

Do Monkeys Want Audio or Visual Stimuli? Interactive Computers for Choice with White-Faced Sakis in Zoos

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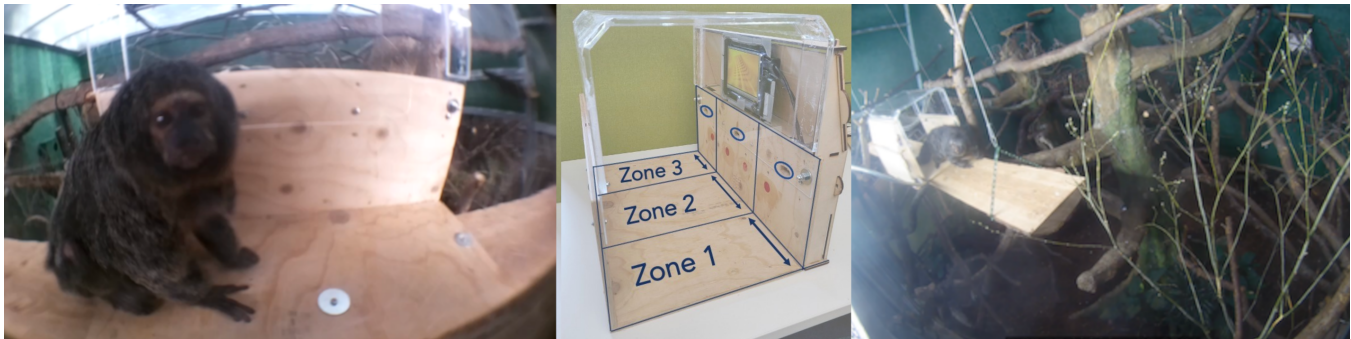


Figure 1: White-faced saki monkeys using the interactive device. Left: an image from the camera inside the device. Middle: the three interactive zones of the device. Right: the device inside the monkeys' enclosure.

ABSTRACT

Interactive systems were built to give monkeys a choice over when and where to trigger stimuli as a way to control their environment to improve their welfare indices. Typically, systems only support the triggering of one stimulus – either audio or visual. In this study, a system was developed for monkeys that allowed them to choose between multiple auditory and visual stimuli. Utilising this system over several weeks, we found that monkeys would interact and choose between different stimuli, though not significantly, and that sakis triggered audio stimuli twice as much as visual stimuli. The monkeys interacted with audio and visual stimuli differently over time, spotlighting how we can define and measure the interactivity and user experience for monkey–computer interfaces. Furthermore, the monkeys' interactions, while initially increasing, declined over the study period, which indicated a novelty effect. This paper builds upon computer systems for primates by uncovering answers to key questions regarding creating and defining interactive systems according to a user's choices.

CCS CONCEPTS

• Human-centered computing → User interface design.



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KEYWORDS

monkey; primate; computer; animal-computer interaction; visual; audio; stimuli; preference

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1 INTRODUCTION

Zoos are increasingly providing non-human animals (hereon animals) access to computer systems for entertainment or enrichment purposes, to measure their cognition and to monitor them. These computer systems are mostly given to non-human primates (hereon primates); for example, researchers have made music systems for apes and monkeys [47, 48, 58], video systems for white-faced sakis [17], projection games for orangutans [62] and food finding puzzles for gorillas [14].

Zoos use these systems to enhance animals' qualities of life by giving them control over their environment and activities. For zoo-housed primates in particular, allowing them to control elements of their environment (such as light, heat, sound and visual elements) using computers has been demonstrated to induce positive behavioural welfare indices and improve the animals' overall living standards [6]. Furthermore, researchers have highlighted the importance of computers in creating choice to reduce an animal's stress and increase socialisation [43].

Yet, while there has been much research on the benefits of choice for animals since Grandin et al.'s study in the 1980s [13], only few computer systems developed for zoo animals give them direct

control over when the system triggers events and what the system does. Instead, most interactive computer systems give animals in zoos no control or consent over the system or its outputs [16], often playing audio and visual stimuli regardless of input [47].

Addressing this gap in choice, recent zoo systems have facilitated primates in choosing when to trigger stimuli [17, 47, 49]. For instance, researchers found that by giving primates a choice to trigger audio and visual stimuli, they will significantly seek out certain forms of stimuli [17, 47, 58], as well as choose when to turn stimuli off [49]. Furthermore, as primates use these bespoke systems in a way that is comfortable to them, a reduction has been noted in abnormal behaviours, indicating an increase in positive welfare indices when choice is introduced through computers [43, 46, 47].

