative design process entirely and tested only the final prototype [14, 59]. Furthermore, when researchers in ACI do undertake more than one iteration, large changes are often implemented prior to any user testing, such as pivoting between prototype designs [12] or altering core features [52]. As a result, the effects of each change remain largely unclear with regard to what aspects and features improve usability and fit with the animals' requirements.

Unlike the field of HCI, no studies in ACI have yet gathered quantitative data to measure the success of prototypes (e.g., interaction times or the number of interactions) and enable more reflective results. In all examples of prototyping with animals for iterative design to date, the feedback gathered relies solely on qualitative data collected from direct observations and video recordings of interactions between the animals and prototypes (and humans if involved) [12, 14, 29, 47, 52, 59, 60]. It may be argued then, as Lawson et al. [31] suggest, that there is wide scope for human bias and misinterpretation when humans judge an animal's experience. This results in a gap that could be filled by undertaking a mixed-methods approach in combination with rapid prototyping to help tap into and form a holistic view of the animals' experiences informed by the animals themselves.

2.2 Interfaces for Monkeys

Most computer-enabled systems for enrichment have been used with great apes and involve tasks on screens [8, 30]. The interfaces have typically taken the form of touchscreens [2, 15, 44, 50, 54] or joysticks [34] but have also involved balls [48], brain-teaser puzzles [14] and projected screens [5]. Very little primate-computing work has focused on monkeys. Monkeys have thus far used touch-sensitive buttons to control lighting [3] and proximity sensors to trigger digital stimuli [17, 43, 47].

In designing intuitive user interfaces for orangutans, Wirman and Jørgensen [61] highlight the importance of physical and tangible interactions, even with digital interfaces. Building on this, Pons et al. [48] propose that tangibility can provide an intuitive form of interaction for any animal that has object manipulation ability or that prefers to use objects to interact with its environment. Building on this, Pons et al. [48] developed a system for orangutans that recognised when a ball was moved inside their enclosure and played sounds with different frequencies depending on the ball's location. However, this system was not used by the orangutans, meaning the results were inconclusive. On the same topic, Webber et al. [59] found that orangutans used hay from their enclosures to interact with a projected screen. These studies provide further evidence that tangible interfaces support the instinctive behaviour of primates using computers. These views are also aligned with the literature on HCI, where it has been argued that tangible interactions are intuitive because they leverage users' prior knowledge from the real world [27]. However, none of the aforementioned studies have investigated the use of tangible interfaces beyond objects (such as balls or hay) in the primates' enclosures.

It is clear from previous work that, while factors related to using screen devices with primates are well understood, there is a gap in understanding what tangible interfaces for controlling computer enrichment might look like beyond screens (RQ1). To create new interfaces, there is also a need to look at how prototyping methods need to transform when taken from humans to animals, in this case, primates (RQ2). Doing so will help shed light on how to transfer HCI methods to ACI and how monkey buttons might be designed.

3 PARTICIPANTS

This study was ethically approved by Korkeasaari Zoo and caused no pain or discomfort to the animals, following the European Act on the Protection of Animals Used for Scientific or Educational Purposes. For this study, a group of white-faced sakis were selected as participants due to their availability at the collaborating zoo, their stable hierarchy and the fact that no changes in their housing were planned, allowing for stable study conditions. The monkey participants were three white-faced sakis (*Pithecia pithecia*), including one female (Bea, 11 years old) and two males (Hubert and Igor, 5 and 4 years old, respectively). The white-faced sakis lived in Korkeasaari Zoo, where they were also born. This group was typical of troops outside of captivity, which are often small, averaging two to three individuals. Saki monkeys are typically shy and move fast and silently through the dense rainforest, preferring to spend time in trees, often leaping among them. For these reasons, sakis are among the least-studied primates [57]. Although they do not use tools to manipulate their environment, they are generally very tactile and tend to explore new objects by biting and using their hands.

4 METHOD

In this paper, we designed tangible buttons using rapid prototyping with white-faced saki monkeys to investigate what tangible buttons for monkeys might look like (RQ1) and what we can learn from adapting HCI prototyping methods to monkeys (RQ2). We first describe the method and then present an overview of the results followed by a detailed outline of the prototyping process through four iteration stages.

We aimed to design a tangible interface for sakis they were able to control and use within the context of computer-enabled enrichment. The interface had to consist of tangible elements that would be manipulated to control potential stimuli. In this paper, we term these objects buttons; however, what the buttons might look like and their functionality were open questions within our iterative process.

To form our initial requirements, we set as our aim that the button should be intuitive to use for monkeys, building on prior studies in ACI and using the term 'intuitive' to describe instinctive behaviour with an artefact [61]. To elicit instinctive behaviour from the sakis and to enable the sakis to interact with the button, the functionality and form of the button had to match the sakis' ergonomic capabilities (such as the size of their hands and the way they manipulate artefacts, e.g. gripping and mouthing), and the sakis had to be able to perceive the manipulability of the button via its appearance and how it responded when interacted with. Furthermore, the button had to attract the sakis' attention without food rewards or training. As such, we divided our overall aim into two requirements:

> **Design requirement 1 (DR1): The interaction mechanism matches the sakis' ergonomic capabilities and perceptions of manipulability.**
> **Design requirement 2 (DR2): The form of the button elicits the sakis' curiosity.**

If the button fulfilled DR1, the sakis would interact with it in a way that matched the interaction mechanism (or intended movement) the button allowed, e.g. pulling, pressing, twisting or grabbing. We deemed the interface to meet DR2 if the sakis chose to interact and engage with it. Fulfilment of both these design requirements would provide a button design that could be effectively used with sakis as part of an enrichment system to trigger digital stimuli, progressing RQ1.

For our method, standard HCI protocol stages were built upon to evaluate and form our buttons using rapid prototyping. These stages included building, testing, analysing and evaluating [9]. In this context, we first built a few prototype buttons (building), then tested the buttons with the sakis (testing), analysed the results (analysing) and, finally, evaluated the buttons by gathering feedback from the keepers and reflecting on the results (evaluation). During the evaluation, new requirements were formed, and design ideas and decisions were considered for the next iteration, generated as a result of discussions and brainstorming. After a full iterative round was conducted and lessons had been learned, the process was repeatedly iterated until we and the other stakeholders deemed that the prototype was ready to be implemented.

The prototypes were tested in sessions in the sakis' enclosure, with the sakis being free to take part in the testing if they chose to. All the sakis interacted with one or more designs during the prototyping iterations, doing so at different stages and with different prototypes according to their choosing. Each testing session was video recorded. After each round of testing, we gathered feedback on the prototypes from the sakis' keeper using unstructured interviews.

To evaluate each prototype, we used video footage, and the keeper's feedback allowed us to measure fulfilment of the requirements (DR1 and DR2) with both qualitative and quantitative data. The qualitative data consisted of careful observation of the sakis' interactions with the prototypes from the video footage, the keepers' feedback and our insights and observations (as expert designers for this troop of sakis). In observing the testing sessions, we paid particular attention to what the sakis' behaviour indicated about their possible reactions, intentions and attention towards the prototypes and listed the ways the sakis interacted with the prototypes (e.g. gripping and mouthing). The quantitative measures included the frequency and duration of the sakis' interactions with the interface. These were manually measured using the video recordings. We classified the start and end of an interaction based on the saki's proximity (approximately 20 cm) from the prototype and direction of attention (manifested through its behaviour). We further coded each interaction based on whether the sakis interacted with the button element of the prototype or only with its other areas. The quantitative measures enabled rigorous comparison of the prototypes and their features and the identification of correlations between the qualitative and quantitative data.

To check the evaluation against the requirements, we used the number of button interactions with matching movement to evaluate how the interaction mechanism suited the sakis (DR1), while we used the measures of interaction time, total number of interactions, number of button interactions and average duration of button interactions to evaluate how well the form of the button managed to elicit the sakis' curiosity (DR2).

