# Co-Designing with Orangutans: Enhancing the Design of Enrichment for Animals

**Sarah Webber[1]** **Marcus Carter[2]** **Wally Smith[1]** **Frank Vetere[1]**

[1] School of Computing & Information Systems, The University of Melbourne, Australia

[2] The University of Sydney, Australia

s.webber@unimelb.edu.au, marcus.carter@sydney.edu.au,
wsmith@unimelb.edu.au, fvetere@unimelb.edu.au

**Figure 1 & 2:** Orangutan Gabby interacting with two of the interactive projections developed for this project

## ABSTRACT

In creating digital technologies for animals, designers often seek to deploy and adapt human-centred techniques of interaction design. A significant challenge lies in enabling animals to play an active and generative role in the design process. This is of particular concern when the primary design objective is to address the behavioural and psychological needs of animal users. In collaboration with orangutans and human stakeholders at a zoo, we conducted co-design to create an interactive installation to enhance the orangutans' wellbeing. This paper presents the design journey undertaken and reflects on the challenges of designing with animals in a complex real-world setting. From this, we propose ways in which interaction design methods can be better adapted to working with animals by integrating qualitative and quantitative techniques drawn from the animal sciences. These reflections and proposals are relevant to researchers and practitioners investigating the design of animal-centred digital technologies.

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### CCS Concepts

•**Human-centered computing → User centered design**

## INTRODUCTION

A significant challenge for conducting interaction design with animal-users is to include non-humans as design partners [32, 37, 49]. As technology designers get closer to the future users of the products they create [57] and aim to address the needs of non-human users, they encounter substantial barriers to eliciting and capturing the perspective of non-verbal others [4]. This is ultimately a grand challenge for Animal-Computer Interaction (ACI) research, which seeks to understand and respond to animals' needs through adaptation of user-centred interaction design methods [39].

In this paper, we describe the design journey of our project, which aimed to explore how digital technologies could enhance the wellbeing of orangutans at a zoo. Environmental enrichment is a strategy for improving the welfare of captive animals by providing increased complexity and life experiences which are relevant to animals' psychological and behavioural needs [45, 77]. It is anticipated that zoos' strategic shift towards conservation and animal welfare will lead to greater emphasis on creating complex enclosures which encourage active exploration and meet animals' behavioural needs [14, 18, 44]. However, it will remain important for zoos to continue to attract visitors and contribute to tourism and public engagement with natural science. The potential role for digital technologies to contribute to visitor engagement and to provide varied and complex enrichment, has been explored by several researchers in zoos [8, 13, 33, 58, 58, 66] and other settings [51, 70, 75].

Our project employed a co-design approach, working with human stakeholders to investigate animals' needs and the organisational context, and was informed by empirical insights into the effects of existing digital technologies in the zoo [65]. We conducted design activities which would allow us to learn directly from animals by providing them with prototype interventions and observing their behaviour [43]. Technical aspects of the installation and findings from an evaluation of effects on zoo visitors have previously been published [66]. In this paper we revisit the project design journey to present an account of the design activities conducted with animals and zoo stakeholders and reflect on the successes and limitations of these activities. This reflective account is followed by a discussion of potential future avenues for co-designing with animals, based on refinement of existing ACI design processes and adopting techniques from the animal sciences. Through this examination of the zoo-based project to create enrichment for orangutans, we respond to ACI debates about approaches for including animals as participants in design, and suggest opportunities for enhancing the practice of co-design with animals.

## APPROACHES TO DESIGNING WITH ANIMALS

While efforts at "animal-centred design" have emerged only fairly recently, in parallel with the rise of the animal-computer interaction discipline [28] there is a long history of designing spaces and devices for animals. In this section, we survey the literature to understand how designers have approached the challenge of understanding and responding to animals' needs and perspectives.

### Designing Housing and Husbandry for Zoo Animals

The design of zoo enclosures has largely been driven by objectives related to public viewing of animals. In the mid-20th Century, zoos moved away from pits or barred cages towards enclosures which prioritised visibility of animals, sanitation and climatic control [23]. These approaches still typically resulted in featureless exhibits with few opportunities for animals to perform natural behaviours [23, 44, 45]. The contemporary design of "good", "modern" zoos [16] favours naturalistic exhibits which display animals as though in their natural habitat, to support the conservation education goals of zoos [5, 59]. Many have argued for naturalistic design as a means to allow zoo animals to behave as they would in nature [24]. For example, artificial 'vines' might allow primates an important opportunity to climb and brachiate. However, many such exhibits prioritise "aesthetic naturalism", for the benefit of the viewing public, but offer little "functional naturalism", in that they provide no new behavioural opportunities which are relevant to the animals' needs [23]. Increasing attention is given to creating opportunities for animals to perform psychologically important behaviours and encourage purposeful exploration of their environment [11, 18]. In these examples we see how in the design of animals' captive environments, the needs of human stakeholders and socio-cultural expectations are given considerable attention, alongside the needs of the animals [9, 18].