Nonetheless, these computer-based choice systems still give minimal control and choice to animals. Current zoo systems give primates access to only one type of stimuli at any one time, e.g. audio [47, 49], visual [17] or a combination of both [43]. While ape species have been given a choice over two forms of audio [58] and scientists have started looking at how to build bespoke systems to examine choices made by apes [63, 64], no system exists that gives primates a choice between audio and visual stimuli. Thus, it remains an open question as to what stimuli type a primate, particularly monkeys, would seek to trigger when given a choice. From this, further questions arise regarding how we may build systems for primates to make these choices.

In this paper, we build a novel interactive system for white-faced saki monkeys (hereon referred to as sakis). This system gives sakis a choice between multiple stimuli at one time; they may pick between either three audio stimuli or three visual stimuli depending on the day. To choose, the system has three zones designated as distinctive interactive spaces that trigger different stimuli if the monkey is in certain location. This method allows the monkey to interact with the system via their ordinary everyday behaviours and choose when to use the system, if at all. We use this system to answer the following research questions:

RQ1: How can we build interactive devices for choice with white-faced sakis?

RQ2: If given a choice, what audio and visual stimuli do the white-faced sakis prefer?

To answer these questions, we deployed our system for several weeks in the sakis' zoo enclosure. The device automatically logs and records their interactions. After analysing this data, we looked at what stimuli the sakis were triggering and how they interacted with the system over time. We found that sakis triggered audio stimuli twice as much as visual stimuli, though not in any significant way. Looking at the sakis' interactions over the course of the study, we found that their usage of the device both increased and decreased in different study periods. Additionally, once the stimuli were removed (post-stimuli), the sakis used the device noticeably less than prior to the system's introduction (pre-stimuli). This drastic decline in usage indicates that while enrichment systems for monkeys may have initial benefits, they also have long-term effects on the zoo animals' space usage. From this, we highlight key questions regarding what choice looks like for monkey-computer interaction and how to objectively measure and quantify choice with monkeys. These bring to attention – for the animal-computer interaction and HCI

community alike – the impact of choice, multimodal systems and the long-term effects of systems for more than human users.

Contribution Statement. This paper is the first work that has looked at how monkeys may use computers to access and choose between audio and visual stimuli. We contribute a novel study methodology and findings to quantify animals' usage of computer systems to access and choose between multiple stimuli. The work on a larger scale points to no significant differences between how sakis seek audio versus screen visual-based technology interventions. Looking forward, work in this area will inform us how to give monkeys more choice and autonomy regarding computer systems while grounding current work in what stimuli primates and other animals would seek to trigger and how animals interact with computers. The findings, while based in the field of animal-computer interaction (ACI), have implications for HCI. This work prompts HCI to address specific user populations, including those with unique abilities and affordances, non-verbal communications and limited cognition. While this paper discusses animals, the methods and systems developed encourage HCI to look at interactive devices differently where findings are reflexive and relationships can be formed between ACI and HCI [22]. Furthermore, when exploring interactive systems for animals, as HCI designers, we are encouraged to question the fundamental assumptions regarding what choice and interactive systems look like and how we make decisions [18]. These decisions include how to measure interactivity, how to meet a user's needs and requirements, how we can evaluate whether a system is meaningful to a user and what creating meaning looks like for users. This paper contributes one of the first steps towards identifying where these knowledge gaps are and reflects on the difficulties in highlighting these gaps.

2 RELATED WORK

In zoos, primates are by far the most frequent users of computer systems. Most of these systems made for primates provide them access to stimuli for different senses such as audio stimuli for hearing [47] and visual stimuli for sight [17, 62]. These systems are used as a way of increasing the primate's welfare through access [64], learning about their preferences [17, 47] and measuring their behaviour in reaction to stimuli [64].

Traditionally, primates are given access to computer enrichment systems to undertake cognition tasks [10]. These tasks motivate animals in zoos to exhibit comparable physical and cognitive processes and behaviours to their wild counterparts [34]. Computers developed for enrichment purposes for primates are typically screen devices designed to be used by humans, often making them inadequate both in terms of usability and function for primates. These devices are typically touch screens [10, 34, 67], tablet devices like iPads [4, 16] and computer screens [2, 3]. Screen devices are used for husbandry purposes [24] and to gain insight into a primate's mood, personality, social skills and food preferences [10].