The prototypes were largely made with wooden materials, which are typically used by the zoo to build enrichment for the sakis, and we ensured that no splinters or sharp edges were present. The materials used were not dangerous to the animals, and the short-term exposure of the sakis to the objects during prototyping was deemed suitable by the zoo. However, some of the wooden parts were laser cut, leaving combustion residue visible. While we were unable to find information on whether the burned edges of the wood were bad for animals, we suspect that they should be avoided in the future. In our prototypes, such edges were mostly present on the platform areas, which the sakis did not interact with using their mouths.

The remainder of this paper describes the four prototyping iterations (Fig. 1).

5 RESULTS: ITERATIVE PROTOTYPING

Table 1 presents an overview of the quantitative prototyping results over the four iterations with prototypes B1–B9, as shown in Figure 1. The first iteration explored the interaction mechanisms of touch and push; the second iteration explored touch, push and pull; the third explored pull, push down and move; and the fourth explored move. The remainder of this section describes the four iterations of our prototyping process.

5.1 Iteration 1: Touch and Push

5.1.1 Building the Prototypes. We began designing the buttons with the interaction mechanism, as this was the core concept for the design of a tangible button and a pressing factor in terms of determining whether the sakis would find the interface intuitive. As buttons had not previously been explored with sakis, there was no prior work to build upon. We considered that a monkey's interaction with a button could be initiated by touching, touching and pushing, or touching and pulling. In addition, the properties of a button, such as its shape, size and material, could contribute to the intuitiveness of its use, offering better usability by matching the sakis' perceptions and capabilities to the button's affordances (DR1). For example, a button that fits into a saki's hand promotes an ergonomic physical interaction mechanism involving the hands. In addition, the properties of the button, such as the colour or texture [27], could affect whether the sakis found it interesting and chose to engage (DR2). For these prototypes, we mostly used wood as the building material as it could withstand the sakis' biting and other exploratory behaviours, and scrap pieces were typically available at the workshop.

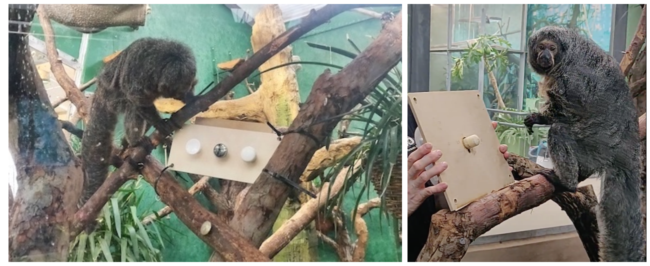

Figure 2: Testing prototypes B1 and B2

Figure 3: Prototypes B1 and B2 (front and back)

For the first prototype (B1), we tested a simple button design requiring only touch for successful interaction. As this was a very simplistic interaction mechanism often used with animals [52], we decided to additionally test buttons of the same shape made of different materials. We began with doorknobs that would fit inside a saki's palm and built a low-fidelity prototype (B1, Fig. 3) with three stationary round doorknobs (diameter 3.5–4 cm) made of metal, plastic and wood attached to a wood plank.

In the second prototype (B2), we tested a push-mechanism as this mechanism type is also commonly used with animals, e.g. [37]. The prototype (B2, Fig. 3) to test this mechanism was a cylindrical wooden button with a round top (diameter = 2 cm) and a spring underneath. The spring ensured that the sakis were unable to pull the button out of its mounting and that it returned to its original stationary position after being depressed. In B2, we additionally measured how much force a saki could apply to the button using a sensor to recognise the interaction; B2 was therefore considered a higher-level prototype. By measuring the force, we were thinking ahead and preparing for subsequent iterations in case the push button was the best design to proceed with.

Table 1: Summary of prototyping results from four iterations: iteration 1 – B1 and B2; iteration 2 – B3–B5; iteration 3 – B6–B8; and iteration 4 – B9.

	Interaction mechanism	Test time (min)	Interaction time	Interactions per minute (total)	Button interactions (BI) of total	Avg. duration of BI	BI with matching movement
B1	touch	50	1% (17s)	0.1 (3)	100% (3)	0% (5.7s)	100% (3)
B2	push	5	18% (54s)	1.0 (5)	80% (4)	4% (11.5s)	0% (0)
B3	push	3.5	5% (11s)	1.4 (5)	40% (2)	1% (2.5s)	0% (0)
B4	pull	3	17% (31s)	2.0 (6)	67% (4)	3% (5.5s)	0% (0)
B5	touch	3.5	5% (10s)	0.6 (2)	0% (0)	0% (0.0s)	0% (0)
P6	pull	4.5	51% (139s)	4.2 (19)	79% (15)	3% (8.3s)	27% (4)
B7	down	5.5	25% (84s)	2.5 (14)	57% (8)	2% (7.0s)	13% (1)
B8	move	5	63% (189s)	1.2 (6)	50% (3)	20% (60.3s)	100% (3)
B9	move	6.5	59% (231s)	3.1 (20)	80% (16)	3% (13.4s)	88% (14)

5.1.2 Testing the Buttons with the Sakis. We placed B1 on a tree within the sakis' enclosure for 50 minutes (Fig. 2). This method was chosen to allow the sakis time to explore the artefact. However, we found the test time of B1 to be highly inefficient (a long period with few interactions) and that all the interactions occurred in the initial few minutes. In light of this, B2 was tested for five minutes, with the designer holding the prototype for the sakis in their enclosure (Fig. 2). The designer held the prototype instead of the sakis' keeper to avoid the potential of external motivation emerging from the presence of a familiar human [12].

5.1.3 Analysing Results. The sakis spent time near prototype B1, observing it from afar and approaching it but often not touching it. As the sakis had only three tactile interactions (1) with the prototype, we could not infer their preference of button material. Because so few interactions occurred, with a duration of only 1% of the 50-minute test period (Table 1), we concluded that the sakis did not find B1 interesting, reflecting on DR2. We observed that the sakis were more curious towards B2: Five interactions with this prototype occurred, four of which were with the button element. Moreover, the interaction time was longer (11.5 s) than with B1 (5.7 s) (Table 1). The sakis also spent a large portion of the test time (18%, Table 1) interacting with B2.

In terms of DR1, the sakis interacted with the button as intended with B1 but not with B2 (Table 1). During one interaction with B1, a saki touched the leftmost plastic knob with its hand, holding it there for nine seconds. In the other two interactions, the sakis interacted with the prototype by mouthing. Similarly, the sakis mostly interacted with B2 through mouthing. Once, a saki gripped the B2 button with its teeth, slightly pushing it. As this was the only interaction in which the button was pushed, the efficacy and sensitivity of the sensor could not be determined.

5.1.4 Evaluating the Buttons. As the prototypes B1 and B2 were not tested with the same method, and the presence of human potentially contributed to the higher interest towards the B2, the results of B1 and B2 were not comparable with each other in terms of their level of intrinsic curiosity (DR2). With that being said, there is room to improve the design of B2 to be more interesting (DR2) as the sakis did not seem interested in exploring the prototype. Regarding DR1, the results indicate that the sakis found the interaction mechanism of B1 more intuitive than that of B2. The implication of this is that combining certain features of B1 (the shape of buttons) and B2 (the push action) could lead to a design that fulfils both requirements.

