Reflecting on Methods in Animal Computer Interaction: Novelty Effect and Habituation

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ABSTRACT

Many studies of animal–computer interaction (ACI), including those for enrichment, have found that animals' initial responses to a technological intervention are followed by lower levels of usage as the product ceases to be new. The 'novelty effect' has been identified and discussed in human–computer interaction research. The related concept of 'habituation' is described in the literature on animal behaviour and enrichment. However, the field of ACI has yet to engage with the novelty effect and habituation as phenomena that have important implications for ACI design and evaluation. In this paper, we examine three ACI interventions that illustrate how the novelty effect can manifest in ACI studies. We provide an overview of current knowledge on the novelty effect and habituation, and we discuss how this knowledge can guide the deployment and evaluation of ACI interventions. These considerations will strengthen ACI methods and contribute to designing technology that has enduring applicability and interactional value for animal users.

CCS CONCEPTS

• **Human-centered computing → HCI design and evaluation methods**.

KEYWORDS

novelty, habituation, animal-computer interaction

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1 INTRODUCTION

Many ACI designers seek to respond to the welfare needs of animal users [15], and they do so by designing interventions that make a positive contribution to animal well-being [24] as well as by minimising adverse impacts. There is the potential for digital technologies to enrich animals' lives by providing them with new behavioural opportunities, increasing choice and the range of sensory stimuli and creating new channels for positive interaction and communication with humans [15]. However, to achieve this, it is important for designers to understand how the value of an interactive device for the animal user might change over time.

In many cases, animals' voluntary engagement with digital technologies is short-lived. For example, 7 of 15 primates (chimpanzees and orangutans), when allowed to use an iPad for up to five minutes, chose to engage with the device for three minutes or less [2]. In two well-documented cases, which we explore further in this paper, researchers found that saki monkeys' use of an installation to access auditory stimuli waned over time [14], and orangutans' interactions with an interactive touchscreen decreased with repeated exposure [3].

Animals' patterns of engagement with new stimuli such as environmental enrichment have been much studied in terms of exploratory behaviour and novelty-seeking [25], which may be shaped by an individual's curiosity traits [11]. It is widely understood that novel enrichment objects lose their appeal over time due to habituation [22]: the phenomenon whereby animals' responsiveness to a stimulus diminishes with ongoing exposure [23]. Habituation is an essential learning process that allows animals (including humans) to pay attention to new and potentially dangerous stimuli but avoid expending time and energy on unnecessary responses to stimuli they have already encountered.

Human interaction with digital systems is also impacted by habituation and novelty. For example, human–computer interaction research has identified the role of habituation in people's diminishing response to repeated warnings [41]. In studies of human technology users' initially high levels of engagement waning with time, this pattern is generally attributed to the 'novelty effect'. Tsay et al. define the novelty effect as "the human tendency for heightened engagement and/or performance when encountering the introduction of a novel phenomenon, such as the introduction of a new technology. [...] Subsequently, user interest and engagement may gradually disappear once game elements and mechanics are no longer keeping users entertained or satisfied" [40]. We note that, for humans, instrumental use of digital tools intersects with the novelty effect, and socio-cultural factors such as trends and social pressures can partially account for initially high levels of use [21]. However, we see considerable value for ACI designers in exploring the overlapping findings from studies of habituation in animals' use of enrichment, and of the novelty effect in human-computer interaction. There may also be parallels in the way that these phenomena can be addressed by intervention designers. For example, research into animal enrichment and human use of public displays indicate that introducing some form of variety can reignite interest and interaction for both animal and human users [21, 39].

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In designing ACI interventions, especially digital enrichment, questions of habituation and novelty effect must be considered carefully by researchers to ensure there is an ongoing benefit to animals and carers [22]. Digital enrichment is embraced for its potential welfare benefits through providing safe enrichment at any time, particularly when human carers are absent; for the ability to introduce greater variety through audio/visual elements, applications and games; and as a means to provide animals with more control over their environment [4, 20]. Exploring how digital interventions can offer long-term effectiveness for animals is critical, given the relatively high upfront cost of many digital interventions compared to traditional enrichment, which is commonly made of paper or cardboard, moulded plastic, and organic items. However, to achieve the potential benefits of digital interventions, there is a need to examine the impacts of the novelty effect and habituation in making decisions about design, deployment and the use of varied content.

Despite this, most ACI studies involve animals for only a short amount of time: in rare cases, for months [14, 16], but most commonly, for only a few hours, e.g. [8, 9, 17, 19]. Very few studies look at the impact of animals' interactions with technologies over extended periods. As such, the results are likely to be affected by the novelty effect and cannot account for the impacts of habituation. It is speculated by scientists that for humans, the novelty effect may endure for up to six months [21], implying that technology trials and evaluations may need to last for over half a year to draw valid conclusions about long-term value and usage patterns. The required duration for evaluating animal enrichment and other ACI interventions will depend on the research aims and study design. Additionally, habituation may occur much more quickly with animals that have a shorter lifespan and in different patterns in various animals (e.g. preys vs. predators, zoo, farm animals, etc.). However, long-duration studies will be required to account for habituation and the novelty effect when seeking to make predictions about future usage patterns and ongoing benefit to animals.

This paper sets out to explain patterns of use similar to the novelty effect that we observed for three digital interventions designed and trialled with dogs, orangutans and saki monkeys. Plotting usage data over time in terms of interaction frequency and duration, we use data to motivate our reflections. In this analysis, we discuss how habituation seems to have manifested in animals' responses to these digital enrichment interventions. This discussion brings to the fore implications and issues for designing, deploying and evaluating animal technologies. From this, we highlight critical future questions to be addressed by the ACI community to work towards creating technologies that are more effective, for longer, in meeting animals' needs.