Building on this, many primates have now used touch screens regularly and successfully for many years in a handful of zoos: chimpanzees, gorillas and mandrills in Kyoto City Zoo [36]; chimpanzees, gorillas and Japanese macaques in Lincoln Park Zoo [25]; orangutans, chimpanzees and gorillas in Heidelberg Zoo [52]; and orangutans in Atlanta Zoo [45] and Indianapolis Zoo [35]. These

touch screen interfaces are used for cognitive research tasks, which are often voluntary and have become part of their daily routines, arguably forming part of their enrichment. Commercial products also exist in this space for great apes, but these devices are expensive and require training to use effectively, e.g. Zenrichment ApeTouch software [34].

By focusing on usability for primates, recent novel systems have been brought to the forefront that combine the traditional animal behaviour cognitive science approach with human-computer interaction design principles. These systems aim to look at how to create usable and interactive physical products for primates in zoos, often through a co-design approach, to explore how primates as users might interact [64]. The majority of these bespoke systems focus on the great ape species, e.g. systems that allow orangutans to play with touch screens [34, 49, 58, 67], projections that use motion tracking [62, 64] and feeding puzzles for gorillas [14]. Following this trend with great apes, systems have emerged for monkeys to play audio [47] and visual stimuli [17]. However, many of these systems are only used for several days/weeks before being abandoned by the primates once their novelty wears off [62] – relatively short when compared with the longer implementation of the screen devices in zoos as mentioned above.

Nonetheless, compared to great apes, monkey-computer interfaces and interactive enrichment devices remain under-researched. Furthermore, with computer systems for primates focusing on screen systems, most enrichment systems made for zoo animals are inherently visual. These visual systems require the primate to touch the screen [58, 67], use a stick as a stylus [14, 49] or be trained to use the system in a human-like manner to undertake tasks [10]. This is often motivated by food rewards [14, 58]. Considering this, many researchers who build systems for primates have suggested that the new wave of computer systems that provide zoo animals with enrichment must change drastically in terms of both usability and function [17, 64]. However, developing an interactive device with a function that an animal understands and desires to use long term is a complex matter [48], especially when creating new and novel interaction paradigms for primates [17].

2.1 Computers for Monkey's Choice

Predominantly, systems that give primates access to stimuli do not give them a choice regarding when or where to access the system or what the system does. Instead, stimuli are played in the animals' enclosures at scheduled intervals [43, 46, 50, 55, 61]. These devices are evaluated by measuring the primates' behavioural changes [43] or biological functions [46], as well as the experiences of the keepers and researchers [64]. Nonetheless, research has indicated that primates show a perception of self-agency with computer displays, suggesting that many primates share with humans the fundamental cognitive processes of being an independent agent [31]. This cognitive function implies that primates can discriminate when they have agency based on their internal aims and observed feedback; for example, they can judge whether they caused an action on a monitor or not [31]. As more research comes to the forefront that puts forward evidence of primates having self-agency with computers, there are more opportunities for them to control stimuli directly.

To exercises choice using touch screens, gorillas, chimpanzees and Japanese macaques have successfully used photographic representations on screens to order and indicate food preferences [26, 29].

For audio and visual based research, orangutans and gorillas have been given access to visual and audio stimuli where they can choose to turn on and off the system [49, 58, 62, 67]. These systems work by recognising when a user is in a certain space using proxemics (standing in front of the device) [46] or skeletal body tracking [62] and moving novel objects in the enclosure that they ordinarily use such as balls [48]. However, these studies – aside from being limited to great apes – are often limited in their amount of access time, inducing novelty in both the location and the device [23].

Considering this, scientists have made a video system for Japanese macaques [43] and video and audio systems for white-faced sakis [17, 47] that play different videos or audio clips when the monkey approaches the screen or enters the device. These systems have seen mixed results, but overall, they induce positive behavioural welfare indices [6]. With macaques, this system reduced abnormal behaviours and showed little evidence of habituation, where the monkeys' watching behaviours differed between contents [43]. Similarly, the sakis' watching behaviour also differed between content, with their scratching behaviour decreasing but becoming habituated to the system [17]. However, these enrichment systems only give the monkeys the choice between turning the stimuli on or off and not what content to access; they played only random [43] or pre-selected videos [17] or audio [47] when the monkeys trigger the system. As such, while these studies have made great strides towards investigating how monkeys can control when, where and what enrichment they access, no research has looked into how monkeys may choose between multiple stimuli at once. This limits ability of choice for monkeys currently to turning on and off a computer system.