The suitability of zoo enclosure design is most commonly audited by assessing housing and husbandry provisions (the "inputs") against sectoral standards, rather than by assessing the impacts on animal behaviour and wellbeing (the "outcomes") [18, 64]. As modern zoos integrate animal welfare science into their husbandry practices [3, 64] they are placing greater focus on assessing animals' subjective experience. Systematic observations of animal behaviour allow researchers to determine how animals spend their time ("time budgets"), to compare these to their counterparts in the wild [63] or to identify changes in welfare status [72]. Behavioural indicators of fear, frustration, pain or poor health include behaviours such as avoidance, hiding, immobility and distress signals, as well as repetitive behaviours such as pacing [3]. In addition to systematic measurement of such behaviours zoos are experimenting with tools which capture keepers' qualitative assessment of animals' subjective wellbeing, as a way to monitor changes in welfare [72]. There is growing recognition of the importance of qualitative assessments in capturing animals' welfare experience, and the value of integrating a range of metrics to make inferences about animal wellbeing [69]. Behavioural researchers also conduct behavioural experiments to examine animals' preferences for alternative resources, and cognitive bias assessments to determine animals' emotional state [3, 44].

### Designing Environmental Enrichment

Environmental enrichment is deployed by zoos to provide opportunities to "work", to encourage physical movement, and to perform behaviours important to their wellbeing [77]. Zoos have developed a variety of approaches and devices, often categorised as sensory enrichment (addition of visual, olfactory, tactile or auditory stimuli), structural enrichment (addition of alternative substrates and physical structures), social enrichment (adding or changing animal groupings), human-animal interactions (including reward-based training), and feeding enrichment (such as puzzle feeders, foraging devices and food scatters) [31]. Studies have shown that the provision of appropriate enrichment can reduce repetitive behaviours, encourage animals' active exploration of the environment and promote a wider range of natural behaviours [77].

Enrichment interventions which allow animals to employ a variety of different methods to work for food can improve welfare by allowing animals increased agency and control over their lives [45]. Cognitive enrichment is proposed as a means to replicate the challenges of problem-solving, navigation and learning required for survival in the wild [11]. To be effective in exercising animals' cognitive skills and allowing control over their environment, the level of challenge must be appropriate to the individual animal [46]. However, constraints on time and resources often prevent zoo keepers from providing cognitive enrichment which offers sufficient variety and ongoing challenge, particularly for primates [31].

Processes to design zoo enrichment vary greatly. In a large proportion of zoos, keepers are responsible for designing and creating enrichment, and draw inspiration primarily from other institutions or published literature [31]. In many zoos, approval processes exist, and in some there are specific staff responsible for designing enrichment. At a few larger organisations, formal frameworks for designing enrichment are in place. For example, at Disney Animal Kingdom, the *S.P.I.D.E.R* framework guides staff to work collaboratively to set goals, plan, implement, document, evaluate and re-adjust animal enrichment [2, 47]. In this process, enrichment goals are set by zoo staff, who review footage of species' wild behaviours and select a priority behaviour to target. Success is generally evaluated through keeper assessments of the intervention's effectiveness. Zoo staff do not always have sufficient time to evaluate the enrichment they provide [31], although researchers have identified a variety of possible approaches to measuring effectiveness through systematic observation of animal behaviour [2].

There is considerable interest in the zoo sector in the use of novel digital technologies as environmental and cognitive enrichment for primates and other species [20, 34, 58, 66]. It has been proposed that technological interventions might contribute to a number of different forms of animal enrichment, including social interaction, human interaction and opportunities to exercise control over the environment [11, 54]. There are indications that digital technologies such as computer-based testing and iPad applications can offer enrichment which delivers animal welfare benefits [8, 11]. Studies entailing the design and implementation of interactive technologies indicate that digital enrichment could be deployed more efficiently than traditional forms of enrichment, and more easily tailored to meet the needs of individual animals and avoid habituation and predictability [11, 12, 34].

### Co-Design and Animal-Computer Interaction

ACI researchers seek to understand and respond to animals' needs through adaptation of user-centred interaction design methods [39]. However it remains an open challenge for ACI to define robust methods to identify animals' design requirements, and privilege the perspective of animals as participants in the design process [32, 37, 49]. The efforts of the ACI community to include animals as active participants can be understood as work which parallels and extends the aims of the Scandinavian participatory design movement of the 1970s and '80s. Just as new types of generative design activities were required for designers to be able to collaborate as partners with trade union members [55, 57], new models of participation are required for non-humans to contribute meaningfully to design. A significant challenge in this regard is to counter human tendencies towards anthropocentrism in design practices and in interpretation of animals' needs [10, 37, 43].

In creating digital enrichment to address the needs of orangutans at the zoo, we sought to work with animals and human stakeholders as co-designers. Co-design has in recent years gained popularity as an approach to including future users and other stakeholders in the design process. The term co-design has been denoted as referring to "the creativity of designers and people not trained in design working together in the design development process" [57]. Definitions which depend on concepts such as "creativity" are problematic for designers working with animals. In the field of animal-computer interaction (ACI), animals are commonly recognised as sentient beings, whose interests should be reflected and addressed in the design of products which will affect them [6]. However, many design activities largely depend on the use of conceptual language and symbolic representations to exchange complex ideas about abstract notions such as goals, priorities and risks. Given the impossibility of communicating with animals in such terms, many established interaction design techniques cannot be used effectively with non-humans. Indeed, it is doubtful whether non-humans can participate knowingly in acts of "creativity", and indeed whether they can be said to be "working together" with human designers. A broader objective for co-design projects which target animals' needs is to include the animal as *an expert of their own experience* [57], learning directly from animals about their needs and desires.

