# More than Human Aesthetics: Interactive Enrichment for Elephants

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## ABSTRACT
Species-specific aesthetics is an important consideration for interaction designers working with animals. The paper explores the concept of species-specific aesthetics with particular reference to elephants. Applying existing aesthetic dimensions and design principles to the challenge of designing interactive enrichment for them, we show how the insights gained can inform *more than human*-centered design in different settings. We offer a multi-faceted, multi-sensory lens for examining an animal-centred aesthetic experience of technology.

## Author Keywords
Aesthetics, Animal-Computer Interaction, elephant, haptics, acoustics, Research through Design, UX design, environmental enrichment.

## CCS Concepts
•Human-centered computing → Interaction design;

## INTRODUCTION
Consumer-driven design for humans places great emphasis on *aesthetics*, which in popular parlance has come to mean the sensory qualities of an object or image that give it broad appeal. We argue that interaction designers focusing on animals might design intrinsically better systems by considering the aesthetic dimensions of their products. For example, von Gall and Gjerris suggest that there are welfare implications relating to aesthetics, in that they may increase an animal's pleasure [49]. Because humans make the decisions about purchasing animal-related equipment, designers may be tempted to appeal to the buyer's sense of aesthetic rather than to that of the non-human user. However, this could impair the user experience and therefore the very functionality of the product. For example, an animal user might choose not to play with a game that did not satisfy its sensory experience, which would defeat its original purpose.



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The aesthetic principles that Western humans have traditionally valued tend to be strongly associated with our visual perception, exemplified by modern dictionary definitions – (i) Merriem-Webster define the adjective 'aesthetic' to be 'relating to beautiful, artistic, attractive (*pleasing in appearance*)'; (ii) Cambridge English describe it as: 'relating to enjoyment or study of beauty, showing beauty' [28] [5]. Yet the aesthetic qualities of an experience vary considerably from species to species, depending on which sensory, cognitive and physical characteristics mediate the animal's perception and interaction with its environment [11]. In consequence, an exploration of alternative sensory and related affective values is required in order to understand which range of qualities have appeal for non-human animals.

While there has been significant research in Animal-Computer Interaction into interfaces for animals that are practical and usable, thus enabling interactions with computer-based systems, there has been less emphasis on the potential *pleasure* associated with the encounter [12]. This is especially important for interactions whose purpose is to positively enrich the lives of prospective animal users. In particular, our work has focused on the development of interactive enrichment for elephants and, in the course of working with these animals, we have found that the mindful consideration of aesthetics has given us insights leading to novel design decisions.

Environmental enrichment aims to enhance the psychological and physiological welfare of captive animals by promoting species-specific behaviours. Differences between species are expressed in their normal behaviour, such as how they interact with the world and with their conspecifics, what their daily activities are and how they perform their usual routines. It is evident that aesthetic sensibilities vary when we compare the activities of different animals. For example, Plotnik [34] reports that, as a part of their self-maintenance and social bonding routines, chimps spend time grooming each other while elephants have mud-baths and spray dust on their bodies (Fig.1). In both cases, these activities enhance the health of the animals' skins while also providing significant tactile stimulation, except that the chimps are removing dirt while the elephants are applying it. These differences in daily practices and aesthetic experiences influence the way in which different species respond to external stimuli, sometimes leading us to misinterpret their capabilities. For instance, the mirror recognition test, typically used to verify whether an animal is capable of self-awareness, involves painting a mark on an animal's face and checking to see if the animal touches the mark when they look at themselves in the mirror, implying that they recognize their own reflection. Plotnik's theory is that, given their grooming habits, chimps might be expected to notice a strange mark on their bodies; on the other hand, given their bathing habits, it is hardly surprising if elephants pay little attention to such a mark and, if they do not, it does not necessarily mean that elephants are any less self-aware than chimps.

**Figure 1: Elephant mud bath, Colchester Zoo 2014.**

Furthermore, research has shown that elephants' sight is relatively poor, and that they have dichromatic vision and can see clearly only as far as the end of their noses [51] [45]. Elephants' olfactory and auditory senses, on the other hand, are extremely sensitive [35] 37]. It therefore makes sense to take the sensory abilities and associated interests of elephants into account when designing enrichment experiences for them. Moreover, the aesthetic dimensions of elephants' sensory characteristics should be a central focus in order to fully engage the animals with any new system, with a particular emphasis on their most developed senses (predominantly their tactile, olfactory and auditory ones).

In this paper, we explore some ideas about aesthetics in general and contemplate how these might apply to the development of interactive systems for animals. In particular, we describe our work on aesthetics for elephants: we describe the materials that were used to craft enrichment devices; we explain the design choices we made in relation to aesthetic dimensions of the physical interfaces and show how an aesthetic perspective can be useful for analyzing and developing interactive systems for animals.

## BACKGROUND

### Aesthetics as a cultural experience

*Aesthetics* as a philosophy deals with what is pleasing to the senses, emotions and intellect. It is not simply about what we perceive but more importantly about how that perception affects us at a visceral and a cognitive level. Even within humans, let alone between humans and other species, there is debate as to whether it is possible to talk about "universal aesthetics" (which would be shared by everyone), because many modern philosophers believe it is inevitable that judgements about aesthetic quality are embedded in cultural contexts and prior experience [4].

For example, in Western culture, aesthetics has been strongly influenced by the work of Greek and then Medieval scholars [41] who emphasized ideals and perfection in design. These ideas tended to be abstract, leading to a regimented approach to artistic representation that focused on things like proportion of form (as in classical Greek sculpture) while often ignoring self-expression [41]. While a connection with nature was deemed essential for artistic expression, this was in the form of *mimesis* – whereby a designed artifact was expected to imitate a natural form in a formal and figurative manner. In the 19th century, Hegel broke away from this tradition, claiming that beauty is a manifestation of freedom, impossible to present in a regular symmetrical form, owing its nature not only to harmonious relationships between components but also to its inherent "spirit" [46]. Hegel's insights did not have much influence during his life, yet this was the era when aesthetics gained most traction as a philosophical theory associated with fine art – in other words, as a visual phenomenon with strict rules of presentation [41].