2 RELATED WORK

We first explore accounts of the novelty effect in studies of human engagement with computing systems, which provides valuable background for our investigation into similar phenomena in animals' use of technology. Subsequently, we describe key insights from studies of animal behaviour and enrichment in the process of habituation, which appears to have parallels with the patterns of use associated with the waning novelty effect, and which we assume to underpin observed decreases in animals' use of ACI interventions, over time.

2.1 The Novelty Effect in Human Interaction with Computers

In human–computer interaction research, there is an increasing need to study the impact of the novelty effect on technology engagement to plan for ongoing use, and avoid inappropriate conclusions about user preferences or long-term effectiveness [21, 36]. The novelty effect has been reported in studies of human use of a range of technologies, including activity trackers [38], public displays in workplaces and public settings [21] and gamified learning [40]. In these cases, an early high level of user interest and engagement declined after the novelty period, which was variously reported as lasting approximately 3 months in a study of activity trackers [38] and approximately 10 weeks in a study of the use of public displays [21].

Following an initial decrease in use, a recurrence of the novelty effect can be triggered by system changes or updates, including new content and added feature changes [21]. It is further reported that the magnitude and frequency of such changes affect the extent of renewed interest. It has been found that the extent to which a system is well-integrated into an organisational setting (such as a workplace or school) is a key determinant of how use is sustained after the novelty period [21, 40].

The novelty effect, both initial and reoccurring (following system changes), can present challenges for human–computer interaction researchers. For example, when a system is enhanced during a field trial, any observed increase in usage may be due to the greater value offered by the enhancements or by the fact that the novelty effect has been triggered by the changes to the system [21]. Disentangling these two possible explanations can be difficult through usage logs alone. Similarly, it can sometimes be impossible to explain sudden increases in user interaction without full-time observation of the system in use [21].

2.2 Effects of Habituation on Animal Interaction

The process of habituation, by which "repeated applications of a stimulus result in decreased responsiveness," is an important aspect of animal learning [23]. For ACI researchers, habituation may be desirable, for example, when animals are required to wear or interact with apparatus (such as drones) likely to elicit initial fear (neophobia) or stress [6]. However, habituation is something to be minimised in the case of digital enrichment and interventions that seek to offer animals ongoing behavioural and experiential opportunities [7, 37].

Studies of animal behaviour indicate that responses to enrichment tend to diminish within the course of an exposure session, and also across sessions [39]. Intermittently presenting enrichment on a variable schedule, rather than providing continuous access, has been found to maintain interest and value [22]. Renewed interest, known as 'spontaneous recovery', tends to occur when enrichment is presented after being withheld [39]. For example, sloth bears' engagement with food enrichment (honey filled logs) was more resistant to habituation when enrichment was presented on alternate days (days 1, 3 and 5 of the study) than on consecutive days. Furthermore, presenting enrichment at unpredictable intervals and times of day is likely to slow the rate of habituation [39]. It has been found that patterns of habituation are different for intrinsically reinforcing enrichment, which provides animals with opportunities to perform highly motivated behaviours, compared to extrinsically reinforcing enrichment, through which animals gain access to rewards, e.g. food. It is generally understood that spontaneous recovery is only partial; initial levels of engagement may not be restored, and the response will again diminish with each exposure. However, there is a need for more data on how habituation to enrichment is affected by the frequency of presentation [39].

Variation of stimuli can, with some limitations, help sustain interest in enrichment. For example, it was found that tigers' engagement with a mechanical prey device was restored through the simple addition of a detachable bag [39]. However, animals can exhibit lowered interest in new stimuli that are similar to current habituated stimuli. This lowered interest happens as a result of 'generalisation', by which a learning experience with one stimulus is applied in the presence of other, similar stimuli. Conversely, new, reinforcing enrichment can have a positive impact on responses to familiar enrichment that had lost interest value, a phenomenon termed 'dishabituation' [39].

It has been found that stimuli that are highly salient, in terms of their overall impact on the animals' environment or their dissimilarity from the existing environment, are likely to result in a more pronounced response and slower habituation. This is highly relevant to the deployment of non-naturalistic stimuli (such as computerised installations) into the naturalistic environments of, say, zoo animals [39].

The two bodies of research summarised above suggest that there are close parallels between habituation in animals' use of enrichment, and the novelty effect in humans' use of computing systems. From this, we suggest that ACI researchers should attempt to integrate knowledge about habituation and the novelty effect into the design and evaluation of interventions for animals.

2.3 Evaluating the Animal Experience of ACI

Although many ACI researchers subscribe to the goal of designing interventions to promote positive animal welfare, an ongoing challenge for the discipline is to define robust protocols for evaluating technologies against this objective [10, 12, 26]. Recent work in ACI has given careful attention to the challenges of ensuring that technology design addresses the physiological, sensory and ergonomic requirements of animal users, which can be equated to notions of 'usability', i.e. the extent to which an intervention can be easily used [35], and 'wearability', i.e. comfort and avoidance of inconvenience for the wearer [27]. Many ACI studies conduct short duration evaluation of animals' interactions with prototypes to determine feasibility of the prototype and ensure no negative animal welfare effects.