2.2 Visual and Auditory Stimulus for Monkeys

Considerable effort has been put into researching how animals experience visual and auditory stimuli in captivity [32]. From the early 1970s onwards, researchers have investigated animal preference for stimulus [28].

For visual enrichment, when using screens, mandrill monkeys were found to be attracted by biologically relevant colours and shapes [33], leading researchers to speculate that monkeys are motivated by biologically-relevant social stimuli such as psychological factors [3], facial expressions and bodies and their movements [54]. However, recent work with white-faced sakis has shown that they prefer visual content of underwater scenes and worms rather than those of forests and other animals [17]. Blessmore et al. have also highlighted that macaques prefer to watch social stimuli over nature documentaries, which the authors call 'reality television for monkeys' [3].

Aside from visual enrichment, the use of audio for primates has long been proposed as a potential way of diversifying the environment of and providing sensory stimulation for zoo animals [65]. While only a few studies exist regarding interactive audio systems for primates [47–49, 58], the impact and potential benefits of audio enrichment for primates have long been studied with

variable and contradictory results [65]. Typically, audio played for primates has predominantly been either human music or naturalistic sounds [47, 58]. Yet, for monkeys, it has been suggested that using species-appropriate sounds as enrichment may be preferred. Using tamarin vocalisation-based music has shown to have a calming effect, while threat vocalisation-based music increase monkeys' arousal and movements [55]. Outside of bespoke audio, rain forest sounds caused an increase in agitated behaviours in gorillas in one study [42]. Another study, however, found that rain forest sounds reduced negative behaviours in gorillas, while classical and rock music increased negative behaviours [65]. Chimpanzees have preferred African and Indian music over silence [38], while white-faced sakis have sought heavy car traffic noise over silence, rain and electronic music [47]. Meanwhile, orangutans have preferred silence over music (like gorillas [58]) but did not discriminate between music and scrambled music, ultimately implying no preference at all for sound [49]. For gibbons, the presence of music had either no effect on their behaviour or, for some individuals, increased stress behaviours [61]. Looking deeper at the properties of sound, monkeys such as tamarins and marmosets have been found to prefer silence and slower tempos over fast ones [37].

Combining this myriad of knowledge in visual and audio enrichment, beyond only a few studies [17, 43, 47], little is known about how monkeys' would use enrichment devices to access different stimuli if they themselves had control over choosing when to use them and what content to play. It remains an open challenge to create systems that provide choice to monkeys (RQ1). Orangutans and chimpanzees (great apes species) typically prefer auditory interactions and bright colours [4], but it is unknown how monkeys would choose between different audio and visual stimuli (RQ2). As such, there is missing foundational knowledge on the preferences of monkeys regarding interactive computers.

3 PARTICIPANTS

All of the experimental procedures and methods described in this study were ethically approved by Korkeasaari Zoo and no pain or discomfort was caused to the animals in accordance with the European Act on the Protection of Animals Used for Scientific or Educational Purposes.



Figure 2: The inside enclosure with the tunnel system inside (top left) and the outside of the sakis' enclosure.

The monkey participants were three white-faced sakis (*Pithecia pithecia*), one female (p1, 11 years) and two males (p2 and p3, five and four years, respectively), living in the zoo in Finland, where

they were born. Sakis typically live to 15 years in their natural habitat but have been recorded to live up to 36 years in captivity [15]. Outside of captivity, sakis form groups of two to twelve individuals on average, making this group representative [56]. Sakis are medium-sized primates that live in extremely remote Neotropical areas, moving fast and silently through the rain forest canopy (typically high up in the canopy at 15–25 meters). Sakis travel for food and resources in the early morning and during the day when they are most active [11], foraging at low levels (3–15 metres). In their ordinary habitat, Sakis travel 0.5–1.25 miles in search for food every day, spending about nine hours on the move. They are adept leapers, making them able to avoid predators [15]. Sakis are extremely social, forming bonded pairs. Grooming and mating behaviours are often exhibited between males and females [11]. However, due to their elusiveness, sakis remain among the least studied primates [60]. Sakis have polymorphic vision, meaning that males have dichromatic colour perception, while females can have either dichromatic or trichromatic perception [12, 30]. In the zoo's current troop, all three monkeys have previously been tested and have been shown to have dichromatic colour perception [59]. Little is known about sakis' hearing other than they react to forest sounds and behave differently in response to the alarm and non-alarm calls of other monkeys towards prey species [1], indicating that they can hear well.