By contrast, the Japanese approach to aesthetics encompasses a more holistic appreciation of the designed object [22]. In a philosophical sense, the object represents its place in society, always embodied in context. A well-known example of this design aesthetic is the concept of *Wabi-sabi*, denoting artefacts organic in form, inspired by or derived from nature, unique (one of a kind), personal, crude or rough, and encouraging the expansion of sensory engagement – very unlike the Western idea of mimesis. Emphasizing the role of intuition and unconventional ways of thinking in design aesthetics, Koren [22] points out how Wabi-sabi "exemplifies many of Zen's core spiritual-philosophical tenets." He states that Wabi (roughly translated as "subdued, living in nature") references a way of life, a subjective perspective, a philosophical construct and the spatial arrangement of objects; while Sabi (historically meaning "rust or impermanence") references aesthetic ideals, materiality, an objective perspective and, crucially, the passage of time. This is why weathered or disintegrating objects may poignantly express Wabi-sabi, reminding us that all things pass. This sense of mortality and melancholy is also illustrated by the term "*mono-no-aware*" which refers to and celebrates the transience of things; this is an awareness to which the annual cherry blossom *Hanami* festival is closely related.

The examples above show how two human cultures have developed distinct aesthetic sensibilities, which would support the argument that a 'universal aesthetics' may not exist. It may equally be true that there exists no 'one-size-fits-all' approach when designing artefacts for more than humans. In fact, we have seen this to be the case in our experimental work with elephants – an enrichment device that fascinates one member of the herd may hold little interest for another. As humans know from experience, the spice of life is to be found in variety – and this may hold true for other animals [47]. Although the philosophical features of Wabi-sabi (such as celebrating impermanence) might be irrelevant for an animal, the emphasis on natural forms and evidence of history might hold some interest for a species for whom classical form (and its representational function) has no value but who can appreciate the immediacy of chemical signals.

### Aesthetics as a multidimensional experience

The word *aesthetic* derives from Greek, meaning 'sensitive … pertaining to sense perception or sensation' [9], which suggests a wide experience of pleasure conveyed through the senses. In contrast to the visual aspects which are still retained in popular definitions of aesthetics, in Ancient Greece, aesthetic values were applied to all the arts, including music, poetry, architecture and drama. These were important media that served to both entertain and educate, whereby an aesthetic experience became the vehicle for intellectual growth and moral development [41].

Clearly, in contemporary design, a range of physiological dimensions come into play, reflected in the great variety of shapes, textures, sounds and smells featured in many everyday objects. For example, the smooth surfaces and rounded edges of mobile phones are designed for enjoyable hand-feel as much as visual appreciation. However, until the 20th Century, the discourse on aesthetics in product design was mostly limited to visual aspects, possibly because vision is such a prominent sense for humans. Indeed, Diaconu suggests that olfactory aesthetics has been neglected [7] because of its ephemeral nature and our lack of sensitivity to smells, and the resulting poverty of linguistic expression with regards to olfaction. Nonetheless, recently Huss *et al*. [20] have explored olfactory aesthetics in relation to humans' relationship with flowers, describing this as an embodied aesthetics whereby we experience pleasure through interactive stimulation.

A parallel perspective is found in the recent conceptual framework of *Somaesthetics*, developed by Richard Shusterman [44]. This emphasises that beauty is not only related to the visual experience, but also to the appreciation of other embodied sensory experiences, including feelings derived from physical actions. Others have built on this, suggesting variations that focus on human experiences of sound, touch and the resulting perception of design itself [25] [39] [19].

Rooted in Dewey's exploration of aesthetics as an emergent phenomenon [26], Flanagan proposes an aesthetics involving the temporal interplay of dimensions of experience other than the usual five senses [10]. She attempts to define a "ludic language" emerging from gameplay and game design, arguing that the prevalence of play culture has permeated other media to the extent that it has created new linguistic frames of reference. A game designer's craft is to sculpt player experience – itself a multisensory and intellectually engaging activity – so that it is as pleasurable as possible. Flanagan shows that it is possible to make judgements about the intrinsic values of particular game design components, based on how they affect human emotions and intellect, just as it has been possible to apply a value system to visual aesthetics. Flanagan describes well-known game elements such as control systems, inventories and HUDs (Heads-Up-Displays) as memes, entering the language as experiential components. These elements are not directly related to individual senses, but encompass the overall *performative* experience of play, which involves both subjective duration and enactment of gameplay sequences. The temporal aspects of gameplay and the performance itself are therefore identified as having their own distinct aesthetic values [10].

This widening of perspective on what constitutes aesthetics can help inform design work for non-human animals, for whom 'doing' is an essential part of their aesthetic experience – since their sensory input relies heavily on active engagement (sniffing, keeping watch, touching and moving objects, eating and so forth). Although some experiences are passive, such as lying in the sun and feeling the heat, life for most adult wild animals is a matter of constant vigilance and activity in order to survive and reproduce [52]. All species have therefore evolved to have heightened sensory, physical and cognitive abilities that promote their survival.

This is one of the reasons why our work has focused on designing interactive devices that offer their users some *control* over their experience. This has clear parallels with both gameplay and tool use, in that animals are enabled to engage directly with an artefact and make decisions about what to do in order to achieve different outcomes, through a performative experience. Moreover, our evaluation of systems for animals tends to focus on their actions, which we can attempt to interpret through observation. Indeed, actions are easier to measure than emotional responses when we lack a shared interspecies language with which to explain subjective experience, as widely acknowledged by animal behaviour researchers [6].