It is common for ACI researchers and designers to work primarily with human carers as *proxies* to learn about an animal's behaviours or needs [6, 29, 41]. Some ACI researchers have noted the challenges of working with stakeholders with varying levels of knowledge about animal behaviour [29, 78]. The inclusion of animals as unwitting collaborators in the design process, whose needs can be easily misrepresented or misinterpreted, raises ethical and conceptual issues. Shaun Lawson, Ben Kirman and Conor Linehan argue that design processes which rely on the ability to reason, speculate and interpret are inherently prejudiced against non-humans [37]. They posit that to attempt to include animals in such activities results in an imbalance of power relationships, but that the design process should give equal weight to the concerns of all stakeholders [37]. These concerns reflect the ideals of participatory design, with its history rooted in politically-driven and rights-based approaches to including people in design practices [55].

In our work with zoo-housed orangutans we sought to position the primates as sentient beings who can participate in co-design by contributing to generative design activities as experts in their own experience. Design with animals has often entailed direct interaction with animals around made objects. Observation of animals' behaviour can lead to design improvements which better correspond to their preferred mechanisms of interaction [42]. This approach has been proposed as a form of co-construction, allowing for open-ended processes of design [40, 71, 74]. Such research draws on Haraway's concept of 'becoming with' companion species [25]. Some ACI designers propose play between animal and researcher as a means for interrogating animals' desires and responses to a prototype solution [70, 74]. In this paper we critically examine how co-design with animals can be conducted effectively through collaborating with human proxies, and working directly with animals as *experts in their own experience* [57]. Based on our design journey, we contribute new insights into how interaction design approaches and behavioural evaluations from animal welfare science can be adapted to working with animals in ACI projects, in line with the goals of co-design and cognisant of the challenges of designing with non-humans.

## DESIGN AIMS AND APPROACH

This project was initiated in collaboration with Melbourne Zoo. The Zoo's animal welfare specialists sought to investigate the role that digital technologies might play in providing animal enrichment. Keepers had been using iPads as a form of enrichment for orangutans, in common with other zoos worldwide [60]. Zookeepers were enthused by orangutans' use, but it was apparent that they faced usability limitations in interacting with these devices. Touchscreen computers constrain animals to specific forms of finger-based interaction, offering fewer opportunities for behavioural choice than physical enrichment items [22, 76]. Consequently, we aimed to investigate whether a bespoke interactive installation could better respond to the species-specific behavioural needs of orangutans:

**Design objective 1:** Develop a digital installation to provide enhanced, varied enrichment for orangutans

In addition to providing new behavioural opportunities for animals, zoo stakeholders quickly imagined that such a technology might contribute to visitor engagement, in-keeping with the Zoo's aims regarding the public presentation of live animals and conservation education. We previously found that digital technologies in the zoo risk, firstly, distracting visitors from the central experience of watching animals, and secondly, disrupting the sense of being immersed in a natural space [65]. In our design project, these two concerns were cast as challenges for our second design objective:

**Design objective 2:** Create visitor experiences which enhance visitors' engagement with animals by fostering respect for and interest in orangutans

These two design objectives reflect the challenge of designing with animals in zoos. In addition to the orangutans, the project had to incorporate a wider variety of stakeholders than initially conceived, including animal welfare scientists, zookeepers, the wider zoo staff, and visitors. This introduced multiple roles and sets of objectives for the designed intervention, in addition to the requirements of both human and animal research ethics.

Consequently, the project sought to achieve our design objectives through a co-design approach, with the research aim of critically exploring how interaction design methods could be adapted to co-design with animals in this complex zoo context. In doing so our approach draws on Research through Design (RtD), a method that involves investigating a research question by way of designing something that can be evaluated [79], acknowledging that insights and contributions to knowledge are generated through the process of design and the produced artefact [26] and not just the final evaluation. Fiona French and colleagues have previously proposed that RtD practices can be effective in designing for animals in zoos and other settings [20]. French identifies the importance of eliciting engagement of keepers and animal experts, suggesting RtD prototyping approaches can foster expert and creative input. Through this approach, we sought to develop deeper insights into human stakeholders' perspectives on opportunities and challenges relating to design for zoo animals.

In the following section, we describe the design activities conducted at each stage of the project and reflect on how they enabled us to address the challenge of co-designing with animals. Through this, we seek to contribute deeper insights into the ways that interaction design processes can be adapted when working with animals.

## DESIGN JOURNEY

This section of the paper provides an account of the co-design project to create digital enrichment for orangutans in collaboration with Melbourne Zoo. For each stage of the design journey we describe the principal design intentions and challenges addressed, the design activities conducted, and the way these design activities influenced the subsequent design of the system.

### Co-Design Phase 1: Understand Context of Use

In this first phase of the design project, researchers aimed to develop a richer understanding of the context of use, the priority needs of animals and keepers, and the limitations and issues affecting existing enrichment.