The habitat of the participant sakis is 80 square metres consisting of several rooms, both inside and outside, that are between two and six metres in height (Fig. 2). During the study, the sakis were able to move freely between these areas. The habitat contains artificial trees, hanging logs, branches, bark on the floor, plants and other enrichment artefacts (see Fig. 1, 2). At the time of the study, the sakis shared their habitat with pygmy marmoset monkeys and turtles.

4 DESIGNING INTERACTIVE SYSTEMS FOR CHOICE

To investigate how monkeys would use interactive systems to make choices and what stimuli they would choose (RQ1 and RQ2), we built an interactive device that the sakis could control and provided them freedom to choose what to watch or listen to. In designing this system, we considered how it could be used and controlled by the monkeys themselves directly, both as a research tool and as a system prototype. To ensure the sakis' welfare and make certain their needs would be met, we began by listing needs and requirements. We used the requirements formulated by Hirskyj-Douglas and Piitulainen for sakis [19], taking an animal-centred approach to make technologies that meet the sakis' and the zoo's requirements while also fitting our context. These requirements are that the system is not (R1) easily breakable, (R2) not frustrating and (R3) can be monitored [19]. We paired this with feedback and requirements from the zoo keepers.

To meet these requirements, we started with a tunnel form made with wood on the bottom and plastic on the top. This tunnel was tall enough for a saki to stand up comfortably inside and long enough to have three seating positions (usability). Plastic was used for the top of the tunnel form to prevent the sakis from feeling enclosed. This was also bite-proof due to concerns voiced by the zookeepers. Wood prevented the sakis from slipping (another concern from the

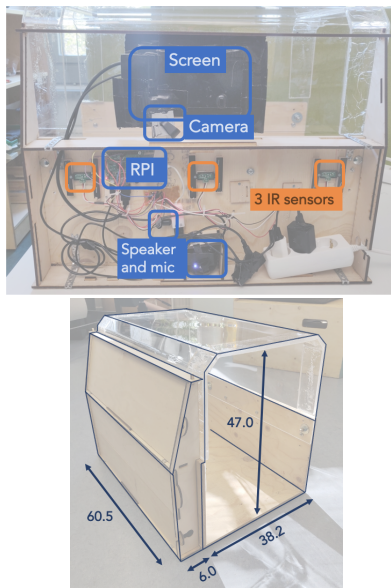


Figure 3: Hardware contents with the back panel removed and the size (in cm) of the interactive device.

zoo) and matched with the material already in their enclosure. We made a space for the technology behind the system’s wall and held it in a waterproof wooden box so that the sakis could not reach the technology, but the zookeepers could spray water at the system as they watered the enclosure. To reach this space, we made a sliding wall that could be locked with a carabiner clip that sakis could not open (again, this was bite- and chew-proof). In this way, we made sure that the device was saki-proof (R1) to meet this requirement. To implement the other requirements, we needed to make sure that the contents of the stimuli and the interaction mechanism were not frustrating (R2) and that ourselves and the zoo were able to monitor the sakis’ usage (R3).

4.1 Interaction Mechanism

Several approaches to forming an interaction mechanism for the sakis that have been done with primates before include tracking through gaze [53], head positioning [9, 69], posture [44], proxemics [17, 47] and physical touch screens [7, 34, 52]. Touch-based screens were an obvious candidate due to their proven track record with primates and ability to allow for a one-to-one mapping of visual stimulus and touch responses [27]. However, whilst we could train the sakis to use an interface (training to use touch-based screens) as the sakis did not ordinarily use screens as part of their everyday behaviour, due to COVID-19, the zoo wanted to limit the number of human–monkey interactions and did not want to use food rewards to balance their diet, which reduced our options. Buttons and tactile systems are recommended for primates [64]. However, buttons and touch interfaces have not previously been successful for sakis for unclear reasons; whether buttons do not work for sakis or the study design did not allow for enough data to be collected with tactile interfaces is unclear [32]. Gaze, posture and head positioning was ruled out due to there being no automatic recognition of these

factors with white-faced sakis. Building robust recognition systems for monkeys, as Witham [69] notes, is challenging under real-world zoo conditions due to changing lighting, partial obscuration, changing rotation of the face, the requirements of zoo keepers and time constraints. For monkeys in particular, recent work has made great strides towards using proximity as a promising suitable interaction method to collect data and facilitate them in controlling computer devices [17, 43, 47]. Furthermore, proxemic-triggered interfaces have been shown to improve sakis’ and macaques’ overall welfare and are influential on their behaviour [17, 43]. Thus, we chose proximity as the interaction method as it has been shown to work with our users and monkeys more widely [17].