## INTERACTIVE ENRICHMENT FOR ELEPHANTS

In our project with elephants, the overarching aim was to explore the use of technology to enhance environmental enrichment experiences for these animals. In order to understand the difference between the aesthetic experiences of elephants living in different conditions, we initially investigated and compared the behaviours of wild and captive elephants. We then worked with keepers and animal experts to identify potential enrichment goals, which had to be appropriate for the elephants, but also feasible within the means and scope of the project.

We adopted a long-term Research through Design and Craft approach, which offered a reflective, iterative design practice, ideal for facilitating collaborative work [53] and for

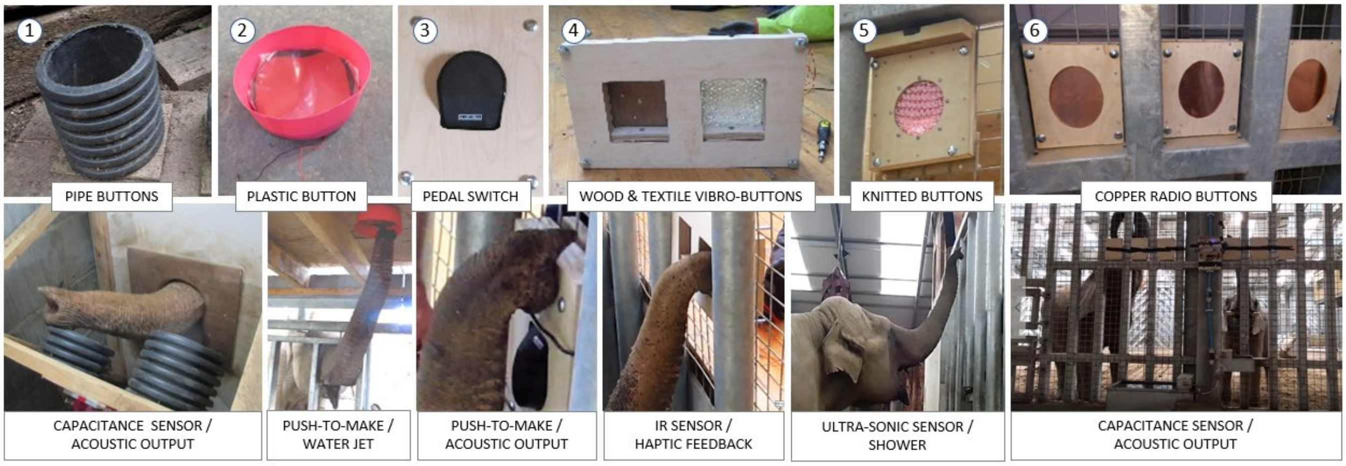


**Figure 2: Early prototypes – extracts from Craft Workbook.**

exploring a previously unknown area, particularly the subtleties involved in designing for aesthetic experience [12]. This method enabled the gradual development of ideas (documented in a series of Workbooks – Fig. 2 and 3 show extracts from the Craft Workbook) and allowed us to build a strong relationship with the elephant keepers. Working with keepers became a crucial aspect of our work – they supported the design and deployment of devices; they shared their expertise, on which we fundamentally relied when we were evaluating prototypes in the field; and they were willing to send feedback and CCTV footage of elephant interactions after we had left the site. An additional benefit of a long-term project was having time to gain relevant skills ourselves and make contact with other professionals who had complementary skills and knowledge. We have also had the opportunity to explore different aspects of our elephant enrichment challenge and share our findings with the academic community over several years.

### Key design features

Building on work done with dogs that identified perceivability, consistency, feedback and affordance as the most relevant design principles [24], we found the critical features that a system interface needed to be able communicate to its elephant users were differentiation, consistency and graduation. We experimented with sensory parameters that supported these features in the use of static interface panels and moving control mechanisms that offered performance aesthetics.

### Enrichment goals

Within elephant herds, there is a strong hierarchy and a lot of communication between family members, which implies that acoustic discernment and response is part of their natural behaviour in the wild. Our main objective therefore became to provide acoustic stimulation (which also implies cognitive enrichment) in order to offer the captive elephants a facet of the wild herd experience which they might lack in their daily life. Beyond this, we were committed to offering choice and control to our users, because the experience of performative aesthetics requires the animal to be able to interact with their environment, rather than be a passive recipient of stimuli.

### Prototyping process

On this basis, we proceeded to brainstorm concepts and craft prototypes to test in the field, work that is discussed in detail elsewhere [13]. Our key commitment was not only to produce systems that were functional, but also to try and enhance the quality of the interactions from an elephant's perspective. This involved experimenting with different input and output methods and devices, then assessing them both in usability terms and according to their potential for being pleasurable or intrinsically appealing for the elephants. We worked with elephants on two sites – Skanda Vale Ashram, a countryside sanctuary in Wales, and Noah's Ark Zoo, in southern England.

Initially, our main user was Valli, an Asian female elephant living in at Skanda Vale. In 2014, we played a range of audio samples to Valli inside her shed and monitored her reactions. Keepers were present to offer their advice and we were reassured that novel sounds would not cause her any anxiety.

In 2015 and 2016, we installed a range of prototypes inside the shed (Fig.2: 1-5) that aimed to provide insight into appropriate technology and interface design, including feedback mechanisms. The devices were built in our London workshop, combining embedded technology with craft, and then taken by the primary researcher into the elephant environment. Installation usually involved keeper support. The elephant's interactions with the early prototypes were recorded by the researcher, while keepers provided rich commentary highlighting salient observations. Working design features (functional and usable) were then incorporated into a radio system that we installed in the elephant shed at Noah's Ark for two African males in 2016 (Fig.2: 6).