Assessing animals' subjective experience of using technology ('user experience') remains challenging, and the long-term value of an intervention with animals requires further study. Discussing the challenges of assessing animals' 'liking' or preference for a stimulus, Ritvo and Allison highlight the benefits of allowing animals to freely choose between alternatives, such as alternative auditory or visual stimuli [32]. However, animals' approaches and interactions with interventions are not necessarily motivated by a preference for the object; they can be motivated by fear, behavioural instinct, compulsion or stereotypies [32]. It has been proposed that in some species, changes in communicative behaviours, for example, tail wagging in dogs, can be used to assess changes in an individual animal's subjective state, triggered by exposure to a digital intervention, through comparison with the individual's baseline behaviours [34]. However, such techniques are costly and challenging in that they must consider the individual's behaviour, physiology, prior experiences and context [34]. Calls to make more extensive use of the methods of behavioural observation developed in animal research [10, 12, 31] suggest that ethological methods for determining the effectiveness of environmental enrichment, might be applied in ACI to evaluate intervention impacts on animals' overall subjective experience and well-being [44].

3 DATA AND ANALYSIS

To look at novelty effect and habituation over different species and computer-enabled devices, we analyse and compare three different data sets. In this paper, we use data from [3], a study in which five orangutans controlled a visual touchscreen in the zoo; [16], where two dogs controlled a screen in their home; and [14], where seven white-faced sakis controlled a screen in the zoo. Details of the participants can be found in Table 1.

Kinecting with Orangutans (KWO) is an interactive system designed to provide varied visual and cognitive enrichment for orangutans [3] [1]. KWO comprises a Microsoft Kinect sensor and projector, used to project applications onto the wall of the orangutans' enclosure. Animals can interact with the applications by touching the projection surface with hands, feet, other body parts or objects, and touches are detected by the Kinect depth sensor. As part of co-designing KWO with animals and zoo personnel [43], orangutans had several exposures to early prototypes, including sessions giving access to a floor-based projection system with some of the applications [42]. Animals' interactions with the first prototype system are not captured in the data presented in this paper.

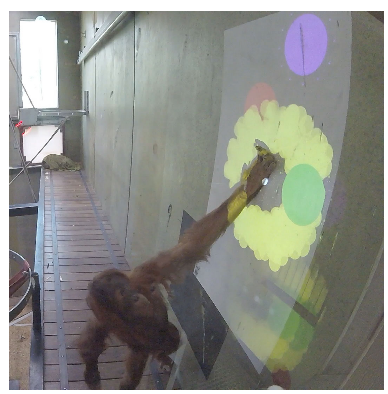

Figure 1: Kinecting with Orangutans: Juvenile orangutan (O3) interacts with the 'Burst' application.

[1] Video of KWO: http://hdl.handle.net/11343/280737

Table 1: Participant Information

	Orangutan [3]					Dog [16]		Saki Monkey [14]						
	O1	O1	O3	O4	O5	D1	D2	S1	S2	S3	S4	S5	S6	S7
Sex	F	F	F	F	M	M	M	M	M	M	F	F	F	F
Age	27Y 9M	39Y 4M	6Y 10M	31Y 5M	40Y	5Y 1M	2Y	21Y	5Y 1M	4Y	22Y	11Y	4Y	4Y

The data in Fig.4 represent the orangutans' interactions in the course of the evaluation reported in [3]. For this evaluation, KWO was installed to project applications onto the enclosure wall. This semi-permanent installation was deployed approximately one year after a temporary floor-based prototype. During trials, orangutans were offered five applications designed as a proof of concept and to introduce the interactivity offered by the installation. Applications provided were 'Burst' (moving coloured discs that 'explode' on touch); 'Sweep' (flickering tiles that disappear when touched); 'Paint' (allows animals to draw on a virtual canvas); 'Gallery' (displaying photos and videos that animals could select from, to view one at larger scale); and 'Match' (an app designed as the first stage of training animals to match by colour and shape). In addition, a selection screen was offered, through which orangutans could choose an application. If none was chosen, then applications would be presented sequentially. Animals were given access to the enrichment by moving them individually into the indoor enclosure space where the projection system was installed. The juvenile (O3) and her mother (O4) participated together, but other orangutans were alone in the indoor space during the treatment and control sessions. Trials lasted one hour and took place at the same time of day, 10:45–11:45 a.m. Each individual had 4 or 5 'treatment' sessions with KWO switched on, and 5 'control' sessions with KWO switched off. Randomisation was used to schedule treatment sessions and control sessions. Data for control sessions are not included in our analysis. The time between treatment sessions for any one animal ranged from 2 days to 14 days. On each study day, only one trial was conducted, with one animal (or with O3 and O4 together). During treatment sessions, animals' interactions with the installation were recorded through continuous sampling by an experienced animal behaviour researcher. Interactions included viewing the interface without touching, deliberate touches, and significant and prolonged interaction.

In DoggyVision, a visual system is made for dogs [16], where the system would recognise when a dog was in front of the system using proximity sensors to create an interactive zone. This interactive zone was a 100 x 20 cm area in front of the screen. When a dog was detected in the interactive zone, the screen would turn on and play randomised visual and audio stimulus, logging and recording a dogs' interaction for as long as a dog was detected in the area. In total, there were 39 media clips that each showed a range of different dogs in different situations. When a dog left the interactive zone, or otherwise, the screen became blank. This method enabled a dog to turn on and off the screen to control a screen device. The DoggyVision system recorded a dogs' interactions with the device, timings and videos both online and offline and the system status.

The DoggyVision system was used with two dogs (D1 and D2) individually in their home over a two-week period 2. During these two weeks, the dog had access to the system constantly (24/7). For the first week, the DoggyVision system was installed in the dog's home but was not activated. The system collected baseline data of the dogs' everyday interactions. For the second week, the system became interactive, triggered based on a dog's interactions. After the study to analyse the results, the data were checked to ensure the system was triggered by the dog, with any human-triggered interaction removed. Other than this, all dog participant data were included and split into interaction times in Fig 5 and usage times in Fig 6.