To use proxemics, we embedded three infrared (IR) sensors to control the playing of different stimuli at any one time. These IR sensors make up three interactive zones (Zones 1, 2 and 3; Fig. 1). When the device detects a saki in one of the zones, the system displays either a video (only visual) on the screen inside the structure or plays audio. If no saki is detected, the system remains turned off (no sound or visual media is played).

The zone sensors are located below the screen at a height of 16.5 cm. The size of these zones was determined by the size of the sakis and their posture (i.e. the space a saki takes up when in front of the sensor’s beam). In this way, the system was designed to be triggered by the sakis’ everyday behaviours in their environment regarding their affordances.

4.2 Hardware and Software

The hardware of the system (Fig. 3) included Raspberry Pi 3 that controls a screen (7-inch HDMI LCD Rev2.1), a camera (Raspberry Pi Camera V2.1), speakers (XMI X-Mini II mini) and IR sensors (SHARP GP2Y0A41SKOF 4-30 cm).

The interactions were video-recorded using a camera within the enclosure and a camera within the system itself to monitor the sakis’ usage (Fig. 1). The system was powered through a cable enclosed in a metal tube across the top of the enclosure. This constant power avoided the necessity of daily maintenance (as is the case with batteries) by the zoo personnel to reduce their workload.

The software of the system was written in Python running on the Raspberry Pi. This controlled the delivery of visual and auditory stimuli clips (MPEG-4 and MP3) and the recording, tracking and processing of the input from the sensors. The software would detect the presence and the location (the zone) of a saki inside the device. When a saki was detected in a zone location, the software started playing the stimuli assigned to that zone while recording and logging information of the interaction (video played, time/date, length, stimulus triggered, zone triggered). This data was then packaged and saved both locally and online to allow remote access to the data in real-time. The device would give regular status updates to monitor any failures and errors in the system.

As the system is remotely accessible, software updates could also be made remotely, making such a system easy to modify and monitor without being physically present at the zoo. Due to these remote access capabilities, the device only required the zoo to install and plug in the system, resulting in minimal time for the zoo personnel and interruption to the sakis’ daily routine. The total cost of the

system (hardware, software, wood and plastic) was approximately 200 euros at the time of publishing.

4.3 Content of Stimuli

To build on prior work, we implemented audio and visual stimulus that was used previously with monkeys in Hirskyj-Douglas et al.'s study [17, 47]. The three audio stimuli used were rain, traffic and music. The three visual stimuli were worms, an underwater scene and abstract videos (see Fig. 4. Links are available in the appendix A). These stimuli were chosen as the audio stimuli had a strong variety of sounds, and the visual stimuli featured a range of different colours and movement speeds (sound spectra and vectorscopes of visuals provided in the appendix A). When each zone was triggered, the stimulus consisted of either video (visual only) or sound (audio only) to investigate the sakis' preference for each. These stimuli were chosen as they have no adverse effects on monkeys and are varied in sound and colour frequencies.



Figure 4: Stills of the videos played to the sakis: underwater, worms and abstract.

5 METHOD AND DATA ANALYSIS

The interactive enrichment device was used in the monkeys' living space for 32 days, being constantly turned on (24/7). To assess a saki's choice, we used the baseline method [21], which compares the animals' regular behaviours against their behaviours with stimuli and after stimuli. First, we gathered their initial everyday interactions with the system over a week (*pre-stimulus*), followed by eighteen days of interchanging cycles of auditory and visual stimuli (*stimuli*). After the stimuli period, we recorded the sakis' interactions to assess the after-effects (*post-stimulus*). This method of gathering *pre-stimuli*, *stimuli* and *post-stimuli* data has been shown to be valuable and viable across animal species to understand the effects of computer enrichment over the intervention life cycle before, during and after [17, 21, 47].

Different stimuli (either auditory or visual) provided on alternate days mitigates the order effect of the stimuli content, stimuli type and interactive zones and reduces habituation [57] (Table 1).