#### *Co-Design Activities: Contextual Interviews*

Zoo personnel were recruited to participate in *contextual interviews* [52], through which we aimed to understand in greater depth the needs of animals and the perspectives of human stakeholders. Animal welfare personnel at the zoo identified and engaged appropriate zoo staff responsible for animal care and visitor experience, explaining the project aims and the purpose of interviews to secure their participation.

We interviewed zoo keepers and an animal welfare specialist at the orangutan exhibit, and *back of house*, in keepers' offices and at the den area away from public viewing. Interviews touched on routine provision of care and enrichment for orangutans, challenges and issues encountered, and keepers' aspirations for this aspect of their work. These contextual interviews revealed the extent of the effort expended by keepers and other personnel in designing and creating enrichment to provide sufficient variety and cognitive challenge for the animals. It was observed that considerable time was spent preparing food enrichment (such as puzzle feeders and forage) and conducting enrichment activities (such as training and painting). The primary design objective raised by keepers was to be able to offer greater variety of enrichment within the organisation's resource constraints. As part of this, they hoped to reduce the predictability of the orangutans' routine and environment. In addition, keepers noted the potential benefits of a system which could not be easily dismantled or destroyed, somewhat proudly showing us evidence of the orangutans' impressive destructive capabilities to emphasise the unsuitability of commercial digital technologies in the zoo. We also noted the challenges of deploying digital technology in a semi-outdoors setting subject to weather and wildlife.

In the course of contextual interviews, we observed the iPads in use as a form of enrichment. Several iPad applications were offered to orangutans in the *back of house* dens area. Orangutans interacted with the iPads in short bursts (generally less than a minute in duration) and received food reinforcement for interactions with the iPad, indicating that the devices did not offer intrinsic reinforcement. It was noted that there were several limitations to the orangutans' use of iPads. Firstly, keepers had to focus on holding the iPad close enough for interaction but prevent the orangutans from taking hold of it in a way that would allow them to break it. This meant that there were few opportunities for any direct, technology-mediated interactions. Secondly, orangutans were constrained to interacting with the touchscreen display with their fingertips, using tapping and swiping motions. Finally, the iPads required keeper supervision. This led some respondents to posit that for the orangutans an important aspect of iPad use was the opportunity for positive interaction with a keeper. However it was also noted that animals should be less dependent on keepers for access to enriching experiences. It was envisaged that an interactive installation which could be safely left with orangutans would increase quality of life substantially through offering out-of-hours enrichment and reducing reliance on keepers.

Contextual interviews with zoo staff also revealed how orangutans are an 'ambassador' species with the potential to inspire visitors' concern for wildlife. To support this, the zoo carefully crafts the presentation of orangutans, and some forms of behaviour are encouraged over others. To understand these requirements, we interviewed zoo personnel responsible for planning and delivering visitor experiences and education. A major consideration is that behaviours enacted by zoo animals should elicit a "sense of connection", in keeping with the organisation's Connect-Understand-Act model of conservation education [38, 50]. An important tactic is to engender visitor empathy through presentations which emphasise similarities between animals and humans, and which elicit positive affective responses.

**Figure 3: Orangutan Malu interacting with an iPad game.**

While most staff at Melbourne Zoo are enthusiastic about the potential role of digital technologies in animal enrichment, debates regarding the importance of naturalism in zoos continue to play out [9, 17]. There were some concerns that seeing animals using computers in zoo animal enclosures will cause public misunderstandings, and detract from zoos' efforts to create links between the animals and their wild habitats. Respondents pointed to other cases where animals and technology have resulted in negative media attention as cautionary tales, such as where footage from an Elephant wearing a GoPro at another zoo resulted in media criticism that the enclosure was too small for the animal.

Working with a broad range of specialists revealed considerable diversity in their perspectives, priorities and concerns, shaped by their disciplinary background and professional focus. This phase also identified how the zoo, as an organisation, might understand such a project to be successful, in addition to the individual stakeholder's perceptions of success. At this stage of the project, researchers met with a member of the animal ethics board to identify potential ethics concerns, which emphasised the need (also expressed by zoo staff) to conduct a summative evaluation of the enrichment using animal welfare science methods.

### Co-Design Phase 2: Identify Alternative Solutions

Based on the understanding of context developed in Phase 1, the design team set out to investigate the problem space and explore the scope of possible solutions. The primary aim of this phase was to generate design ideas and make key design choices which would shape the proposed system. Including animals in the initial stages of design presents considerable methodological and communicative challenges. Nonetheless, in this phase researchers sought to keep orangutans' needs and perspectives at the centre of the design project.

#### *Co-Design Activity: Design Workshops*

To explore the problem space and encourage creative participation of co-designers, design workshops were conducted with HCI experts and with zoo personnel. Through authors' professional networks, HCI researchers were recruited to participate in a technology design workshop. The objective of this first workshop was to identify relevant technologies which might address the Zoo's design objectives for digital enrichment for orangutans. Group brainstorming activities were conducted to draw inspiration from other domains, and to ideate alternative approaches to using emerging digital technologies in this problem space.