In reflecting on the testing session, the sakis' keeper proposed that pulling, rather than pushing, might be more intuitive to the sakis. Furthermore, the placement of buttons had to be considered in relation to the interaction mechanism: For sakis, push buttons might be more suitable on the floor, and pull buttons on vertical walls. Regarding the testing method, the sakis' interactions with the prototypes were all short (B1: 3–9 s, B2: 4–15 s), and the sakis quickly lost interest (their interactions occurring in the beginning of the test session). In light of the rapid prototyping method, the short test time of B2 was therefore judged to be effective in capturing the sakis' interactions, yielding enough information to continue the design process to the next iteration. We also decided that the early prototypes should strictly be of low-fidelity (similar to B1 rather than B2) as the testing of features like sensors (as with B2) is not useful when the interaction mechanism has not been validated, slowing down the speed of the prototyping process and distracting from the core concepts that need to be refined. Furthermore, we determined that the designer holding B2 to the sakis likely influenced their interest towards it. Moving forwards, we therefore planned to hold all the following prototypes as well to produce comparable results across them.

5.2 Iteration 2: Touch, Push and Pull

5.2.1 Building the Prototypes. Following the insights from iteration 1, we built three low-fidelity prototypes (B3–B5, Fig. 4). In B3,

Figure 4: Prototypes B3 (front and side), B4 and B5

the features of B1 (its form) and B2 (its interaction mechanism) were combined. It comprised a doorknob placed over a hole and connected to a spring. For B4, we used pull mechanism, consisting of a pull button and a purple pull-rope dog toy with a large ball at the end. The rope was placed through a hole in a piece of plywood and attached to a rubber band so that when the rope was pulled and let loose, it sprang back to its original position. For B5, we decided to test the simple touch mechanism again (as with B1) in contrast with the push (B3) and pull (B4) prototypes; this prototype involved a piece of metal (H 10 cm, W 14 cm) connected to a wooden plank.

5.2.2 Testing the Buttons with the Sakis. Building on the findings from iteration 1, for comparability, we tested the three prototypes in iteration 2 using the same method and with the same person holding the prototype for the sakis. The prototypes were tested during a single session lasting 10 minutes. The testing time for each prototype varied from 3 to 3.5 minutes; we did not want to interrupt the sakis' interactions and therefore waited until no more engagement was shown before moving to the next prototype. During testing, Hubert was the only saki who interacted directly with the prototypes, while Bea and Igor showed interest by approaching them and watching nearby.

5.2.3 Analysing the Results. In terms of DR2, of the three prototypes, the sakis were most interested in B4. They had the most interactions with it (six, Table 1), spent the most time interacting (17%, Table 1) and had individual interactions of the longest duration (5.5 s, Table 1). While they did interact with B3, their interaction time with this prototype was low (5%, Table 1). The interaction time with B5 was similarly short, and the sakis did not interact at all with the button element of B5.

With regard to DR1, none of the sakis' interactions with any of the prototypes matched the interaction mechanism (button interactions with matching movement, Table 1). The sakis interacted with the B3 button twice, once by mouth and once by hand, but did not push it, again indicating that the push mechanism was not intuitive to the sakis. Although Hubert interacted with B4 by gripping the ball with his hand and frequently moving it sideways to see what was underneath, he did not pull the rope in any of the interactions.

5.2.4 Evaluating the Buttons. The sakis' keeper speculated that B4's colour and shape were what made it the most interesting to the sakis. Specifically, defining the buttons with colours may have helped the sakis consider that they should be interacted with as they had experience with defined colours from toys and training sessions. We thus proposed that colouring the buttons could improve the design in light of both of our goals. The colour could help the sakis perceive the button as an interactive object or simply increase its appeal. Similarly, in HCI, designers often exploit texture and colour to draw the attention of the user [27]. Further, we thought that B4 was too big for the sakis to interact with according to the intended mechanism.

The keeper also added that objects exhibiting movement are interesting to sakis and that, despite the fact that they are relatively inactive monkeys, sakis like to explore and fiddle with objects to investigate the areas behind/underneath them. In particular, Hubert was familiar with colourful toys that had small moving pieces. In addition to paying attention to the elements of colour, size and movement, using objects with affordances familiar to the sakis (e.g. with pieces that moved sideways) could also work better, as speculated by Wirman and Jørgensen in relation to primates [61]. Leveraging users' prior knowledge of the world is a core part of tangible interaction design in HCI [27].

5.3 Iteration 3: Pull, Push Down and Move

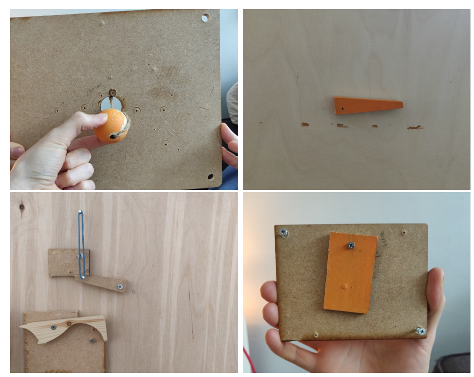

Figure 5: Prototypes B6, B7 (front and back) and B8

5.3.1 Building the Prototypes. For the third iteration, we deployed three prototypes (B6–B8, Fig. 5) that were bright orange in colour and sized such that the sakis could grip them easily. We chose the colour of the ball as orange because the sakis had earlier learned to react to this colour. Each button exhibited a different type of movement. Furthermore, B8 afforded movement mimicking a toy the sakis had used previously (a dog puzzle). B6 was a revised version of B4, comprising a pull button made of a wooden ball attached to a jute string. The ball was smaller than that in B4, facilitating easier movement, and the pull distance was longer (the ball could be pulled for approximately 15 cm). When released, the ball returned quickly to its original position tight against the plywood. B7 involved a lever button (a concept suggested by the keeper) built from wood, which sprang back into place after being pressed down. B8 comprised a movable wooden piece (a 'panel') mounted on an axle (a screw), hiding a red dot when in the neutral (downward) position. To see the colourful dot, the wood had to be moved. It was hoped that the red dot would function as a cue that the sakis would search for.

5.3.2 Testing the Buttons with the Sakis. We tested these prototypes following the method used in iteration 2, that is, they were presented by the designer to the sakis in the enclosure. The three prototypes were tested during a single 15-minute session. As before, we switched between prototypes when a natural break occurred in the sakis' interactions with them. Both Bea and Hubert were active in interacting with the prototypes.

5.3.3 Analysing the Results. In relation to DR2, the sakis interacted with B6 and B5 three times as many and twice as many times as B8, respectively (B6: 19 interactions, B7: 14 interactions, B8: 6 interactions, Table 1), interacting most frequently with the button element of B6 (79% of interactions involved the B6 button, Table 1). Despite this, the longest times were spent interacting with B6 and B8 (51% and 63% of the test times, respectively, Table 1). For B8, the sakis had only three button interactions, but Hubert spent most of the test time engaged in a single interaction that lasted nearly three minutes (165 s), which was long in comparison to the sakis' average interaction time of four seconds with the digital stimuli [17, 47]. Hubert was very active and would have continued interacting with the prototype had the session time not ended. This resulted in the sakis having the longest interactions with B8 (60.3 s on average, Table 1). Based on these measures, prototypes B6 and B8 were considered the most interesting to the sakis, while B8 best engaged them in long interactions. This was also demonstrated in the observations of the sakis' behaviour.

In terms of DR1, the sakis instinctively interacted with B6 by touching it with their mouths or by moving the ball by hand (without pulling it). They quickly learned to pull the ball when Hubert gripped the jute string with his teeth and pulled it. After learning this movement, the sakis successfully repeated it several times using their mouths and hands (Fig. 1). Of the 15 interactions the sakis had with the button of B6, they interacted with it according to the interaction mechanism in four (B6, Table 1). The sakis touched the button of B7 with their mouths and gripped it with their hands. In only one button interaction out of 8 did a saki push the lever down as was intended (B7, Table 1), indicating this design was not intuitive for the sakis. With B8, the sakis instinctively interacted by hand, moving the wooden piece sideways; after this, they also used their mouths, attempting to bite and pull it. Of all the prototypes, B8 had the most intuitive button: In all of the button interactions with B8, the sakis performed the intended movement (B8, Table 1).