Having developed this range of simple 'switch' buttons, we turned our attention towards exploring tactile dimensions of the interface and offering a more engaging user experience by using moving elements. At the same time, we were interested in finding appropriate auditory enrichment and increasing provision of control. These goals complemented each other through the design and development of an analogue control system, whereby the elephant could modulate an acoustic output using movement. Between 2017 and 2019, we experimented with different methods for synthesizing audio, tested more interfaces and sensors at Skanda Vale and gradually refined our designs for a slider control (Fig.5).

#### Iterative evaluation

Throughout the research, we produced a range of prototypes at varying levels of fidelity, which aimed to provide a variety of enriching experiences from controlling water jets to playing natural and musical sounds.

Our primary indication that a prototype might hold potential for a positive aesthetic experience was whether the elephant voluntarily interacted with the device, particularly during periods of solitude or between feeding opportunities. Supported by the keepers' expertise, we understood this to mean that the object had some intrinsic appeal, inviting exploration because of sensory invocation or through cognitive stimulation or both. From 2018 onwards, Valli had a companion – another Asian female called Lakshmi – and a CCTV system was installed in the Skanda Vale enclosure. This enabled remote monitoring and allowed us to see how the elephants reacted when humans were not present – for example, at night.

The following sections explain our thinking around prototype designs and exemplify our research in relation to the aesthetic dimensions of interactive enrichment devices for elephants.

## AESTHETICS FOR ELEPHANTS

Interacting with a computer system is a form of conversation, with the user providing input and the system outputting a response that mediates the subsequent action or reply of the user, thereby facilitating an engagement with the system. Our research addressed the question of what design qualities an interactive system would need to have when designing interfaces and experiences for elephants, in order to best support such a conversation.

### Design Principles

To contextualize our work in the contemporary environmental and cultural climate, we have ascribed to design values that we feel are supportive of both sustainable development and environmental ethics. These values are consistent with the aim of designing technology for animals who are often kept in captivity for conservation purposes due to the environmental degradation and habitat loss that is now threatening many species' survival. The physical representations of our work share some of the aesthetics of Wabi-Sabi – hence, products seem rough, natural and weathered. Meanwhile, the embedded functionality is inspired by Arduino's open-source philosophy [1].

We established some key principles at the start that embody these values and ethics. They have underpinned all our subsequent development work. In particular, we wanted our designs to be:

- Eco-friendly – we always attempted to *recycle* found objects, such as drainpipes, ropes and plastic buckets; we used off-cuts of wood to *reduce* waste; we repurposed existing mechanisms in order to *reuse* objects.
- Natural – most of the prototypes were crafted from materials that would be encountered naturally by a wild elephant, such as wood and plant-based textiles.
- Simple – the principle of KISS (Keep It Simple, Stupid) [33] was applied to our work, both to aid technical development and construction, and to facilitate the inclusion of non-experts in the team.
- Open-source – we wanted to share projects with the wider community, enabling greater collaboration, so we used free software and development environments such as Arduino [1], Audacity [2], MicroPython [29].

### Five senses +

Every device we created had visual, olfactory, aural and tactile properties – each physical object within reach could be seen, smelled and touched, and in each case the feedback or output from the device had an audible aspect. Some of these features were specifically designed to be part of the system (for example, knitted textile interfaces); others were inevitable (for example, the scents added by humans manually crafting objects). We were careful to avoid using food as part of or as a reward for engaging with our systems, as we were keen that the devices should have intrinsic appeal and not be related to foraging behaviour or fitness. However, the sense of taste is closely related to the sense of smell and we were not able to judge whether chemical properties of the devices would also have gustatory appeal.

We do not know whether the ability to analyse one's perception and to distinguish between different sensory modes is part of an elephant's cognitive abilities, since it implies an awareness of each sense as a distinct element. Humans tend to integrate all senses simultaneously; similarly, it seems likely that an elephant would gain experience and understanding in a synaesthetic and holistic way. At the same time, it is possible that changing a small part of one aspect of an interface element might have a significant effect on the overall experience, by targeting a particular sense.

The following sections discuss elephants' different senses and describe how our designs related to these.

#### Smell: Olfactory aesthetics

Elephants initially use their trunks to smell the world around them. They have a large vomeronasal organ situated in the roof of their mouth. In order to perceive a scent in more detail, they may flehmen, which involves sniffing the scent sample with their trunk (akin to the nose in humans) then placing the trunk tip into the mouth to access this special organ. They can also detect chemical signals using taste [23] [40].

Although chemical signals are synchronous, they may persist for hours or days or months once the object or event they signify is no longer present. Their range is both near and far, depending on the senses of the perceiver and external factors such as humidity and wind. They are therefore a 'material' that is hard to control. Furthermore, as we have indicated earlier, humans currently have a poor understanding of olfaction, epitomized by a lack of vocabulary to describe different aromas. This made it very challenging to use smell in our designs, as we were unable to discriminate between smells as well as an elephant, nor could we identify all the aromas contributing to the scent of any object.

We did consider some early enrichment concepts that used olfaction. These concepts included scent trails in the environment, stool samples from hitherto unknown conspecifics, and 'pungent boxes' to explore. However, none of these concepts gave the recipient much control over their experience because smells are pervasive (like sounds) yet have no reliable 'volume control' due to factors such as air temperature and substance volatility. Only the pungent boxes afforded a measure of choice if the olfactory stimulus was weak. Although every crafted object that we subsequently developed was permeated with scents that an elephant could discern, and which therefore contributed to the overall aesthetic experience of the device, as mentioned above, we were not in a position to appreciate the effect of and make decisions about this property of our designs. We therefore directed our attention to alternative sensory stimulation.