Subsequently, a workshop was conducted with zoo stakeholders, and a small number of HCI experts, to explore in depth the aims, opportunities and challenges for digital orangutan enrichment at the zoo. In this workshop, design ideation drew inspiration from the orangutans' known motivations and preferences identified in the contextual interviews. For instance, in learning about the individual personalities and preferences of the orangutans, the research team also identified that mobile phone screens were a commonly utilised form of digital enrichment. Smartphones were used opportunistically to show videos and photos of a variety of content, such as photos of keepers' children, of other orangutans, other animals, cartoons and photos of the orangutans. It was through this activity that Kiani, a 36 yr old female orangutan, displayed significant preference towards looking at photos of herself, exhibiting disinterest or frustration when shown other photos. Her preference has become an anecdote frequently mentioned during keeper talks, with staff believing it is an effective way to connect visitors with the orangutans as individuals having unique personalities. In some cases, in response to these accounts, visitors used mobile phones in an effort to interact with the orangutans, attempting to show photos or videos to the orangutans through the glass. Pervasive attempts by visitors to take 'selfies' with orangutans inadvertently facilitated these types of interactions. On several occasions we observed orangutans viewing these screens, though much more commonly they were ignored.

This characterised the existing relationship between zoo visitors and the orangutans. Our observations and meetings with visitor experience and conservation education teams emphasised that while the orangutans were interested in zoo visitors, their interactions were fleeting and distributed across the day, changing based on weather, other enrichments, time-of-day and individual preferences. Gabby, for instance, was extremely fond of men with large, red beards, while Kiani was fascinated with the content of people's bags. Keepers reported that the orangutans sometimes showed a preference for areas of the exhibit from where they could observe visitors.

The existing enclosure at MZ was a part of the *Trail of the Elephants*, a multi-part 'immersive' exhibit that simulated a south-east Asian environment, oriented towards a conservation message related to deforestation associated with palm oil. In workshops, staff in the conservation education team expressed strong interest in enrichment as a means to demonstrate orangutans' physical superiority to humans, thereby fostering visitor awe and sense of connection with the animals.

Findings from design workshops enabled the research team to define more closely the aims of the digital enrichment system and make fundamental choices about the system design. Through this process, alternative technologies were weighed as the foundation for the enrichment system. There was ample data to suggest that a physical, tangible component would be successful in eliciting orangutans' interaction. However, keeper perspectives suggested that a sensor-based system, providing a virtual 'touchscreen' through a projected interface sensor, would provide significant benefits. Firstly, it would allow greater flexibility, as new applications could be developed and deployed relatively easily, with varying levels of complexity to provide ongoing mental stimulation and challenge. Secondly, it would minimise safety and engineering issues by avoiding the need for physical components to be provided to the orangutans.

Another decision made during this phase in the co-design project related to the use of food rewards. A concern emerged that rewarding orangutans for touching the interface might bias their interactions to those behaviours that had been rewarded, subsequently limiting the potential welfare benefits. It was also felt that food rewards could lead to perceptions that the orangutans were being coerced to 'perform' for visitors, irrespective of the welfare benefits of food-based cognitive enrichment [48]. Since much of the enrichment provided to orangutans was food-based, the decision was made that this system would not, in the first instance, involve food rewards. Instead, the co-design team adopted the aim to develop something that was *intrinsically* rewarding to the orangutans. Of note, some keepers did not think that the orangutans would engage with the interface at all without food rewards, but agreed to trial it without food first.

The deployed system used a Microsoft Kinect sensor and projector to create a large 'touchscreen' style interface on the floor of the orangutan enclosure (see Figure 1). This technology was selected to allow orangutans to adopt their preferred mechanism of interaction. We developed our own touch-detection software that was responsive to the breadth of ways orangutans might touch the projection; with whole hands, feet, faces and objects, building on the approach of

Wilson et al. [73] Both the data projector and the Kinect sensor operated through a glass wall of the orangutan enclosure. This design placed hardware outside of the animal enclosure, significantly reducing safety risk, and allowing the orangutans as much freedom as possible in their interactions, without having to make changes to the enclosure. The installation was positioned on a glass corner of the orangutans' enclosure to be readily visible to visitors entering the exhibit area. From the outputs of workshop-based ideation, the project team designed five applications for orangutans. Two of these aimed to introduce the system as interactive (*Burst* and *Sweep*); two were designed to explore creative engagement (*Gallery* and *Painting*); and the most complex game required orangutans to match coloured shapes (*ZZZaap!*).

Insights into the orangutans' preferences and habitual behaviours provided substantial material as inspiration for the design of enrichment applications. Keepers used painted red dots on the walls of the enclosure during training which the orangutans would be cued to touch, to encourage movement and as part of 'station' training. This trained behaviour inspired the design of the *Burst* application for orangutans, which features a large moving red dot which explodes when touched. Orangutans routinely use their forearms and objects such as blankets to sweep platform areas clear of debris, likely an imitation of keepers' routine sweeping, as observed elsewhere [56]. This behaviour motivated the *Sweep* application, which features flashing coloured tiles that disappear when touched.

While both design workshops produced valuable insights, the validity of creative outputs was constrained by the fact that HCI experts had little understanding of orangutans' cognitive capabilities and motivations, while zoo stakeholders lacked substantial knowledge of possible solutions offered by emerging technologies. Ideation was most effective in workshop groups which included both HCI and zoo expertise. However, an important limitation of this approach is that it did not include direct input from orangutans in the ideation of possible solutions and early exploration of design concepts.