5.3.4 Evaluating the Buttons. All these prototypes (B6–B8) had better results than the preceding ones (B1–B5), indicating that the changed attributes including a more ergonomic size, a new colour and different movements had a significant effect. However, at this point, we noticed that we had tested too many variables at once. From these findings, we concluded that the sakis were the least interested in B7 (DR2). This could have been due to the relatively small size of the button. In addition, B6 and B8 both allowed for a greater range of movement and, we suggest, had more interesting shapes than B7. B8 engaged the sakis for the longest period of time; however, this did not necessarily mean it had better interactive features. The sakis also interacted with B8 as was intended in each of their interactions with this prototype, meaning the design of the B8 button matched the sakis' capabilities and perceptions in this respect. Designing for the many ways that an animal might want to interact with a button may be the key to designing buttons for animals. Based on the observations and the quantitative measures, we chose the B8 design moving forwards to create a higher-level prototype.

5.4 Iteration 4: Touch and Move

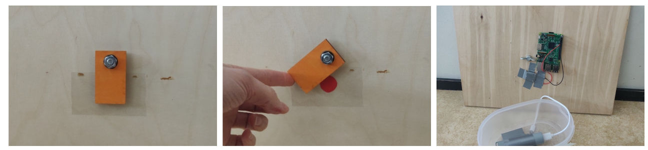

Figure 6: Prototype B9: Front, revealing of the red dot and the technology in the backside.

5.4.1 Building the Prototype. In the final stage of prototyping, we extended the B8 design concept to a higher-level prototype (B9, Fig. 6) that tested the interactive features. We added hardware built into the mechanism to detect the movement of the panel button, including a magnetic switch and a magnet as well as a Raspberry Pi and a portable charger. These adaptations meant that each movement of the button away from the centre point had the potential to trigger the detection mechanism (the magnetic switch), leading the software to automatically log the interaction.

5.4.2 Testing the Button with Sakis. We tested B9 for 6.5 minutes. In addition to observing how the sakis used the prototype (as in the previous iterations), we observed whether the physical modifications to the prototype changed the sakis' interactions with it and tested whether the adapted system correctly logged the movements of the button.

5.4.3 Analysing Results. The sakis spent 59% of the test time interacting with this prototype, which was the second-highest proportion (after that for B8) (Table 1). The average duration of the interactions was also high compared to those for the other prototypes (13.4 s, Table 1). In total, the sakis interacted 20 times with B9, with 16 of these interactions being with the button. This result showed improvement in comparison with the other prototypes (Table 1). To summarise these results, the sakis found B9 to be one of the most interesting of all the tested prototypes, validating the design concept in terms of DR2.

The sakis mainly interacted with the button by gripping it with one or two hands, moving it around its axle or trying to pull it off. In some interactions, the sakis bit the button or licked the red dot underneath it. A typical interaction involved a saki triggering the system an average of 6.4 times. In two interactions, the sakis only bit the wooden button and moved it slightly, and the red dot was not revealed; however, the system still recognised these as interactions, which indicates that it was too sensitive. Of the 16 button interactions, 14 included the matching movement (moving the panel to reveal the red dot), representing 88% of all button interactions (Table 1). This was the second-highest value for this measure (again, after that for B8); we were thus able to confirm that B9 fulfilled DR1. The small physical changes made to the prototype (to make it more durable) following the testing of B9 did not affect how the sakis interacted with the prototype.

5.4.4 Evaluating the Button. The B9 prototype performed similarly to its successor B8. The results confirmed that the sakis interacted with the button matching the interaction mechanism (DR1) and were seemingly curious towards the prototype (DR2). Testing the prototype with sensors confirmed that the button could be used as a trigger, e.g. for digital stimuli in a computer-enabled enrichment system. The testing also revealed that the sakis tried to lick the red dot placed underneath the panel, indicating they were potentially hoping for food rewards. Furthermore, the sakis' exhibited pulling, proposing that pulling could be the preferred way of interacting for the sakis compared to sideways movement.

6 DISCUSSION

In this study, we explored what tangible buttons might look like for white-faced sakis using the rapid prototyping method. The findings of this study benefit two main areas: the design of tangible buttons for white-faced sakis (RQ1) and the transferring of prototyping methods from humans to animals (RQ2). The discussion is split over these themes.

6.1 Button Findings

Prototyping with sakis resulted in concrete findings regarding monkey preferences for pull buttons and sideways-movement buttons over push and touch buttons. Specifically, we found that push buttons mounted on a vertical wall did not work with sakis, leaving open the possibility, however, that push buttons could be mounted on a horizontal surface. At the same time, all the prototypes tested other than the touch panel involved touch in addition to another movement type (e.g., touch and push for a push button). This need for two processes (touch and move) did allow for versatile methods of interaction; the sakis interacted with the button prototypes both with their hands and mouth, exhibiting various behaviours, such as fiddling, biting, pulling and smelling. However, the fact that the sakis often attempted to pull the panel button seems to indicate that a pull mechanism was more intuitive than a swinging-movement mechanism for these monkeys. Overall, our results indicate that mouthing (touching by mouth or placing into the mouth) and gripping with the hands to move or pull objects are the main methods of interaction for monkeys. We propose that catering to the many ways the animal want to interact with interfaces is key in designing for animals; for monkeys, these include pulling and swinging movements.

Suggestion 1: Monkeys prefer prototypes with pulling/swinging movement over pushing/touching and prefer interacting by gripping and mouthing.

Regarding material and colour, we used wood as the main material to build the prototypes. As a building material, wood was found to be easy to work with and build buttons of various forms. Furthermore, the material is durable for animals that typically chew and interact by mouthing objects, such as monkeys. Along with wood, we tested buttons made with metal, plastic, rope and jute. However, after the first prototype (B1), we decided not to focus on iterating on materials, although we found that metal was not an appealing material to sakis as they did not interact with these objects. We also found that button prototypes that were colourful and inhibited movement best caught the sakis' attention, leading to the highest interaction times. Regarding the form of the prototypes, non-flat shapes and smaller buttons seemed to also influence the prototypes' appeal. However, larger objects could be appealing if their range of movement was greater (e.g., a large pull button, B4), and non-flat small prototypes might not be engaging if they do not inhibit movement (e.g., small lever button, B7). Furthermore, having an ergonomic size and fitting into the sakis' hands were found to be important in terms of whether the sakis' interactions matched the intended button interaction mechanisms. As such, both size and movement were found to engage the sakis as they interacted with these objects past the point of initial interest. Colour, size and movement were key factors in the third iteration, with all the prototypes (B6–B8) eliciting more interaction than the previous ones.

Suggestion 2: Buttons with suitable colour, movement, and ergonomic size influence monkeys' engagement.

We also noticed a need for balance between designing for discovery and mitigating external motivators. While colour seemed to increase the appeal of the button to the sakis, it is unclear whether this was an instinctive behaviour or a learned association from the sakis' previous training experience with colours. With many zoo animals trained to touch coloured balls, this is an overarching factor in creating interfaces for animals. Similarly, the selected final button mimicked the movement of a toy the sakis were familiar with, leveraging their prior experience in the design of the interaction mechanism. This association with a toy could also have led to increased interaction in hope of food rewards or other intrinsic motivators. As such, the sakis' previous experiences were found to influence their interactions, indirectly involving external motivators. While some researchers developing interfaces for animals have used familiar objects [19, 48, 52], there is a trade-off here between making a user interface intuitive and testing its new transformed function.