**Taste: Gustatory aesthetics**

One of the things that engages all our senses simultaneously is food – unsurprisingly since it is vital for survival. In human food technology, quality criteria include mouthfeel, smell, taste, acoustics (e.g. crunch), colour and presentation.

It might be assumed that most non-human animals eat to live, with foragers spending such large portions of their time searching for and consuming food, and hunting occupying a significant part of predator time. However, non-human animals can also be selective and may make choices related to aesthetics as well as self-preservation [43]. Our experience with Valli offers anecdotal evidence of food appreciation. One time, she was given a tiny piece of chocolate by her keeper as a treat; instead of chewing and swallowing it as she might have done with a cabbage leaf, she kept it in her mouth, swirling it around until it melted. One might suppose she was savouring the smell, the sweetness, the rich cocoa taste and the buttery mouthfeel, much as a chocolate-loving human would do.

For the reasons discussed earlier, it was important that during our research we tried to avoid food associations. On the other hand, we recognise that gustatory aesthetics would be an interesting topic for future exploration and most likely very popular with any non-human client.

**Sight: Visual aesthetics**

Elephants have limited visual acuity. African elephants can discriminate a gap of 2.75cm about 2m from their eye – in other words, at the end of their trunk – while Asian elephants can discriminate at a much smaller distance (0.5cm) [45]. However, anecdotal evidence from the Elephant Voices site [8] suggests that elephants can recognise shapes very well, and that they can determine small changes in another elephant's demeanour from a significant distance – when a human might require binoculars.

When testing with elephants, we noted that if our devices were not visible to them, they were less willing to interact than if when they were visible. Early prototypes were placed in areas of the elephant's environment that were trunk-accessible but hidden from view (Fig.2: 1, 2). Valli needed to be shown that a new device existed, which turned out to be a problem because one of her care-givers used fruit as an olfactory lure. Having established that bananas might be a feature of the new experience, other pleasures became insignificant for her, so we were unable to gauge her interest in alternative sensory aspects of the design. Later, in the zoo environment, we installed a prototype radio that would allow the two resident African elephants to touch buttons in order to trigger different sounds (Fig.2: 6). Our system was placed above eye-level, and initially ignored by the elephants. Only when they were far enough away to spot a new object mounted on the fence did they spontaneously return to engage with it – exploring and triggering the buttons.

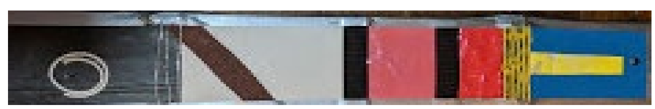

**Figure.3: Four part multi-material tactile panel**

As mentioned previously, elephants have dichromatic vision (they see yellow, blue, black, white). One of our later prototype controls was a panel of touch-sensitive buttons, which were differentiated using a range of materials that offered contrasting colours, textures, positions on the controller and scents (Fig.3). This was the only device that used colour (yellow and blue) as well as visual contrast design features. Video footage analysis of Valli investigating the control showed that she was interested in exploring the surface with her trunk. Although we do not know whether vision played a role in her tactile exploration of the object, it is plausible that its striking visual appearance would have attracted her attention and enticed her to interact with it. Yet, this could not be true for Lakshmi, who is blind. Keepers reported that after *she* located the device, Lakshmi visited it repeatedly until she had dismantled it.

When it comes to humans, past experience (memory and cognition) enables them to tell, for example, if the embers are hot when they look at a fire. Therefore, human awareness of colour has an obvious fitness benefit, although at close range temperature sensation would render vision redundant. It is plausible that colour perception could be similarly grounded in elephants' biology and that colour might have a useful place in the elephant-interaction-design palette. Other visible features (size, shape, pattern, location) are discussed in subsequent sections.

### Hearing: Auditory aesthetics

Auditory signals are synchronous with their production, and then they dissipate. The distance that the signal carries depends on how quickly the waveform attenuates, which in turn depends on environmental conditions such as weather and landscape. Low frequency infrasound (10-20 Hz) is outside normal human hearing range but persists over much longer distances than higher frequency sounds and is known to be used by whales and elephants to communicate with conspecifics. As well as seismic vocalisations, elephants can generate infrasound using their feet. An elephant stomp can travel up to 32km, depending on soil type for attenuation [32].

Elephants can detect infrasound through both bone conduction and somato-sensory perception. Their inner ear has an enlarged malleus, which provides a bone-conducted pathway for seismic signal detection. Elephants can occlude the opening of their ear canal, potentially building pressure in the air canal to enhance bone conduction. In addition, they possess an aerated skull and sinuses, and fatty deposits which may act in a similar way to acoustic fat in dolphins and manatees – facilitating low frequency detection. [32]

Our original intention was to develop digital instruments that could be operated by an elephant, allowing them to control the quality (volume, frequency, timbre) of the sounds being produced.

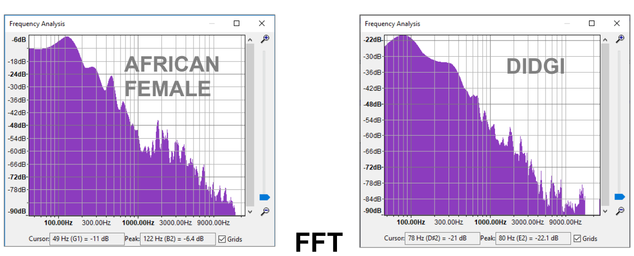


**Figure 4: Rumble-roar (left) and didgeridoo sample (right).**

We identified the didgeridoo as an instrument capable of generating a potentially interesting acoustic waveform. This was because of the inherent similarity between the shape of the instrument and the shape of an elephant trunk; indeed the kinds of sounds produced when air vibrates inside a didgeridoo have characteristics in common with some elephant calls. On analyzing African elephant calls that we downloaded from the open-source repository at ElephantVoices.org [8], we were able to see typical wave shapes and peaks. We therefore investigated this further by running an FFT (Fast Fourier Transform) analysis of (i) an African female elephant rumble and (ii) a didgeridoo sample, showing a strong similarity in shape (Fig.4). Unfortunately, there was less data available on Asian elephant vocalisations.