### Co-Design Phase 3: Deploy Prototypes

In this phase, we deployed the digital enrichment system for use by the orangutans after a long period of development and applications for ethics approval. We anticipated that it would be necessary to refine the prototype touch-detection system and applications based on observations of the orangutans' interactions. An important aim was to learn about orangutans' preferred mechanisms of interaction, through observing their spontaneous, unprompted interactions with the system.

#### *Co-Design Activity: Observation of Prototypes in Use*

The technology was introduced twice weekly (for periods of 2-3 hours) over a 4-week period in February 2016. Orangutans' behaviour during trial sessions was recorded using a static camera and a handheld camera. Zoo keepers and welfare specialists observed orangutans' behaviour closely to make inferences about the impact of the trial on their wellbeing, and determine session length. As the adult orangutans were mostly given individual access to the enrichment to reduce the chance of territorial interactions over the system's use, most periods of access were kept relatively short (20-30 minutes). The longest period of access, by a family group of three, was approximately 90 minutes. Debriefing meetings were conducted by researchers with the zoo keepers and animal welfare specialist to support iterative refinement of the applications during this process.

As noted above, to be able to observe the breadth of ways that the orangutans would choose to interact with the novel interface, and their preferred forms of interaction, orangutans' interactions with the installation were not rewarded with food or other reinforcement.

The orangutans at Melbourne Zoo are familiar with moving projections, as animated movies are sometimes projected on to a sheet hung in the enclosure. It was therefore expected that they would not immediately understand that the new installation was interactive. The first two applications (*Burst* and *Sweep*) were designed to attract orangutans, encouraging their approach and interaction with the projected interface. The applications were created so as to be immediately responsive to any interaction, to emphasise the ability of the orangutan to impact the visual projection. Concerns on this front proved to be unwarranted, as the orangutans immediately investigated the new screen and discovered the interactive features.

### Co-Design Phase 4: Evaluate Against Requirements

The Melbourne Zoo animal welfare specialists sought to evaluate the effectiveness of the system as a form of enrichment for zoo-housed orangutans. This aim of contributing to industry knowledge about appropriate enrichment for the species is in keeping with zoos' conventional approaches to applied animal welfare science, and demands research methods which will allow for statistical inference about a population despite small sample sizes [61]. The research team also set out to investigate in what ways the digital enrichment system influenced visitors' perceptions of orangutans. Findings of the latter study have previously been published [66].

#### *Evaluation Activity: Animal Welfare Evaluation*

To study effects on animal welfare, orangutans were given access to the digital enrichment on a randomised treatment allocation. Ten study days were allotted for each individual. On the study day, the relevant individual was given access for one hour to the enclosure area where the enrichment system was installed. For five of the ten days (randomised), the system was enabled, and for five it was switched off. Observations of animals were recorded at five-minute intervals against a predefined catalogue of behaviours to detect changes in welfare state. All instances of interaction with the digital enrichment system were observed and recorded. Animals' behaviours were observed using five-minute sampling for two hours afterwards, to detect flow-on effects.

The animal welfare study provided concrete data about orangutans' use of the digital enrichment system, and revealed some impacts on welfare indicators. It was found that the juvenile (female) orangutan interacted with the installation far more than others. Those animals that used the system most exhibited more play behaviours, and were more active on days when they had access to the system. The study also revealed clear differences in the extent to which animals' use of the system waned over the course of the study. One female orangutan exhibited more behaviours suggestive of high levels of arousal or vigilance on days when she was able to use the digital enrichment (perhaps associated with changes in social groupings). However, no statistically significant behavioural differences were detected for the group on days when the enrichment was provided. Study outcomes provide licence for continuing investigation of digital enrichment for zoo-housed orangutans.

This evaluation revealed several inherent tensions between conducting an animal welfare study and the interaction design methods adopted in this project. Firstly, this form of evaluation requires that the intervention be fixed for the duration of the study. Secondly, the quantitative data gathered did not contribute to understanding which aspects of the installation were of most value to orangutans or support improvement.

## FUTURE AVENUES FOR DESIGNING WITH ANIMALS

The preceding reflective account of our design journey reveals limitations in some of the interaction design activities we conducted, as well as pointing to fruitful approaches for designing with animals. The remainder of this paper provides recommendations for how such activities could be enhanced or supplemented in an animal-centred design process. This critical reflection has been informed through subsequent discussions with specialists in animal welfare and behaviour, as well as a continuing collaboration with Melbourne Zoo and other institutions regarding the design, use and evaluation of interactive technologies for animals. Through these cross-disciplinary connections we have identified ways in which qualitative and quantitative methods, drawn from the animal sciences as well as design disciplines, might be combined effectively. These techniques and their potential contribution to animal-centred design are discussed below.