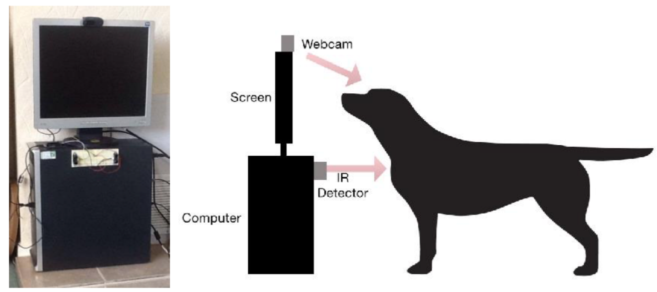

Figure 2: DoggyVision System: Left, the system in the home; Right, the system diagram

In Saki Tunnel, there is a visual systems that can be used by saki monkeys [14] (Fig 3). This system was used with seven sakis (S1–S7) placed in their indoor zoo enclosure for several weeks. These sakis were a family group, having access to indoor and outdoor spaces during good weather and summertime, which was during the study period. The tunnel system played a visual stimulus when a white-faced saki was detected within the tunnel system. The system used proximity sensors to detect when a monkey was inside, building on design and research reported in Piitulainen and Hirskyj-Douglas [28] and Hirskyj-Douglas and Read [16].

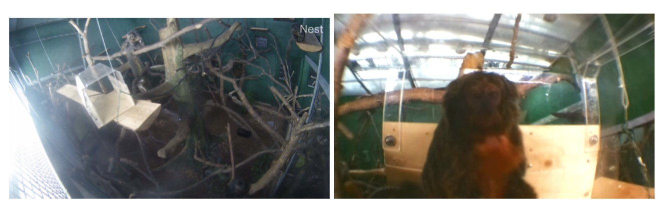

Figure 3: Saki Tunnel: Left: The tunnel inside the monkeys enclosure. Right: A saki inside the tunnel structure in front of the screen.

When a saki was detected inside the tunnel, the screen would play preselected media (video only), which was defined as an interaction. These videos were of underwater, worm, animal, abstract art and forest videos chosen to be varied in both colour and movement. The system would record via video, and it would log and save the interactions both online and offline along with the system status. This media would change in weekly (7 day) iterations. The sakis had access to the system 24/7 inside their main enclosure for six weeks, with the first week collecting baseline data: no stimuli in week 1, forest stimuli in week 2, underwater stimuli in week 3, worm stimuli in week 4, abstract stimuli in week 5 and animal stimuli in week 6. As the system was used as a troop without individual analysis, it is not possible to analyse individual variability.

Further study details, such as the method and detail of the computer-enabled interactive systems, can be found within the respective papers [3, 14, 16].

For the analysis, where possible, the interaction time and interaction frequency per day or session were calculated for each study. These results are presented individually (for each animal) if the data are available [3, 16], or else as a group [14]. The data are plotted along with a polynomial trend line because this gives more realistic plotting than linear plotting with smaller data points.

4 DATA

4.1 Projection System with Orangutans: Kinecting with Orangutans (KWO)

Figure 4 shows the count of individual and averaged orangutans' interactions with KWO for each treatment session. Two adult female orangutans (mother and daughter), O1 and O2, showed moderate levels of response to the system in Session 1 (6 or 7 interactions). In Session 2 and 3, they interacted with the installation only 1-3 times, and in Sessions 4 and 5, the interaction count was negligible. Juvenile female orangutan, O3, showed the highest levels of interaction. However, her interactions also seemed to follow an overall pattern of waning from initial high levels of interest: from 9 interactions in Session 1 to 2 interactions in Session 3, with the exception of an interesting spike in interactions in Session 4. We posit that higher levels of interest on this occasion might be due to extraneous temporary factors such as social factors, or visitor numbers or behaviour, not captured in the data available here. Interaction counts for adult orangutans O4 and O5 are too low to present observable patterns.

4.2 Visual System with Dogs: DoggyVision

Figure 5 shows the count of individual and averaged dogs' interactions per day with DoggyVision. Figure 6 presents dogs' daily use time of the DoggyVision system. D1 and D2 had varied interaction numbers, with D2 triggering the system more frequently than D1. This could be due to age differences and activity levels. The dogs' activation of high and low periods with DoggyVision changed in distinct patterns for unknown reasons; it is unclear why these periods occurred. Nonetheless, from the data, it could be argued that the dogs has still not learn to use the system even after seven days.

4.3 Visual System with White-Faced Sakis: Saki Tunnel

Figure 7 presents sakis' interaction count and total time spent interacting with the device, Saki Tunnel. Data are presented as an average (per monkey). This was the second time the sakis had used the tunnel device; when previously deployed, Saki Tunnel offered audio enrichment [28]. As the system alternated between different visual media during the study, the peaks and declines in interaction counts and time spent with the device could indicate that some stimuli were preferred to others; or, these patterns might be due to habituation and spontaneous recovery. Extraneous factors are likely to be at play on days where outlier data points are seen (e.g. interaction counts on Day 11 and Day 22). Nonetheless, even with varied stimuli, the sakis' interactions with Saki Tunnel decreased noticeably after Day 15.