Initially, we played short low frequency audio samples (sine waves) to Valli, to determine whether she might have interest in low frequency audio. Keepers interpreted her posture and reaction, concluding that she appeared to show most interest in samples in the60-70Hz range. Interestingly, Ayers and Horner [3], identified the fundamental frequency of a didgeridoo as 62.5 Hz with small peaks at 174.5 Hz and 187 Hz.

While the quality of sound is an important aspect of auditory enrichment, the choice of audio in the first place is also critical. In this regard, there is a lot of scope for future research into elephant acoustic preferences.

### Touch: Tactile aesthetics

Rasmussen and Munger [38] analysed the sensorimotor specialisations in the trunk tip of the Asian elephant and concluded that it was a very sensitive apparatus. They compared the sensory capacity of the trunk tip to the lip tissue of monkeys or to the mystacial skin surrounding a rat's whiskers, stating that this finding correlated with the tactile ability of the trunk, which can grasp small objects and place them into the vomeronasal organ for chemosensory processing.

While elephants' trunks do not possess mechanisms that respond to dynamic changes or control motion and grip, they do possess mechanisms that respond over a larger area to vibrations and changes in pressure, hair-cells for the perception of form and texture, free nerve endings and other receptors [18].

During our investigations, we became increasingly aware of the elephants' interest in the tactile qualities of our devices. For example, when we presented a large push button made from an old sewing machine pedal, Valli never voluntarily pushed it, but she did spend several minutes exploring the ridged surface and running her trunk tip around the wooden frame (Fig.2: 3). It was not clear if she was feeling or smelling the interface, or indeed perceiving it with both senses simultaneously. As a consequence, during our system's interface design process, we made various aesthetic design decisions in an attempt to enhance the tangible experience of the interaction.

As a case in point, initially we offered rounded shapes, taking care to cut out circles instead of squares in an attempt to be less formal and more "natural". However, corners and edges seemed to generate as much interest from Valli as curves and, moreover, they were simpler to manufacture. We also observed that perfect circles are geometric, rather than organic, and therefore equally out of place in a natural environment.

Other aspects of form, such as size, were more critical. In fact, scale became a major design challenge due to the geographical distance between the workshop and the elephant shed. Although we understood that the controls had to be an appropriate size for an elephant trunk tip to activate, it was difficult to fully appreciate the scale and strength of an elephant without being in close proximity. Our solution was firstly to use a template – a paper trunk tip to-scale – and then to craft a physical 'trunk-glove' that a human could wear in order to test the usability of the interface.

We paid particular attention to certain qualities (temperature, weight, plasticity) that can only be perceived through touch. Variable temperature (for example, of a water supply) was outside our scope due to cost implications. The weight of our installations was a compromise between making them sufficiently robust and making them portable and easy to mount and dismount. Objects with embedded technology were securely fastened with bolts and the base structures were constructed from 20mm sustainable wooden ply (Fig.3: 5, 6). This meant that the elephant would not gain any kinaesthetic feedback from weight.

Regarding plasticity, we found this to be awkward because we were unable to produce an electronic device that was both safe and flexible. Hanging ropes offered motion, but a digital signal was difficult to capture accurately in order to map movement to output. For this reason, controls were mostly rigid. On the other hand, we were able to embed tactile haptic feedback into devices in the form of tiny vibrating motors, which we believe would also provide low frequency audio that an elephant could perceive (Fig.3: 4).

For our elephant radio installation, we developed two sets of identical three-button systems (Fig.3: 6). The buttons could be distinguished from each other by their position on the wall – arranged horizontally. The two radios needed to be the same so the two male elephants in the enclosure both had something to play with and did not need to compete.

Over time, we experimented with a variety of surface details, repurposing existing items and crafting new textures from natural materials.

**Interaction: Performative aesthetics**

All the devices installed in the elephant enclosures required interaction on the part of an elephant, and so far we have considered some pertinent sensory aesthetics, such as whether an object is interesting to touch, whether it smells or is clearly visible. These features are designed to attract the user to the device in the first place, while acoustic elements are part of a system design that aims to offer interesting feedback and make the device 'sticky' (enticing). The choice of interaction modes is also important to make the experience pleasurable and we are currently exploring the design of analogue systems that allow greater control and discrimination regarding the nature of the system's output.

Our early designs focused on functionality with regard to mechanism of activation, and we found that tactile interfaces with hidden sensors worked better than switches that required active pressure [13]. It is plausible that an elephant would quickly learn to touch or not in order to trigger a reaction and thereby have a choice, but initially at least, these designs force researchers to take a 'clandestine' approach because the elephant's actions are picked up by the sensors whether she intends it or not, which subverts the aim of providing control.

One early prototype aimed to afford Valli control over her water supply, by offering a choice of two buttons – one triggered a jet of water, the other a fine spray (Fig.3: 5). When these shower fittings were left in place overnight, Valli destroyed the control system by grasping wires attached to a microcontroller mounted *on the other side of the balcony fence*. She subsequently ripped the cables into bits, managed to reach the water pipes providing the shower and apparently '*had a lot of fun with it!!'* (quote from keeper).