### Enhancing Phase 1: Understand Context of Use

*Contextual Interviews*

Contextual interviews with zoo personnel were highly effective as a means to understand the needs of animals as well as the perspectives of zoo stakeholders. The benefits of contextual research have been long appreciated by HCI researchers [30] and comparable methods have been used in some ACI research projects [36, 41]. Interviews conducted in the course of keepers' interactions with animals and routine work enabled us to gain a rich understanding of animal care objectives and challenges faced. Observations of the work environment provided clues as to the priorities, daily routines and constraints that needed to be addressed to improve on existing enrichment provisions.

The elicitation techniques we used with a range of Zoo personnel were successful in drawing out diverse perspectives on the orangutans' needs and how a digital enrichment system might benefit them. In these activities, the zoo personnel acted as 'proxies' in the design process, standing in for the animal in workshops and interviews, and providing interpretation of their behaviour. A strength of our project is that it is based in the zoo, and so has throughout been able to obtain input from specialists representing a wide range of animal disciplines. However, reconciling stakeholders' different perspectives and competing priorities was challenging at many points in the co-design process. ACI researchers can enhance their ability to conduct effective contextual interviews and analyse data gathered from proxies by acquiring knowledge about the species of study, husbandry practices and the disciplinary perspectives of different animal sciences and being aware of stakeholder's competing priorities.

*Expert Prioritisation of Behavioural Needs*

At the outset of an animal-centred design project, defining the requirements from the perspective of the animal can be supported by species-specific knowledge about highly motivated behaviours: those behaviours which the animal needs to perform for psychological wellbeing. In recent years, Veasey has developed a technique for gathering and synthesising expert judgements on species' behavioural and experiential needs [62]. The AWPIS technique, based on the Delphi method [15] asks a panel of experts to rank behaviours and cognitive processes against twelve criteria, reflecting motivational characteristics, evolutionary significance and known welfare impacts for the species. From these rankings are derived priorities for the species' psychological welfare, providing guidance for design and management of animals in zoos and other captive environments. By surveying the existing environment and experiences provided to animals, designers and carers can determine which AWPIS priorities should be addressed for the animals they work with. This promising approach might supplement carers' existing knowledge about animals' needs, and provide a critical foundation for the co-design work of determining design objectives when developing interventions for animal welfare.

### Enhancing Phase 2: Identify Alternative Solutions

*Design Workshops*

From design workshops with HCI experts and zoo stakeholders, we gained deeper insights into the priorities and challenges relating to animal enrichment, and an overview of possible solutions permitted by emerging technologies. These activities elicited fresh perspectives on design challenges and opportunities, as other researchers have found when conducting similar design workshops for animal-oriented interventions [21]. However, we found that the relevance of HCI workshop outputs was constrained by the participants' lack of detailed knowledge about animals' motivations and the goals and practices of zoo enrichment. We posit that more effective brainstorming would have resulted from co-design workshops which co-ordinated the relevant expertise of animal specialists and HCI researchers. Informed by data about the animals' behavioural needs (perhaps developed through the AWPIS protocol described above), groups of participants with combined technical and contextual knowledge might rapidly ideate solutions which are both feasible and relevant.

#### *Wizard of Oz to Explore Conceptual Designs*

Design projects can benefit from obtaining direct feedback from future users about the suitability and desirability of a proposed intervention early in the design process [52]. However, usual approaches to communicating design concepts (such as sketches and walkthroughs) are inaccessible to non-humans. Our project, like many other ACI endeavours, sought animals' input by developing and deploying working prototypes [19, 70]. This approach has the drawback of delaying direct input from animal users, and foreshortens the exploratory and creative phase of design ideation.

To explore animals' responses to early design concepts, Wizard of Oz techniques can be used [27, 52]. Mock-ups which are safe for animals to use, but which rely on human intervention to provide the proposed interactivity, could be more quickly created than fully computerised prototypes, allowing designers to rapidly trial several alternative design proposals. To quickly create low-fidelity prototypes which are known to be safe, designers might repurpose equipment and materials which are already used by the animals, rather than introducing new devices or materials. In conjunction with *prototype decomposition*, described below, these approaches could be used to develop a fine-grained understanding of which aspects of a proposed solution are likely to be of value to the animals.

### Enhancing Phase 3: Deploy Prototypes

#### *Observing Prototypes in Use*

Zoo stakeholders' feedback from observations of animals' use of prototypes provided formative input to the design project. We found that responses were subject to variance through the course of the project. We posit that greater consistency could be achieved by nominating specific project stakeholders to review video footage of animals' interactions with the prototypes. Qualitative observations might be supplemented by quantitative approaches such as single subject studies and qualitative wellbeing assessments, as outlined below.

#### *Prototype Decomposition*

In designing digital enrichment for orangutans, we explored the *behaviours* (mechanisms of interaction) that would be of value to the animals, the *consequences* (such as access to photographs, triggering visual effects) that they would prefer, and the *cues* (visual stimuli such as the projected moving dots and flickering tiles in *Burst* and *Sweep*, respectively) that would elicit interaction. A limitation of deploying fully working prototypes was that it was difficult for researchers to disentangle animals' responses to the cues, behaviours and consequences offered by the proposed solution.