To determine for how many days to assign a stimulus to a zone (cycle length), we measured the frequency of the sakis' interactions with the device and its zones during the *pre-stimuli* week. We chose a week for pre-stimuli and post-stimuli as this recorded the sakis' usual routines over a long enough period to mitigate other variables (e.g. more zoo visitors on the weekends). The sakis had 60 zone activations, with each saki activating 2.9 zones per day on average. Based on this, we set the cycle length as three days, as this theoretically allowed each saki eight instances to trigger different zones to fully explore the system and its content. With the three-day cycle and three zones, both audio and visual stimuli conditions were turned on for nine days each (18 in total) to mitigate the ordering effect.

Over the study, there were no system failures. The process of the data analysis required three stages: (1) cleaning and verification, (2) coding and (3) comparison. During the cleaning and verification stages, we also labelled the data from each individual saki based on our video analysis, which allowed for both grouped and individual data. During comparisons of the study conditions, we used the grouped data.

At the beginning of the data analysis, the automatically collected data containing 166 zone activations was cleared of instances triggered by the other monkeys (pygmy marmosets) sharing the sakis' enclosure (nine activations). Consequently, 157 zone activations were further analysed using R Studio IDE software with external packages of Tidyverse (for data manipulation and visualisations; v1.3.0), rstatix (for Wilcoxon tests; v0.6.0), moments (for D'Agostino-Pearson's test; v0.14) and Kendall (for Mann Kendall trend tests; v.2.2). Data and R code can be found online <https://github.com/vilmakankaanpaa/sakicinema-bodytracking.git>.

We measured the amount of time the troop spent interacting with the device daily (*daily interaction time*) to investigate their preferences between conditions. First, the distribution of *daily interaction time* was tested for normality via a D'Agostino-Pearson's test (skew = 1.22, $z = 2.83$, $p = 0.005$; <0.05), which showed that values were highly skewed. Thus, we used a Wilcoxon rank-sum test (unpaired and two-tailed) to analyse whether the differences in *daily interaction time* between conditions were significant. The Wilcoxon rank-sum test was conducted between the three zones ($N = 18$ for each); between the *pre-stimuli* ($N = 7$ days), *stimuli* ($N = 18$ days) and *post-stimuli* conditions ($N = 7$ days); between audio and visual stimuli ($N = 9$ days for both); and between the stimuli contents of audio and visual stimuli ($N = 9$ days for each content). While the log-linear Bradley-Talor model (LLBT) has been used to assess preference in primates in prior studies, e.g. [26, 29], here, we did not use this analysis, as our data does not have enough instances and contains zeros.

As the sakis often triggered multiple audio or visual content within one session, we defined each individual trigger as a *zone activation* and several of these interactions within the same session as an *interactive period*.

Throughout this study, we utilised the participant-controlled method and let the sakis freely interact with the device as they wished, using the amount of interaction as an indication of preference to build upon prior work in zoos [17, 47]. However, the meaning of these preferences and their applicability towards defining monkey-computer interactions will be revealed within the discussion. The term *preference* here is used to differentiate between which audio or video the sakis triggered or which type of stimuli they used more. Likewise, the term *interaction* refers to the triggering of a stimulus via the sakis' presence within one of the system's zones.

6 RESULTS

The troop of sakis had an average of 3.6 interactive periods per day, each lasting around 5.1 seconds. Within an interactive period, they triggered 1.4 zones on average. On a typical day, the troop spent 18 seconds in total interacting with the device.

Table 1: Stimuli triggered during the study by day and zone.

	Pre-Stimuli	Audio	Visual	Audio	Visual	Audio	Visual	Post-Stimuli
	Day 1-7	Day 8-10	Day 11-13	Day 14-16	Day 17-19	Day 20-22	Day 23-25	Day 26-32
Zone 1	No stimulus	Rain	Abstract	Traffic	Worms	Music	Underwater	No stimulus
Zone 2	No stimulus	Traffic	Worms	Music	Underwater	Rain	Abstract	No stimulus
Zone 3	No stimulus	Music	Underwater	Rain	Abstract	Traffic	Worms	No stimulus

The amount of time the troop spent daily interacting with the system decreased over time; however, this decrease was not linear, following a zigzag pattern instead (Fig. 5). This pattern is formed by a few interactive periods that lasted longer than what was typical (e.g. 47 seconds on day 14 and 53 seconds on day 24), having a strong effect on the pattern in Fig. 5, which presents the total interaction time per day. Equally, the cycles that included days with a few longer interactions have a higher median and larger variation of the daily total interaction time (Fig. 6), with the median duration of single interactive periods remaining between 3.1 to 3.2 seconds for each cycle. Furthermore, a Mann Kendall test showed that there was no trend in the zigzag pattern ($p = 0.08, >0.05$).