5 DISCUSSION

Based on our analysis of the three data sets represented above, we consider the broader relevance of the novelty effect and habituation for ACI designers and researchers. We discuss the implications for ACI design and deployment. We then reflect on the implications for ACI evaluation. From there, we identify challenges and questions to be addressed by ACI researchers regarding the design and evaluation of interventions for ongoing use by animals.

5.1 Implications for ACI Design and Deployment

As noted in Figure 4, Figure 5 and Figure 7, the number of interactions that dogs, great apes and monkeys have with computer systems vary over time. These different interaction patterns are also reflected in Figure 7 and Figure 6, where the amount of time a dog or a monkey spent using a computer-enabled system varied over the study days. However with the saki monkeys [14], this could also be due to different stimuli. Nonetheless, as the data across species, contexts and technology indicate, short-term data (captured over a couple of days, hours or a few weeks) do not give the full picture of interaction patterns. These short-term data are impacted responses to novelty and habituation affects. For instance, we might conclude that orangutans (Figure 4) habituate to visual stimuli more quickly than saki monkeys (Figure 7) or dogs (Figure 6). However, it should be noted that the KWO and Saki Tunnel data do not reflect exposure to the first prototypes: floor-based temporary KWO installation and auditory enrichment through Saki Tunnel. The long-term effects of prototype exposure and habituation on ongoing usage patterns for digital enrichment are, as yet, not well understood, and they will require further study within by ACI researchers.

Further, as Figure 6 demonstrates in dogs, and Figure 4 with orangutans, usage patterns can differ substantially between individuals within species. For instance, while overall, orangutans had decreasing interactions with KWO over their five treatment sessions, interaction counts for juvenile orangutan O3 increased markedly in Session 4. Examination of observational data and the trial conditions does not offer any explanation for this increase. For example, we note that for O3 (with O4), Sessions 2 and 3 were six days apart, and Sessions 3 and 4 were also six days apart, so this increase is not due to KWO having been withheld for a longer

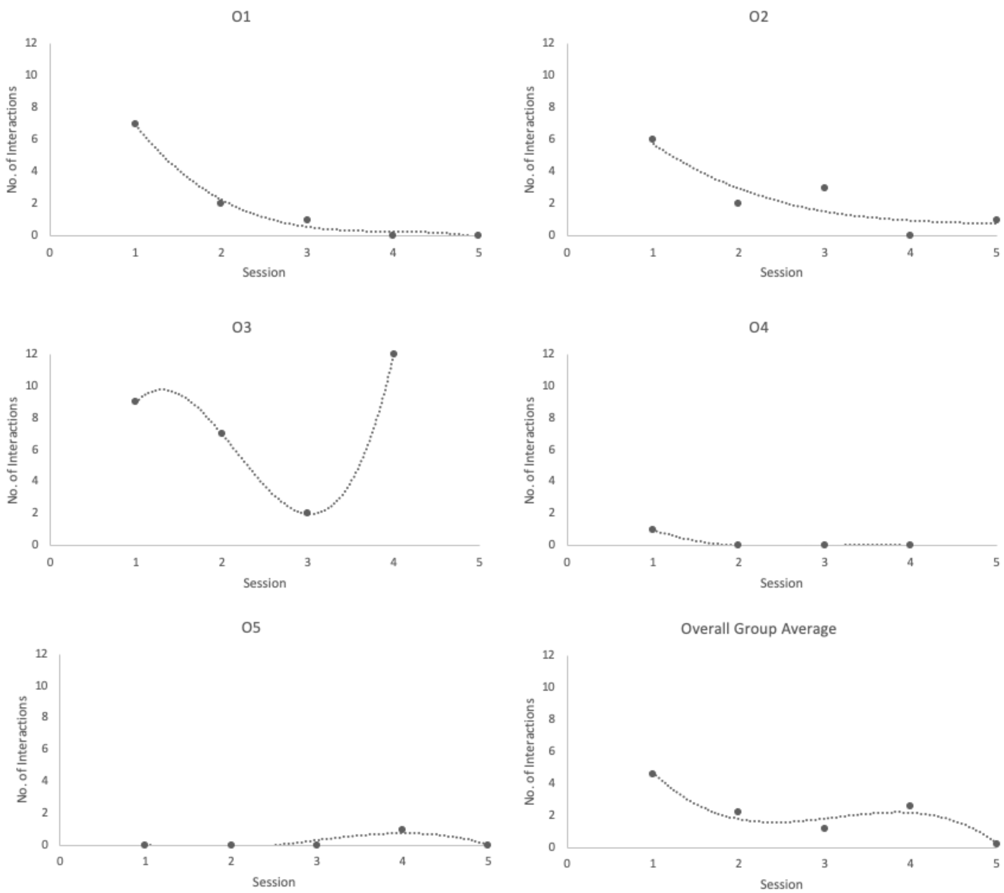

Figure 4: Number of interactions per session of exposure to Kinecting with Orangutans, per orangutan (O1-6) and an overall average.