The challenge of supporting both discovery and usable interaction is made more complex when the interactions are tested without the resultant stimuli. It could be argued that testing prototypes with many variations of the interaction and similarities across these variation is inherently confusing to animals. Furthermore, the animals' learning from testing can distort their interactions with the final design connected with the stimuli. Prototyping an interface isolated from the stimuli inevitably involves evaluating and refining another interaction (other than the stimuli), with the effect augmented by the evolving experience of the participating animals.

While it would be useful to study the interface and the stimuli together in a single prototype, this would create intertwining narratives of stimuli and interface. Other researchers have tested stimuli as a static feature within prototyping (e.g. [12]). Combining low-fidelity prototypes with stimuli, the animal users could become habituated to the stimuli before the implementation of the final system, to the detriment of the device's ability to remain interesting to animals and the interactivity of the final device. As such, there is reflexivity between the stimuli and interface; only through amalgamating the two in one prototype can the combination of these factors be tested with animals, but this results in the particular influence of each factor remaining unknown. Separating these two influential factors strikes at the heart of designing novel interfaces for animals to use: Little is known about what makes systems usable for animals. This work, however, takes a significant step towards addressing these issues by providing some initial scaffolding.

Suggestion 3: In designing interfaces for animals, there is a tension between using familiar interfaces to make use of the animals' intuition and mitigating the influence of external motivations and prior experience.

Looking at the individual monkeys' interactions, it seemed that Hubert was more eager to interact with the devices when humans were present, while Igor was more cautious and preferred to explore new objects by himself. The individuals' levels of engagement in testing the prototypes held by humans reflected their previous experiences of human–animal interactions [28]. Hubert may have also found the interaction with humans enriching in itself. These strong individual differences echo the findings of others studying primates [14, 34, 41, 44]. Further, Hubert was the most familiar with the movement of the panel button (B8/B9), which could have led to his long interactions with the button. As such, there is a tension between designing for the individual and designing for the troop as a whole. The question of whom we are designing for and how we build systems for monkeys on these two levels is a complex one, especially during the testing phase, where the significance of an individual animal's actions is magnified as every choice within each iteration echoes profoundly into the next design iteration. Fundamentally, the choices we make as humans in prototyping with and for animals are part of a reflective process in which decisions are influenced by stakeholders on both sides of the fence. Hence, we propose that prototyping for animals is primarily guided by the animal user, who has a strong influence on the gathered results, but that we, as humans, also hold significant influence.

Regarding the unravelling of the tension between the troop and the individual, zoos typically have small sample sizes available, with most work in ACI designing and prototyping with only one or two individual animals. Further research is needed to explore how to prototype inclusively, giving the individual animal the chance to express its perspective, while balancing this with the troop perspective to build designs based on generalisable and transferable insights. From another viewpoint, one can argue for a more individualised approach to designing for animals; some designers have suggested that an animal's personality affects how it interacts with computer devices [7, 60]. From whichever angle the issue is viewed, what this discussion brings to the fore is that there are different approaches to designing and prototyping for animals and tension in the balance of power among them.

Suggestion 4: Prototyping needs to balance individual animal's needs, the group's needs and the species' needs (which can be different) in both method and findings.

6.2 Findings from Prototyping with Monkeys

We noticed contradictory decisions taking place while determining an effective way to test the prototypes with the monkeys. On one hand, we aimed to test the prototypes with the sakis without providing any external motivation. On the other, we hoped to gather data on the sakis' interactions effectively, within a reasonable time frame. We found that short test sessions were most effective with the sakis as they typically had short interactions with the prototypes taking place early in the session, echoing results from others [17, 47]. However, we also learned that gathering enough data within a relatively short time frame (i.e., in five minutes instead of an hour) was possible due to human presence in the prototyping sessions as it increased the sakis' interest in and thus their interactions with the prototypes. This finding on human presence as a motivator is echoed in Piitulainen's [46] and French et al.'s [12] work. However while human presence increased the monkeys' interactions, this contradicts our aim of eliciting curiosity with the prototypes wholly resulting from the sakis' ordinary behaviour and unbiased choices. As such, prototyping with animals involves a balance between the factors impacting the animals' interactions and controlling for the validity and effectiveness of the testing method.

Suggestion 5: When prototyping with monkeys, the presence of humans influences their interactions.

The discoverability, novelty and interest of the prototypes posed a challenge. A highly engaging interaction method itself could impact the interactions with the final computer device rather than acting as a medium to provide stimuli. The final design concept was selected based on the fact that the sakis' method of interacting with it matched the intended interaction mechanism and because they engaged with the design for the longest periods of time. However, it can be questioned whether the measure of engagement and time is alone suitable for evaluating an interface. There is a tension between having a tangible interface that is discoverable and uses ordinary affordances and having one that does not distract from the stimuli it is a medium for. This is part of the larger picture when building interfaces for animals: While we want the most attractive and appealing interface, this can potentially mean the animals use it for the interface rather than the stimuli it provides.

Suggestion 6: With animals, the interface itself should be engaging without distracting from the stimuli it triggers.

6.3 Prototyping Methods from HCI to ACI

Many lessons were learned from applying a standard HCI prototyping methodology to animals. Ideally, in iterative design with humans, there would be time to go from low-fidelity (paper prototypes and wireframes) to high-fidelity (mock-ups and code) prototypes. However, with animals, this is challenging. With humans, low-fidelity prototypes can be fragile (e.g., made of paper and cardboard) and abstract (e.g., drawings and design fiction), but with animals, they must be durable, safe and concrete. As such, while we term our process 'low-fidelity', aligning it to the human prototyping method, it is actually high-fidelity as low-fidelity was not possible.

Another difference is the ambiguity with animals regarding when it is time to move to higher-fidelity prototypes. In this study, we determined that we had found the most successful prototype when the design requirements were met. Furthermore, with humans, there would be more iterative stages, while prototyping with animals involves constraints regarding novelty and habituation [25], with most interfaces losing their appeal over time. As such, finding a suitable level of fidelity can be challenging with animals as prototyping can mitigate against the final deployment. While our work progresses research on low-fidelity prototyping with animals and the emerging challenges, it also highlights the problems with the lack of low-fidelity processes and the fact that animals' interest can decrease from repeated prior stimulation during prototyping.

Humans can provide feedback directly or via a proxy for communication, such as is done by a parent with very young children [33] or to those with certain disabilities [55]. For animals in zoos, the proxy is the animals' keeper and other stakeholders (e.g., vets, zoo visitors or research staff), who can provide invaluable insights, supplementing the research's coded data. In our case, the sakis' keeper had a strong impact on motivating the prototype design decisions. However, it can be argued that the keepers' insights were not evidence-led and that we could be replicating human biases when relying on the keeper as a proxy. Additionally, keeper and visitor insights diverge because they are influenced by differing motivations [18]. Similar problems are echoed in research fields such as child–computer interaction, where much of the recent narrative has focused on methods to maintain the child's voice, thoughts and feelings [33]. Future work in prototyping with animals should also explore approaches to how we share power with the humans close to the animals and their role in influencing the design of interactions.

Another aspect of applying HCI to ACI that becomes apparent with animals is that humans tend to design on the basis of their own assumptions, needs and understanding. While this is a known problem across many facets of HCI, it becomes even more evident when designing for a user of a different species; adapting focus to animals' needs and requirements is difficult, representing a challenge faced when designing for non-human agents. The design concepts tested with animals in this study were inevitably limited to what we as human designers could imagine, build and design. Early on in our design process, we noticed that the sakis instinctively interacted in a multitude of ways with tangible interfaces, using their mouths and hands to touch, chew, bite and smell the prototypes. The full variety of ways in which animals interact with computers is yet to be discovered, and animal interactions often prove the assumptions of a design's efficacy for animals to be wrong or inaccurate. To cater to the multitude of ways that monkeys, or animals in general, interact, it is important to prototype using a wide breadth of designs to capture valuable feedback from the animals. By testing varied interaction mechanisms and forms for the tangible interface, we made branching decisions that allowed for the simultaneous iteration of multiple prototypes as well as for a comparison between these, yielding varied feedback for each iteration. These lessons inherently reflect on HCI and encourage designers to push beyond standard prototypes and presumptions.