Animals' preferences could be more efficiently determined by investigating separately their responses to alternative cues, behaviours, and consequences. In designing for behavioural opportunities, a beneficial first step would be to investigate animals' intrinsic motivation to perform target behaviours (perhaps using motivation tests, described below). This would provide a foundation for exploring the relative success of alternative cues in eliciting those behaviours. And, if relevant, animals' responses to alternative consequences might be investigated using preferences tests (described below). This approach could be combined with Wizard of Oz techniques to provide a fine-grained understanding of animals' responses to different system components.

#### *Preference and Motivation Tests*

To determine how appealing possible solutions are to animals, systematic preference tests and motivation tests can be deployed [53]. Such tests can be devised to determine whether, and to what extent, an animal is motivated to access a resource, such as an enrichment intervention, or one of its components. They can also be used to examine whether the animal is more motivated to access one resource than another, so might allow researchers to compare animals' preferences between two or more proposed solutions. Motivation tests might also be used to investigate whether an animal's motivation to access an enrichment intervention changes over time or is affected by environmental factors.

### Enhancing Phase 4: Evaluate Against Requirements

#### *Animal Welfare Evaluation*

To evaluate the effects of the digital enrichment on orangutans' behaviour, zoo personnel conducted a randomised controlled study, in keeping with habitual methods of applied welfare science [18]. However, the outcomes of this study were non-significant, as has been the case for other zoo-based researchers conducting similar evaluations [2].

In the context of an iterative design project, this form of evaluation is somewhat limiting in that it requires that the intervention be 'fixed' for the duration of the study. During the study period, no changes to applications or system configuration were made.

Following calls for use of multi-method approaches in the animal welfare sciences, evaluation based on quantitative behavioural metrics might be supplemented by qualitative assessment. Integrating different types of data about animals, and knowledge from a range of disciplines (e.g. behavioural, ecological, veterinary, psychological), can provide greater confidence in judgements about their wellbeing [67, 72]. To evaluate the effect of enrichment, researchers might combine two or three types of measures, including quantitative measures of behaviour, qualitative assessments of wellbeing (described below), and physiological measures (such as levels of stress hormones detected through saliva or faecal samples).

#### *Qualitative Assessments of Wellbeing*

Several lightweight, qualitative techniques and tools for monitoring animal wellbeing have been developed, which might be applied to the evaluation of enrichment. One approach is to ask carers to rate animals (on a Likert scale) across items relating to mood, sociability, and ability to achieve goals [35, 68]. Another technique, *free choice profiling* [69], prompts carers to conduct qualitative assessments of animals' behaviour and assign their own descriptors. These approaches capture carers' subjective knowledge of individual animals and their behavioural history, and have been found to be reliable when compared to objective measures of welfare [72]. Tools such as these could be rapidly deployed to evaluate the effectiveness of an enrichment intervention over a short period, and perhaps provide a means of conducting formative evaluation of a prototype, as part of a co-design project.

#### *Single Subject Studies*

It has been proposed that studies of enrichment need not aim to make conclusions about effectiveness for the general population, as was attempted in our animal welfare evaluation [2, 7]. Alligood and colleagues explore how applied behaviour analysis methods, which are used to study the effects of interventions on individuals, might be deployed to evaluate enrichment [1]. They argue that this approach is particularly appropriate for interventions targeting wellbeing, as animal welfare is measured at the level of the individual animal. It is proposed that single-subject study designs might be used to measure whether an enrichment intervention increases targeted species-specific natural behaviours (such as foraging) or reduces stereotypic behaviours (such as pacing).

Evaluation techniques which draw on applied behaviour analysis could be highly compatible with iterative co-design processes. Behaviour analytic study designs might be used to examine the effects of alternative prototypes (multiple-treatment designs), investigate how animals learn sequential steps for interaction, as part of a phased intervention (multiple-probe designs), or generate evidence about the effects of an intervention under different environmental conditions (reversal designs and multiple-baseline designs) [1].

## CONCLUSION

In this paper we have provided a reflective account of the co-design journey undertaken to develop digital enrichment for zoo-housed orangutans. Our extended collaboration with Melbourne Zoo revealed significant challenges in adapting conventional co-design practices to working with animals, as well as the tensions that arise in working with a large number of diverse stakeholders. Through critical reflections on the design journey we identify limitations of the design activities that we conducted in terms of the ability to include the animals as experts in their own experience. Zoo enrichment design is a creative practice and cannot rely on quantitative methods alone. Based on our findings and resulting from reflective conversations with zoo practitioners, we have proposed future avenues to enhance co-design with animals. Firstly, we suggest that designers of interventions for animals can understand needs and context through contextual interviews and expert prioritisation of animals' behavioural needs. Secondly, alternative design solutions might be identified through design workshops, and through Wizard of Oz prototyping to explore conceptual designs with animals. Thirdly, designers can obtain critical insights into the animal's perspective at the stage of prototype deployment through observation of prototypes in use, prototype decomposition, and preference or motivation tests. Fourthly, evaluation of animal-oriented interventions should include quantitative animal welfare studies alongside qualitative assessments of animal wellbeing and single subject studies.

We contend that ACI designers can benefit from heeding calls, in the animal behaviour and welfare sciences as in interaction design, to combine multiple types of data and techniques to understand needs and evaluate interventions. In this paper we suggest ways to expand techniques for including animals as experts in their own experience, and humans as proxies, in designing for animals.

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