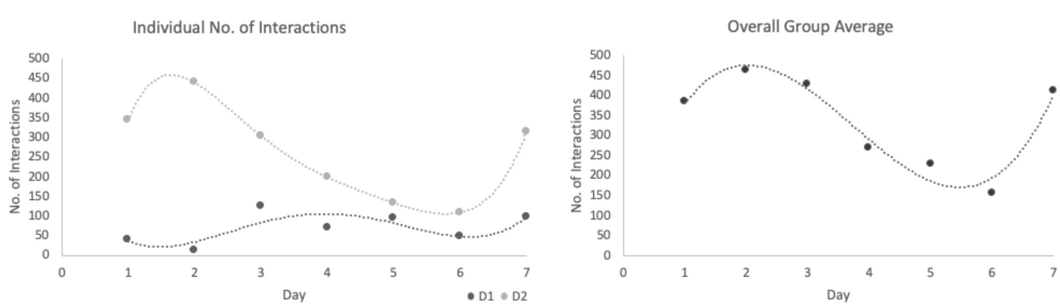

Figure 5: Dogs' number of interactions per day with DoggyVision system split via participants (D1-2) and an overall average.

period. Similarly, dogs D1 and D2 both had a rise and fall in the number of interactions with DoggyVision: D1 interactions peaked at Day 4, but for D2, this peak was at Day 2. Cox et al.[5] suggest that when playing non-digital games with dogs, personality characteristics may lead to different interaction styles and behavioural patterns. Our analysis suggests, moreover, that personality and individual differences within species may play a factor in novelty and habituation, creating additional complexity for designers of digital enrichment.

Design of an interactive device for animals is only part of the story. Equally important are considerations such as the frequency and duration of presentation, the design of stimuli (including physical and digital components) and the extent to which stimuli are

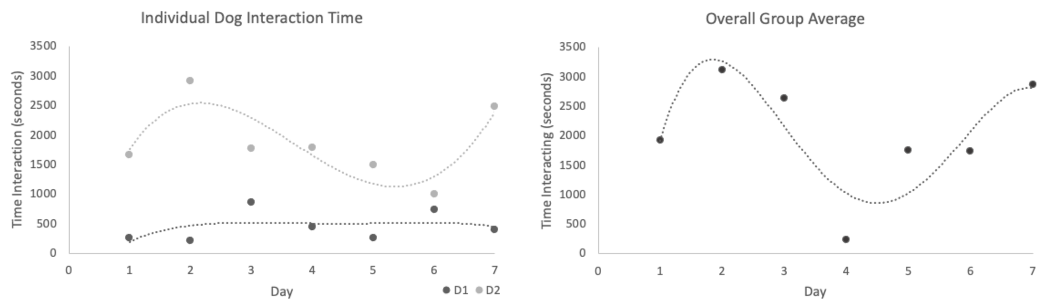

Figure 6: Dogs' time interacting per day with DoggyVision system split via participants (D1-2) and an overall average.

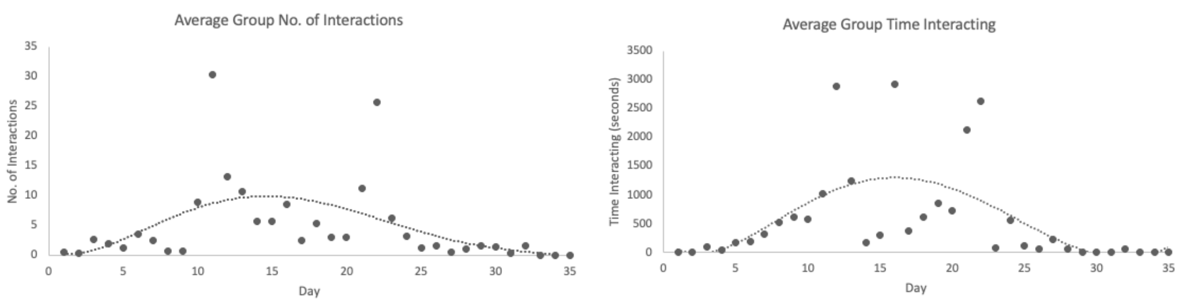

Figure 7: An average of a white-faced saki's interaction time and time spent per day with the visual system.

varied over time. Animal behaviour studies of enrichment use indicate that one approach is to withhold enrichment and then offer it again later, intermittently and perhaps on an unpredictable schedule [39]. This requires that enrichment can be removed from the animals' environment altogether, suggesting that there might be advantages to temporary, removable enrichment structures and devices. However, to what extent engagement with computerised systems can be rekindled through a removal process and if this can feasibly attain the original level of interaction is a question that requires continued investigation. We note that in dogs' use of non-digital toys, it has been found that neither recovery nor dishabituation is possible [30]. Furthermore, it has been found that dogs are insensitive to varying the sensory attributes (colour and odour) and time interval between presentations of the toy (10 seconds-15 minutes) [30]. Cats, however, have less intensive play with enrichment toys if the play sessions are spaced further apart (25–45 mins) [13]. Further, while Hirskyj-Douglas and Kankaanpää [14] changed the visual stimuli, this did not sustain the novelty of the system.

Because ACI combines physical and digital elements, some physical components might be more salient to some animal users than digital components. For instance, in Piitulainen and Hirskyj-Douglas [28], the authors note that they choose the device form (tunnel) that the sakis most frequented, and that it was impossible to disentangle their preference for using the system to trigger digital content from the desire to be inside the tunnel structure. As such, there could be a benefit in being able to vary the physical stimuli associated with a digital intervention, and thus, to counter habituation.

Choices about salience in design are also relevant to decisions about using naturalistic or non-naturalistic designs, and the selection or design of physical components. For example, the use in ACI of off-the-shelf objects that might be familiar to animals, such as balls and tug toys, might result in faster habituation than novel physical components. However, many ACI designers who require specific behaviours incentivised by food rewards use such familiar affordances for interactive systems [33]. Outside of this context, where the computer-enabled system is for enrichment, animals' rapid response to familiar devices might run counter to the long-term value of devices that offer some intrinsic reward but are dissimilar from other items in the animal's environment. A continuing challenge for ACI is to demonstrate the design of technologies that increase behavioural choice or sensory variety in a way that provides ongoing intrinsic reinforcement, rather than encountering rapid habituation.