The challenges faced in designing for ACI are not unique and have similarities with those in other more-than-human design pursuits ([6, 39, 42]). Shifting to the perspective and assessing the experience and ecology of the non-human user remain pertinent core challenges to overcome ([39, 42]). Improving the ability to engage with multiple perspective and, as a result, grasping how human designs affect non-human entities can advance our adaptation to and design of the environments in which people, animals and organisms alike meet [56]. Integrated with this is the challenge of exploring how human and non-human entities can thrive and cohabit together ([56]) and with the artificial ecologies ([6]).

7 FUTURE WORK

In this study, we worked towards investigating the large issue of prototyping with animals. However, our findings were set within a specific context of time, species and place, and further studies on various species will enrich and solidify our suggestions. Additionally, while we acknowledge that new features should be added in small steps and one at a time, in the end, we did test certain independent variables simultaneously (e.g., the pull mechanism and colour in B4), making it unclear how much each contributed to the results. Furthermore, when prototyping with animals in zoos, the limitations to the number of participants leads to an order effect as each new iteration is influenced by the animals' experience with the preceding prototypes. In future, the next step would be to build the final prototype design and introduce the stimuli triggered by the button interface to test the prototypes in a working system. Equally, while we recognised the need to experiment with wide variety of forms outside of what humans are used to, we were still limited to our human perspective. In the future, it would be pertinent to test various interaction mechanisms beyond pushing and touching, such as chewing and biting. We did not introduce these into our button prototypes as the buttons would gradually degrade over time; however, it would be interesting to scope into destructible interfaces rather than create for permanence.

8 CONCLUSION

With this work, we aim to offer significant insights into the design of tangible computer buttons and the adaption of HCI prototyping methods to monkeys. Part of this narrative includes exploring how to involve animals in the iterative design process. For the former, we found that the monkeys preferred prototypes with pull/swinging movement over push/touch buttons and typically interacted by gripping and mouthing. Colourful prototypes inhibiting movement and with ergonomic size (fitting in the monkeys' grip) had a strong effect on eliciting the monkeys' curiosity. We highlight the tension between leveraging familiarity with certain features and the fact that this familiarity might influence the monkeys' interactions by drawing on their prior experiences. Further, we found that the presence of humans influenced the animals' interactivity with the devices and that the individual animals responded differently, uncovering tensions between the requirements of the individual and those of the troop. When transferring HCI methods to ACI, we found that using low-fidelity prototypes was not possible with the animals. Additional factors were also relevant with animals, such as novelty and habituation, which forced us to quickly iterate in short bursts. We also found that humans had a significant influence on the process, both as a proxy speaking on behalf of the animals and as the designers making key design decisions. To mitigate these issues, we highlight the use of quantitative measures of the animals themselves to unravel these tensions and encourage designers to push beyond their assumptions. For the ACI community, this paper encourages and uncovers new ways for monkeys, and animals more generally, to interact with computer interfaces. For the HCI community, this paper pushes at the edges of what prototyping is, shifting and reframing what prototyping might look like when it is based on design for the other.

ACKNOWLEDGMENTS

This work was supported by the Royal Society of Edinburgh Fellowship [grant 2514]. We thank Korkeasaari Zoo staff and the white-faced sakis involved. Delving into new areas in the intersection between computer science and animals is never easy, and we are thankful for their patience and willingness to explore with us.

REFERENCES

[1] Eric P.S. Baumer. 2015. *Usees.* Association for Computing Machinery, New York, NY, USA, 3295–3298. https://doi.org/10.1145/2702123.2702147

[2] Helen Boostrom. 2013. *Problem-Solving with Orangutans (Pongo Pygmaeus and Pongo Abelii) and Chimpanzees (Pan Troglodytes): Using the iPad to Provide Novel Enrichment Opportunities.* Master's thesis. Texas A&M University. http://oaktrust.library.tamu.edu/handle/1969.1/150918

[3] Hannah M Buchanan-Smith and Inbal Badihi. 2012. The Psychology of Control: Effects of Control over Supplementary Light on Welfare of Marmosets. *Applied Animal Behaviour Science* 137, 3-4 (2012), 166–174. https://doi.org/10.1016/j.applanim.2011.07.002

[4] Bradley Camburn, Vimal Viswanathan, Julie Linsey, David Anderson, Daniel Jensen, Richard Crawford, Kevin Otto, and Kristin Wood. 2017. Design prototyping methods: state of the art in strategies, techniques, and guidelines. *Design Science* 3 (2017), e13.

[5] Marcus Carter, Sally Sherwen, and Sarah Webber. 2021. An evaluation of interactive projections as digital enrichment for orangutans. *Zoo Biology* 40, 2 (2021), 107–114. https://doi.org/10.1002/zoo.21587 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/zoo.21587

[6] Paul Coulton and Joseph Galen Lindley. 2019. More-Than Human Centred Design: Considering Other Things. *The Design Journal* 22, 4 (2019), 463–481. https://doi.org/10.1080/14606925.2019.1614320 arXiv:https://doi.org/10.1080/14606925.2019.1614320

[7] Elizabeth Cox, Clara Mancini, and Luisa Ruge. 2020. Understanding Dogs' Engagement with Interactive Games: Interaction Style, Behaviour and Personality. In *Proceedings of the Seventh International Conference on Animal-Computer Interaction* (Milton Keynes, United Kingdom) *(ACI'2020)*. Association for Computing Machinery, New York, NY, USA, Article 4, 12 pages. https://doi.org/10.1145/3446002.3446122

[8] Crystal L. Egelkamp and Stephen R. Ross. 2019. A review of zoo-based cognitive research using touchscreen interfaces. *Zoo Biology* 38, 2 (2019), 220–235. https://doi.org/10.1002/zoo.21458 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/zoo.21458

[9] Interaction Design Foundation. 2021. *Rapid Prototyping, Faking It Until You Make it in a UX Driven World.* Retrieved August 5, 2022 from https://www.interaction-design.org/literature/article/rapid-prototyping-faking-it-until-you-make-it-in-a-ux-driven-world

[10] Fiona French, Ilyena Hirskyj-Douglas, and Heli Väätäjä. 2020. Designing Technologies for Playful Interspecies Communication. In *Proceedings of the Seventh International Conference on Animal-Computer Interaction* (Milton Keynes, United Kingdom) *(ACI'2020)*. Association for Computing Machinery, New York, NY, USA, Article 20, 6 pages. https://doi.org/10.1145/3446002.3446003

[11] Fiona French, Clara Mancini, and Helen Sharp. 2016. Exploring Methods for Interaction Design with Animals: A Case-Study with Valli. In *Proceedings of the Third International Conference on Animal-Computer Interaction* (Milton Keynes, United Kingdom) *(ACI '16)*. Association for Computing Machinery, New York, NY, USA, Article 3, 5 pages. https://doi.org/10.1145/2995257.2995394

[12] Fiona French, Clara Mancini, and Helen Sharp. 2018. High tech cognitive and acoustic enrichment for captive elephants. *Journal of Neuroscience Methods* 300 (2018), 173–183. https://doi.org/10.1016/j.jneumeth.2017.09.009 Measuring Behaviour 2016.