From the keepers' point of view, this activity had been enriching for Valli, exciting her curiosity, allowing her to express herself physically while engaging with a novel object in her enclosure, and testing both her dexterity and her strength. They believed that the experience would have given her cognitive, sensory and physical stimulation (although clearly not in a way we had planned or foreseen). Accordingly, we might need to rethink the kinds of system we offer an animal as large and strong as an elephant, if we want them to engage enthusiastically, using their full physical capacity without destroying the source of the fun.

We observed an example of a more substantial source of entertainment when watching night footage of Valli. We noticed that she spent a large portion of her waking time interacting with a tyre – a large, robust physical object, too heavy to throw but light enough to be manoeuvred. Firstly, she selected one tyre, then she rolled it close to her. She kept the tyre balanced under her body for over an hour, walking around while maintaining it in this position between her legs.

When we subsequently discussed this behaviour with a keeper, he explained that this tyre had a long history. When Valli arrived as a calf, over 30 years ago, that tyre was her first toy and accompanied her at night when she slept. Around 2010, a new elephant shed was built for her. In order to facilitate the transition from old draughty-but-familiar shed to new heated accommodation with pool, her keeper asked her to pick up the tyre and carry it into the new building. Thus, her willing relocation of the tyre was the embodiment of her autonomous choice to move; the act of physically bringing it into a new environment gave Valli control over what was happening. Although there are now several tyres in the elephant compound, Valli seems attached to this one in particular. It could be argued that this shows how the tyre (manmade, unnatural shape and material) has come to represent a more general (or even universal) concept of home and security for her.

As a result of our findings regarding Valli's interest in objects which could be moved and which reacted in a way that offered kinaesthetic feedback, we tried hanging ropes,

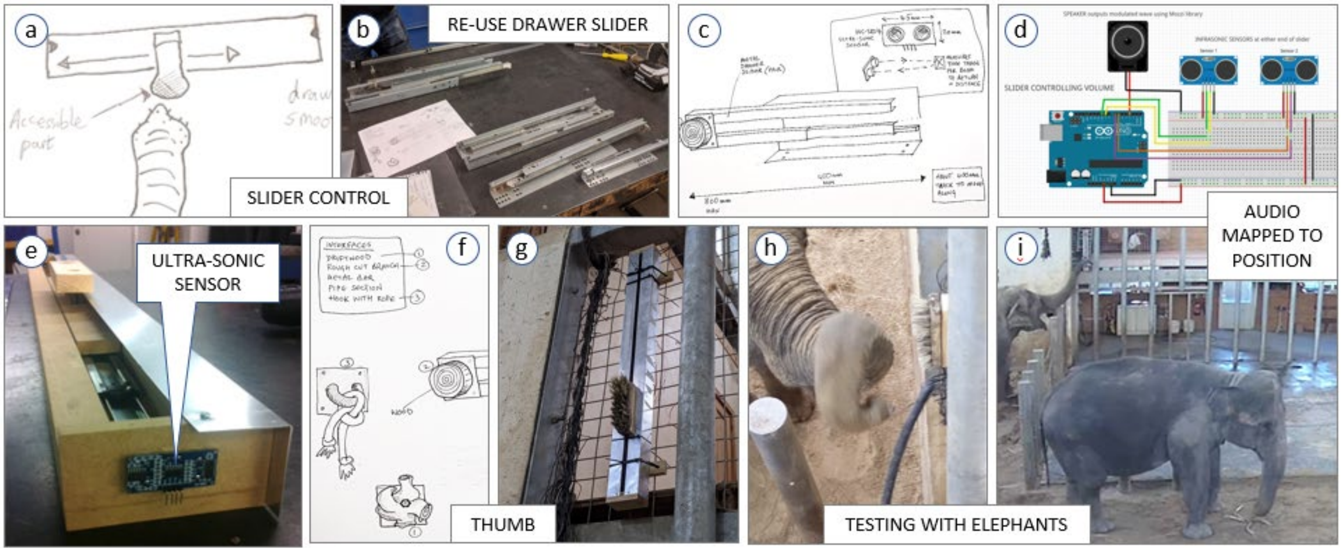


**Figure 5: Showing development of analogue slider control – (a) concept; (b) sourcing materials; (c) blueprint; (d) embedded tech; (e) prototype; (f) thumb designs; (g) installation; (h) test with keeper; (i) CCTV playing at night - from Craft Workbook.**

which proved popular with both elephants, but especially Lakshmi.

More recently, we designed a large volume control slider made from repurposed drawer runners (Fig.5). The slider thumb (old scrubbing brush) moved freely up and down the track, changing the acoustic output. When the device was installed, Valli and Lakshmi showed little interest, but the CCTV footage later revealed that they both touched the device several times during the evening. The following day, Valli pulled off the thumb and 'groomed herself' with it, according to keepers. It was re-fixed more securely and subsequent footage shows Lakshmi sliding the thumb up and down the track during the night.

## DISCUSSION

### Understanding the 'other'

As well as experiencing the world at a different scale, non-human animals often rely heavily on different senses. Even if the animals' abilities transcend humans' own in many areas, such as pheromone identification or balance, they lack the exposure most people have had to computer systems and interactions with technology. Moreover, physical capabilities such as strength and speed, psychological motivations such as group dynamics, and activities such as hunting and foraging may make a significant difference to how an animal perceives and interacts with the world. So, how can humans designing for other animals compensate for human limitations while capitalizing on the other species' abilities?

For a UX designer working in an office or workshop environment, rather than in an animal enclosure, it can be difficult to fully appreciate the qualities of the 'other' that will help define the most appropriate way of designing an interface or system or experience [17]. While this is true even of humans, who have variable characteristics and requirements within the same species, the dilemma becomes more critical when the user is a different species – in other words, when humans are designing for a non-human animal.