For researchers conducting co-design with animals, it may be tempting to see an animal's early, enthusiastic engagement with a novel device as an indication that it is 'well-designed' for the species, or that the animal 'likes' the intervention. However, our analysis indicates that early high levels of interaction can diminish quickly, after only a few days. This supports the findings that animals can habituate rapidly to enrichment that offers only intrinsic reinforcement [39].

5.2 Implications for ACI Evaluation

The observation of how habituation affects ACI use and design, outlined above, present important considerations for the evaluation of ACI interventions.

Animals' use of digital technologies changes substantially in the first days and weeks of an intervention. Our analysis confirms that initially high levels of response generally diminish quickly, over 5 exposures, in the case of KWO, and over the course of 15 days, in the case of Saki Tunnel. Evaluation over a period of weeks or months is generally required to observe how habituation affects animals' responses, and thus to draw conclusions about the long-term value of a proposed intervention. In studies of the human use of technology, the novelty effect has been proposed to last ten weeks [21], but some also claim this could persist up to six months, based on Prochaska's trans-theoretical model of change [29]. ACI researchers should consider that habituation and response to novelty can be affected by many factors in animals' wider environment and life experiences [22]. Decisions about the appropriate duration for an ACI technology trial should be informed by data on how the animals have habituated to previous interventions, including enrichment.

ACI designers will note that there is a tension between extended duration evaluations and the rapid iterative prototyping cycles favoured by interaction design. We affirm that observing animals' early interactions with a prototype can provide insights into usability, in terms of ergonomics and learnability of the mechanism of interaction, and the extent to which the artefact elicits approach and exploration behaviours versus neophobia. For example, observing orangutans' early interactions with KWO confirmed that the animals could easily and enthusiastically interact through touch with a projected interface, but it also revealed that floor-based interaction was ergonomically challenging because projections were often obscured by animals' upper bodies [43]. Likewise, [28] prototyped different shaped interfaces with sakis and selected the mechanism of interaction (proxemics) from observing the monkeys' typical behaviours of sitting inside the tunnel installation, as well as investigating and discounting alternative prototypes. Initial cycles of prototyping and animal trials can be followed by an extended period of evaluation to explore the effect of habituation and ongoing use of enrichment systems. More data are needed, though, to understand how habituation to an early prototype can affect animals' interactions with subsequent prototypes. In addition, the overall implications for iterative design with animals and the effectiveness of the final implemented system require further study.

Habituation occurs within a single presentation, and as noted above, it is a key consideration in deciding how long an ACI intervention should be offered to an animal. To inform these decisions about the duration of deployment, evaluation should capture data about the duration and intensity of animals' interactions with a prototype, as well as the nature of the interaction (for example, touching, manipulating, moving, hitting, looking at the object) throughout the course of a trial session. Reviewing data captured in the evaluation of KWO 4 reveals that more precise data about the duration of each interaction would allow for determining whether total interaction time decreased during the course of the study, and for investigating the effect of habituation during sessions.

When an intrinsically reinforcing intervention is withheld for a period of time and then offered again, animals' responses can partially recover to some extent. For KWO [43], this was particularly noticeable following the time taken (approximately one year) for redesign and semi-permanent installation at the orangutan exhibit. However, this recovery was short-lived. To inform how an intervention should be deployed for maximum value to animal users, researchers should capture data on how the recovered response diminishes with each exposure.

As noted above, digital forms of enrichment may potentially mitigate habituation effects and provide sustained value because it is relatively cheap and easy to vary the stimuli they offer. For example, visual, auditory or interactive content can easily be switched, and their functionality can be modified. In the case of Saki Tunnel, audio stimuli were initially provided [28], but this device was later used to offer visual enrichment [14]. To capitalise on this opportunity, it is essential that ACI researchers investigate how habituation is affected by specific types of stimuli, the way that variants are introduced and the rate of change.

Noting that, through generalisation, habituation affects animals' responses to different stimuli, it is important to also examine how responses to new digital content are affected by prior habituation, and the degree of dissimilarity required to overcome generalisation. To this end, researchers should note the nature of the stimuli, and the extent to which they are similar or different, as part of reporting design, deployment and evaluation. Where feasible, researchers might provide exemplars of content, published as supplementary material when reporting ACI evaluation.

Animals exhibit high levels of response to stimuli that are very salient and substantially different from their existing environment. This is significant for ACI designers who might be in the position to introduce technological devices very different from animals' previous experience of the world; this is particularly true for animals housed in naturalistic environments, such as zoos and sanctuaries. It is all the more important in such cases to avoid assuming that animals' initial exploratory responses are predictors of sustained use or value to the animals.

Another important possible outcome of offering animals varied stimuli through ACI is the dishabituation effect: that new stimuli or reinforcing enrichment can overcome animals' habituation to other stimuli. To explore this effect, there is a need for more data about how animals' responses to new stimuli affect responses to habituated stimuli, over time. In reviewing animals' interactions with KWO, we note that the lack of detailed data about animals' use of different applications through the course of the trial, and the decision to provide all applications on rotation, represents a missed opportunity for investigating dishabituation.

6 KEY QUESTIONS FOR ANIMAL–COMPUTER INTERACTION EVALUATION

In addition to the broad insights drawn in the preceding section, we also identify key questions to be considered by ACI scholars to address the challenges posed by habituation and the novelty effect. As part of this, we echo the call from Alligood et al. for more systematic evaluation of technological enrichment [1]. We contend that many of these issues relate to animal interaction for functional purposes, as well as enrichment.