[13] Fiona French, Clara Mancini, and Helen Sharp. 2020. More Than Human Aesthetics: Interactive Enrichment for Elephants. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS '20)*. Association for Computing Machinery, New York, NY, USA, 1661–1672. https://doi.org/10.1145/3357236.3395445

[14] Stuart Gray, Fay Clark, Katy Burgess, Tom Metcalfe, Anja Kadijevic, Kirsten Cater, and Peter Bennett. 2018. Gorilla Game Lab: Exploring Modularity, Tangibility and Playful Engagement in Cognitive Enrichment Design. In *Proceedings of the Fifth International Conference on Animal-Computer Interaction* (Atlanta, Georgia, USA) *(ACI '18)*. Association for Computing Machinery, New York, NY, USA, Article 6, 13 pages. https://doi.org/10.1145/3295598.3295604

[15] Priscilla P. Grunauer and Justin W. Walguarnery. 2018. Relative Response to Digital Tablet Devices and Painting as Sensory Enrichment in Captive Chimpanzees. *Zoo Biology* 37, 4 (2018), 269–273. https://doi.org/10.1002/zoo.21431

[16] H.Rex Hartson and Eric C. Smith. 1991. Rapid prototyping in human-computer interface development. *Interacting with Computers* 3, 1 (1991), 51–91. https://doi.org/10.1016/0953-5438(91)90005-M

[17] Ilyena Hirskyj-Douglas and Vilma Kankaanpää. 2021. Exploring How White-Faced Sakis Control Digital Visual Enrichment Systems. *Animals* 11, 2 (2021). https://doi.org/10.3390/ani11020557

[18] Ilyena Hirskyj-Douglas and Roosa Piitulainen. 2020. Developing Zoo Technology Requirements for White-Faced Saki Monkeys. In *Proceedings of the Seventh International Conference on Animal-Computer Interaction* (Milton Keynes, United Kingdom) *(ACI'2020)*. Association for Computing Machinery, New York, NY, USA, Article 3, 12 pages. https://doi.org/10.1145/3446002.3446123

[19] Ilyena Hirskyj-Douglas, Roosa Piitulainen, and Andrés Lucero. 2021. Forming the Dog Internet: Prototyping a Dog-to-Human Video Call Device. *Proc. ACM Hum.-Comput. Interact.* 5, ISS, Article 494 (nov 2021), 20 pages. https://doi.org/10.1145/3488539

[20] Ilyena Hirskyj-Douglas, Patricia Pons, Janet C. Read, and Javier Jaen. 2018. Seven Years after the Manifesto: Literature Review and Research Directions for Technologies in Animal Computer Interaction. *Multimodal Technologies and Interaction* 2, 2 (2018), 29 pages. https://doi.org/10.3390/mti2020030

[21] Ilyena Hirskyj-Douglas and Janet C. Read. 2014. Who Is Really In The Center Of Dog Computer Design?. In *Proceedings of the 2014 Workshops on Advances in Computer Entertainment Conference* (Funchal, Portugal) *(ACE '14 Workshops)*. Association for Computing Machinery, New York, NY, USA, Article 2, 5 pages. https://doi.org/10.1145/2693787.2693793

[22] Ilyena Hirskyj-Douglas and Janet C. Read. 2018. DoggyVision: Examining how Dogs (Canis familiaris) Interact with Media using a Dog-Driven Proximity Tracker Device. *Animal Behaviour Cognition* 5 (2018), 388–405. https://doi.org/10.26451/abc.05.04.06.2018

[23] Ilyena Hirskyj-Douglas, Janet C. Read, and Brendan Cassidy. 2017. A dog centred approach to the analysis of dogs' interactions with media on TV screens. *International Journal of Human-Computer Studies* 98 (2017), 208–220. https://doi.org/10.1016/j.ijhcs.2016.05.007

[24] Ilyena Hirskyj-Douglas, Janet C. Read, and Matthew Horton. 2017. Animal Personas: Representing Dog Stakeholders in Interaction Design. In *British Human-Computer Interaction proceedings* (Sunderland, UK). Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.14236/ewic/HCI2017.37

[25] Ilyena Hirskyj-Douglas and Sarah Webber. 2021. Reflecting on methods in animal computer interaction: novelty effect and habituation. In *Eight International Conference on Animal-Computer Interaction.* 1–11.

[26] Lydia M. Hopper. 2017. Cognitive research in zoos. *Current Opinion in Behavioral Sciences* 16 (2017), 100–110. https://doi.org/10.1016/j.cobeha.2017.04.006 Comparative cognition.

[27] Eva Hornecker. 2012. Beyond Affordance: Tangibles' Hybrid Nature. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction* (Kingston, Ontario, Canada) *(TEI '12)*. Association for Computing Machinery, New York, NY, USA, 175–182. https://doi.org/10.1145/2148131.2148168

[28] Geoff Hosey. 2008. A preliminary model of human–animal relationships in the zoo. *Applied Animal Behaviour Science* 109, 2 (2008), 105–127. https://doi.org/10.1016/j.applanim.2007.04.013

[29] Pinar Kaygan and Gülşen Töre Yargin. 2019. Design for the well-being of domestic animals: implementation of a three-stage user research model. *Design and Technology Education: an International Journal* 24, 3 (10 2019), 12–30. https://ojs.lboro.ac.uk/DATE/article/view/2663

[30] Nicky N.E. Kim-McCormack, Carolynn L. Smith, and Alison M. Behie. 2016. Is interactive technology a relevant and effective enrichment for captive great