Our Research through Design and Craft approach has enabled us to engage with this problem in a creative, systematic manner, by hand-building multiple versions of elephant enrichment objects and gaining an aesthetic perspective on aspects of the design.

Within each sensory feature, there are many variations in degree and many possible permutations. There are therefore a myriad of possible solutions for creating interfaces, requiring designers to experiment with different combinations to produce a valuable aesthetic experience for a given animal – and in doing so, gain a more subtle appreciation of their user. For example, if contrasting switches are required for different outputs, then depending on the sensory preferences of the user, the switches can be designed so that the user can discriminate between them using smell, or touch, or vision, or sound, or taste, or indeed any combination of perceptions.

It seems that the only feature unique to the sense of sight (at least in close proximity for elephants) is *colour*. Many other visual features, such as texture, size and movement, can be perceived even when the user is unable to see them, if such features are presented in a suitable format. In particular, for an elephant, tactile features seem to work well. Stereopsis can provide depth information about an object; in the case of elephants, their lateral eyes give them good peripheral vision and limited binocular vision looking forward. However, stereoscopic vision is enhanced through *motion*, which allows the brain to deduce depth information from views acquired simultaneously by each eye [30]. Thus, a static object requires the animal to *move* in order to assess its position in space accurately.

Pitch, volume and timbre are strongly associated with the sense of hearing. Yet, even this is not clear-cut – noises are created and perceived via vibrations that set up sound waves, and which can also be sensed through touch. As mentioned earlier, when Valli showed interest in a vibrotactile panel, we were unable to tell if she was feeling it, listening to the motor or doing both simultaneously.

In relation to touch, it is evident that elephant performance is critical to enable certain sensations – for example, the trunk must be moved across the surface of an object to feel the texture and discern the shape, which is achieved by *haptic perception*. In our example interfaces, Valli's action was seemingly always a *kinaesthetic perception*, and presumably always offered some kind of *tactile* feedback because the interaction was with a physical object. There seems to therefore be a strong link between performative and sensory aesthetics – a symbiotic relationship whereby action enables sensory perception and sensory perception informs action.

### Object play and affordance

Object play in elephants occurs throughout their lives and is a pleasurable experience [8] [50] which suggests that it could be a measure for performative aesthetics. As McGonigal [27] has pointed out, play involves free improvisation: "… *we discover and reinvent purpose as we go along, constantly evolving our actions with great spontaneity*" (p.654). Play is grounded in the promise of a pleasurable experience [10], an idea that fits very well with our emphasis on enhancing the aesthetics of our designed objects.

Objects designed for human play often have affordances that suggest how they might be used. Although these may be innate properties of the design, such as the smooth surface, spherical shape and bouncy material of a ball, their real-world applications still have to be initially learned through interaction. Gibson [16] described affordances as "*action possibilities*" in the world. His early work on the topic related affordances to the experiences of all animals in their respective environments; later, the term gained traction within the HCI (human-computer interaction) community when it was applied to designs for humans. More recently, the idea of affordance has been broken down into *signifiers* that offer (usually visual) clues to interaction possibilities [31] and *feedforward* [48] which is an understanding of what will happen when an interaction takes place. Together these provide the user with a mental model that enables them to control the system, but this knowledge only comes with experience and is a hallmark of accomplishment [16]. An elephant that encounters an interactive device will also have to learn how the device works by exploring the interface, manipulating controls and paying attention to the feedback. Although animals can be trained to perform such tasks, one of our goals was to make our devices intrinsically appealing so that the elephant would take pleasure in playing with them.

Although all our interfaces had a performative aspect that required trunk movement to trigger an output, only some provided simultaneous haptic feedback that was directly mapped onto the action of the elephant, thus potentially offering a clear sense of control. The slider is a case in point (Fig.5). Friedman [14] suggests that a slider encourages "*exploration rather than precision*", which is exactly what we needed from an analogue control that could enable an elephant to modulate the pitch, intensity or tone of a digital signal. Our research with elephants showed that *exploration* of the environment was one of their key behaviours, likely associated with their foraging habits, but also part of their innate attentiveness [42].

At first, we would not expect an animal to understand the mechanism of a slider. However, in designing the object we made important aesthetic decisions. The *thumb* was designed to be visually distinct and have tactile interest, thus inviting the elephant to touch it. The smooth movement along the *track* required only a light touch; moreover, the boundaries of the object were obvious to see and also to feel when the thumb reached its limit. The slider solicited action and in doing so, it facilitated the *learning* of it – its sensory and performative aesthetic dimensions facilitated the elephant's interactions and consequent understanding of the slider as a control mechanism.

## CONCLUSION

Using an aesthetics lens to support the design of systems for non-human animals gave us a chance to explore their preferences and hopefully offer them a more pleasurable experience. Craftwork has enabled us to uncover aesthetic elements that are relevant to the animals we worked with, and potentially to a wider elephant audience. We focused on auditory and tactile elements, noting the convergence between these perceptions. We grounded our design decisions in suitable choices and treatment of materials, appropriate technological innovations and elephant reactions, as interpreted by keepers. More fundamentally, our exploration has enabled us to develop aesthetics sensibilities that a human-centred perspective might fail to appreciate but that more-than-human-centred design demands. We specifically note the strong link between performative and sensory aesthetics, whereby *doing* is an extra aesthetic dimension that gives the animal doer control and provides innate sensory and cognitive feedback.

As we discover more about how other species perceive and interact with the world, and crucially what appears to give them joy, we may gain greater understanding of their sensory, emotional and intellectual capacities. With this knowledge, perhaps humans will learn how to relate to other animals more respectfully, to ensure a sustainable lifestyle for all.


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