6.1 What Metrics Should Be Used in Evaluating ACI?

In analysing how ACI interventions were evaluated, we note that while usage counts alone provide limited insights into ongoing value to animals, verifying that animals are using a system may be a prerequisite to effectiveness [1]. Data on the number, duration and quality of interactions can also be valuable where the objective of enrichment is to broaden animals' behavioural and sensory opportunities [1]. In addition, interaction data can provide valuable insights into patterns of habituation, and they can show how use is affected by varying stimuli. In other cases, however, to better evaluate enrichment effectiveness, it may be more useful to measure impact on animal behaviours that are desirable and indicative of positive welfare (e.g. play behaviours, positive social interactions) or on unwanted behaviours such as stereotypies (e.g. pacing). Physiological measures such as levels of stress-related hormones, and carers' ratings of animal mood and well-being, can also be valuable for assessing how an intervention affects animal welfare [1]. These factors would give more insight into the quality of the interaction. However, disentangling the impacts of enrichment from other variables related to environment, social group interactions and seasonal changes, for example, can be complex, especially in zoos and shelter environments.

6.2 What Does Long-Term Effectiveness Look Like, in ACI?

When building a system that is perceived as successful for animals, there is a tension between creating novel and interesting systems for animals to elicit early engagement, while also ensuring sufficient familiarity so animals can easily learn system functionality. Intertwined with this tension is the question of how to measure animals' interactions and what this means in terms of success. It is worth noting that what success looks like in terms of evaluating a system over time is complex, and there are no clear criteria. As our data analysis illustrates, most animals become habituated to computer stimuli over time. Yet, there is still value in these short-term computer enrichment devices. A future area of study for researchers and designers alike is to consider and develop criteria regarding factors of success over time, and corresponding metrics. Subsequently, the challenge will be to establish approaches for meeting these success criteria over the long term, for individuals and groups of co-housed animals.

6.3 How Long Should ACI Studies Run?

There is no single answer to this question. We propose that ACI researchers should assume that habituation will occur to novel interventions and should identify ways to examine and measure this phenomenon, and its impacts of variation, as part of the evaluation. We recommend that this question is further explored through dialogue with animal behaviour researchers and species experts, considering how digital technologies can facilitate systematic evaluation.

6.4 What Is the Role for Automated Data Capture in Technology Evaluation?

A significant barrier for enrichment evaluation is the considerable workload placed on animal carers [18], who, we believe, have a crucial role to play in assessing effectiveness. We propose, therefore, that technological interventions should automatically log animals' interactions both numerically and by video [14, 28]. This automatic data capture reduces the need for intense (continuous sampling) observation during enrichment sessions. Further, along with other forms of qualitative and quantitative evaluation data, this automatic capture can provide valuable insights into the impacts of the intervention from multiple perspectives [43], and it can identify patterns of habituation. There is a need for further dialogue between ACI designers and animal scientists to define what data should be captured to inform design decisions and evaluate long-term impacts for animal users.

7 LIMITATIONS AND FUTURE WORK

Although our paper provides critical directions and a more comprehensive analysis of the ACI field, drawing from literature and prior studies, we have only considered three studies, offering primarily visual stimuli as enrichment, conducted chiefly in zoo environments. Nonetheless, this work provides a foundation for expanding the understanding of novelty and habituation in the ACI community. A future iteration of this paper could look across multiple modalities, a broader range of species and other settings.

Looking forward, we suggest that our key questions can ground approaches to design and evaluation with animals and computers. Following these guidelines, we stress the importance of evaluating current computer systems as seeds from which to grow novel devices for animals.

Another learning process involved in animals' patterns of interaction is extinction, which we have elected to not include in this conversation. Extinction is primarily involved with extrinsically motivated interaction (for example, food-based enrichment and cases where food rewards are given for interaction with systems). Extinction is therefore beyond the scope of the present analysis, but it may be relevant to the design and deployment of other ACI interventions.

8 CONCLUSION

It is important that ACI researchers attend to the novelty effect and habituation in the design, deployment and evaluation of interventions for animal use.

The analysis presented in this paper illustrates the substantial decline over time in animals' use of interactive systems that offer no extrinsic (food) reward. Studies of animal behaviour and enrichment suggest that habituation can, to some extent, be mitigated, first by withholding enrichment and providing it on an unpredictable, variable schedule, and second, by varying the stimuli offered. However, our analysis indicates that habituation can occur such that animals' interactions with an intervention are negligible after a few exposures, or after a few days or weeks. This pattern of declining interaction was seen even when varied visual media and games were offered, as was the case for all three of the interventions we studied. It was also seen for the intervention, KWO, which was only provided intermittently. These findings have important implications for the way that ACI researchers approach the design of digital enrichment and the types of conclusions that can be drawn from animals' early patterns of interaction with novel, interactive interventions.

This paper has drawn attention to the importance of the long-term evaluation of digital interventions for animals. Observing animals' interactions with novel interventions can shed light on feasibility and usability, in terms of ergonomic, sensory and psychological factors. However, to make conclusions about the extent to which an animal will choose to interact with a device, or derive benefit over the long term, requires extended trials and evaluation methods that account for habituation, drawing on existing cross-disciplinary knowledge about the novelty effect and patterns of animal habituation. In addition, ACI researchers can plan evaluation and data collection so as to build knowledge about the processes of habituation to variation in digital media and interactive applications, and the ways in which animals habituate differentially to the physical and digital components of interactive devices. Developing robust understandings of animal habituation in ACI will provide a foundation for effective design that benefits animals, and for refining methods of iterative prototyping with animals.

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