apes? *Applied Animal Behaviour Science* 185 (2016), 1–8. https://doi.org/10.1016/j.applanim.2016.09.012
[31] Shaun Lawson, Ben Kirman, and Conor Linehan. 2016. Power, Participation, and the Dog Internet. *Interactions* 23, 4 (June 2016), 37–41. https://doi.org/10.1145/2942442
[32] Mark James Learmonth, Sally Sherwen, and Paul H. Hemsworth. 2021. Assessing preferences of two zoo-housed Aldabran giant tortoises (Aldabrachelys gigantea) for three stimuli using a novel preference test. *Zoo Biology* 40, 2 (2021), 98–106. https://doi.org/10.1002/zoo.21585 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/zoo.21585
[33] Florence Kristin Lehnert, Jasmin Niess, Carine Lallemand, Panos Markopoulos, Antoine Fischbach, and Vincent Koenig. 2022. Child–Computer Interaction: From a systematic review towards an integrated understanding of interaction design methods for children. *International Journal of Child-Computer Interaction* 32 (2022), 100398. https://doi.org/10.1016/j.ijcci.2021.100398
[34] Suma Mallavarapu, Mollie Bloomsmith, C. Kuhar, and Terry Maple. 2013. Using multiple joystick systems in computerised enrichment for captive orangutans. *Animal Welfare* 22 (08 2013). https://doi.org/10.7120/09627286.22.3.401
[35] Clara Mancini. 2011. Animal-Computer Interaction: A Manifesto. *Interactions* 18, 4 (July 2011), 69–73. https://doi.org/10.1145/1978822.1978836
[36] Clara Mancini, Shaun Lawson, and Oskar Juhlin. 2017. Animal-Computer Interaction: The emergence of a discipline. *International Journal of Human-Computer Studies* 98 (2017), 129–134. https://doi.org/10.1016/j.ijhcs.2016.10.003
[37] Clara Mancini and Jussi Lehtonen. 2018. The Emerging Nature of Participation in Multispecies Interaction Design. In *Proceedings of the 2018 Designing Interactive Systems Conference* (Hong Kong, China) *(DIS '18)*. Association for Computing Machinery, New York, NY, USA, 907–918. https://doi.org/10.1145/3196709.3196785
[38] Ann Morrison, Hannah Larsen, Caroline Fieldus, Alexander Kist, and Ananda Maiti. 2020. Platypus Surfing: In Search of the Perfect Wave. In *Proceedings of the Seventh International Conference on Animal-Computer Interaction* (Milton Keynes, United Kingdom) *(ACI'2020)*. Association for Computing Machinery, New York, NY, USA, Article 15, 6 pages. https://doi.org/10.1145/3446002.3446052
[39] Iohanna Nicenboim, Elisa Giaccardi, Marie Louise Juul Søndergaard, Anuradha Venugopal Reddy, Yolande Strengers, James Pierce, and Johan Redström. 2020. More-Than-Human Design and AI: In Conversation with Agents. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 397–400. https://doi.org/10.1145/3393914.3395912
[40] Steve North and Clara Mancini. 2016. Introduction: frameworks for ACI: animals as stakeholders in the design process. *ACM Interactions* 23 (07 2016), 34–36. https://doi.org/10.1145/2946043
[41] Maria Obsen, Sarah Bøgh Madsen, Sanne Sloth, Marcus Gintberg, Trine Jensen, Aage Alstrup, Sussie Pagh, and Cino Pertoldi. 2021. Sleep Meditation as Auditory Enrichment for Captive Chimpanzees (Pan troglodytes). *Genetics and Biodiversity* 5 (06 2021), 71–87. https://doi.org/10.46325/gabj.v5i2.953
[42] Netta Ofer, Fiona Bell, and Mirela Alistar. 2021. Designing Direct Interactions with Bioluminescent Algae. In *Designing Interactive Systems Conference 2021* (Virtual Event, USA) *(DIS '21)*. Association for Computing Machinery, New York, NY, USA, 1230–1241. https://doi.org/10.1145/3461778.3462090
[43] Tadatoshi Ogura. 2012. Use of video system and its effects on abnormal behaviour in captive Japanese macaques (Macaca fuscata). *Applied Animal Behaviour Science* 141, 3 (2012), 173–183. https://doi.org/10.1016/j.applanim.2012.06.009
[44] Bonnie M. Perdue, Andrea W. Clay, Diann E. Gaalema, Terry L. Maple, and Tara S. Stoinski. 2011. Technology at the Zoo: The Influence of a Touchscreen Computer on Orangutans and Zoo Visitors. *Zoo Biology* 31, 1 (2011), 27–39. https://doi.org/10.1002/zoo.20378 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/zoo.20378
[45] Daniela Petrelli, Nick Dulake, Mark Marshall, Matt Willox, Fabio Caparrelli, and Robin Goldberg. 2014. Prototyping Tangibles: Exploring Form and Interaction. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction* (Munich, Germany) *(TEI '14)*. Association for Computing Machinery, New York, NY, USA, 41–48. https://doi.org/10.1145/2540930.2540966
[46] Roosa Piitulainen. 2020. *Designing auditory enrichment for white-faced saki monkeys*. Master's thesis. Aalto University. School of Science. http://urn.fi/URN:NBN:fi:aalto-202005243299
[47] Roosa Piitulainen and Ilyena Hirskyj-Douglas. 2020. Music for Monkeys: Building Methods to Design with White-Faced Sakis for Animal-Driven Audio Enrichment Devices. *Animals* 10, 10 (2020), 26 pages. https://doi.org/10.3390/ani10101768
[48] Patricia Pons, Marcus Carter, and Javier Jaen. 2016. Sound to Your Objects: A Novel Design Approach to Evaluate Orangutans' Interest in Sound-based Stimuli. In *Proceedings of the Third International Conference on Animal-Computer Interaction* (Milton Keynes, United Kingdom) *(ACI '16)*. ACM, New York, NY, USA, Article 7, 5 pages. https://doi.org/10.1145/2995257.2995383
[49] Benjamin Ishak Resner. 2001. *Rover@Home: computer mediated remote interaction between humans and dogs*. Master's thesis. Massachusetts Institute of Technology, Department of Architecture, Program in Media Arts and Sciences, Massachusetts. http://dspace.mit.edu/handle/1721.1/7582
[50] Sarah Ritvo and Suzanne Macdonald. 2016. Music as enrichment for Sumatran orangutans (Pongo abelii). *Journal of Zoo and Aquarium Research* 4, 3 (08 2016), 156–163.
[51] Sarah E. Ritvo and Robert S. Allison. 2014. Challenges Related to Nonhuman Animal-Computer Interaction: Usability and 'Liking'. In *Proceedings of the 2014 Workshops on Advances in Computer Entertainment Conference* (Funchal, Portugal) *(ACE '14 Workshops)*. Association for Computing Machinery, New York, NY, USA, Article 4, 7 pages. https://doi.org/10.1145/2693787.2693795
[52] Charlotte L. Robinson, Clara Mancini, Janet van der Linden, Claire Guest, and Robert Harris. 2014. Canine-Centered Interface Design: Supporting the Work of Diabetes Alert Dogs. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 3757–3766. https://doi.org/10.1145/2556288.2557396
[53] Luisa Ruge and Clara Mancini. 2019. A Method for Evaluating Animal Usability (MEAU). In *Proceedings of the Sixth International Conference on Animal-Computer Interaction* (Haifa, Israel) *(ACI'19)*. Association for Computing Machinery, New York, NY, USA, Article 14, 12 pages. https://doi.org/10.1145/3371049.3371060
[54] Vanessa Schmitt. 2019. Implementing Portable Touchscreen-Setups to Enhance Cognitive Research and Enrich Zoo-Housed Animals. *Journal of Zoo and Aquarium Research* 7, Article 2, 8 pages. https://doi.org/10.19227/jzar.v7i2.314
[55] Laurianne Sitbon and Shanjana Farhin. 2017. Co-Designing Interactive Applications with Adults with Intellectual Disability: A Case Study. In *Proceedings of the 29th Australian Conference on Computer-Human Interaction* (Brisbane, Queensland, Australia) *(OZCHI '17)*. Association for Computing Machinery, New York, NY, USA, 487–491. https://doi.org/10.1145/3152771.3156163
[56] Nancy Smith, Shaowen Bardzell, and Jeffrey Bardzell. 2017. Designing for Cohabitation: Naturecultures, Hybrids, and Decentering the Human in Design. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 1714–1725. https://doi.org/10.1145/3025453.3025948
[57] Jean-Christophe Vie, Cecile Richard-Hansen, and Christine Fournier–Chambrillon. 2002. Abundance, use of space, and activity patterns of white-faced sakis (Pithecia pithecia) in French Guiana. *American journal of primatology* 55 (01 2002), 203–21. https://doi.org/10.1002/ajp.1055
[58] Sarah Webber, Marcus Carter, Sally Sherwen, Wally Smith, Zaher Joukhadar, and Frank Vetere. 2017. Kinecting with Orangutans: Zoo Visitors' Empathetic Responses to Animals' Use of Interactive Technology. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 6075–6088. https://doi.org/10.1145/3025453.3025729
[59] Sarah Webber, Marcus Carter, Wally Smith, and Frank Vetere. 2020. Co-Designing with Orangutans: Enhancing the Design of Enrichment for Animals. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS '20)*. Association for Computing Machinery, New York, NY, USA, 1713–1725. https://doi.org/10.1145/3357236.3395559
[60] Michelle Westerlaken and Stefano Gualeni. 2016. Becoming with: Towards the Inclusion of Animals as Participants in Design Processes. In *Proceedings of the Third International Conference on Animal-Computer Interaction* (Milton Keynes, United Kingdom) *(ACI '16)*. Association for Computing Machinery, New York, NY, USA, Article 1, 10 pages. https://doi.org/10.1145/2995257.2995392
[61] Hanna E. Wirman and Ida K. H. Jørgensen. 2015. Designing for Intuitive Use for Non-Human Users. In *Proceedings of the 12th International Conference on Advances in Computer Entertainment Technology* (Iskandar, Malaysia) *(ACE '15)*. Association for Computing Machinery, New York, NY, USA, Article 58, 8 pages. https://doi.org/10.1145/2832932.2837008