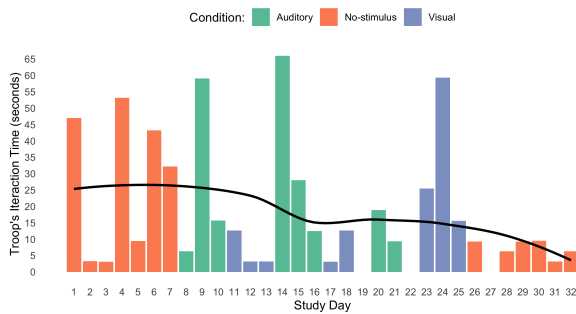


Figure 5: The time the troop spent interacting with the device split over study days with a trajectory line (in seconds)

The sakis interacted with the device only between 5 am and 6 pm, with a decrease in interactions around 11 am (Fig. 7). They interacted with the device primarily by walking or running through

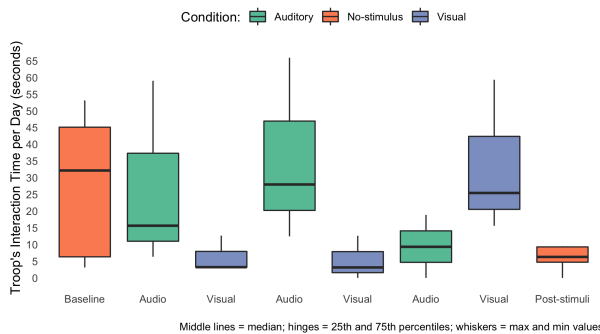


Figure 6: The time the troop spent interacting with the device per day split over conditions (in seconds).

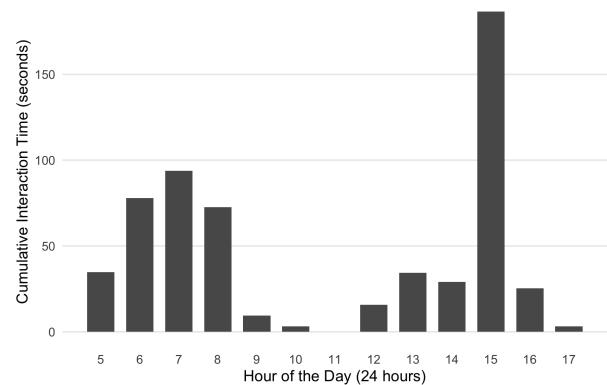


Figure 7: The cumulative time (in seconds) the sakis spent interacting with the device over the whole study at different hours of the day (24 hours). The sakis did not have any interactions outside of the presented hours.

it (71% of interactive periods were this interaction style). Sometimes the sakis paused with their back legs and tail still inside the device before continuing (26% of interactive periods). Three times they sat down on one of the sides of the structure (3% of interactive periods). Their style of interaction did not change over the study; these behaviours were consistent throughout the study.

Due to the sakis mostly interacting with the device by walking through the system, they activated the zones located in both ends of the device the most frequently (Fig. 1; Zone 1 = 62, Zone 2 = 13, Zone 3 = 82 interactions). When this behaviour occurred, usually the first activation zone a saki passed through at either end (Zone 1 or 3) was the only zone triggered (due to the minimum length of three seconds per stimuli). As a result, Zone 2, which was located in the middle ($M = 1.3s, SD = 1.7$), was used significantly less than Zones 1 ($M = 7.8s, SD = 12.8$) and 3 ($M = 10.4s, SD = 13.0$) located at the end/beginning (Zones 1 and 2, $p = 0.006^*$; Zones 1 and 3, $p = 0.13$; Zones 2 and 3, $p = 0.0002^*$; $* < 0.05$; Table 11 in the Appendix B). Furthermore, the sakis showed a slight preference for Zone 3 over Zone 1, possibly reflecting their usual direction of locomotion inside their enclosure.

Individual Usage

There were individual differences; P3 was the most active (interactive periods and interaction time, 2), P1 and P3 increased their interactions for stimuli over time and for P2, there was strong initial interest that declined in stimuli and post-stimuli stages (Table 2). The longest interactions were by P1 (47s) and P3 (53s) (Table

Table 2: Total interactive periods with the enrichment system by an individual monkey and under stimuli conditions. Time and duration are in seconds.

	Total					Total per day			
	Interactive periods	Interaction time	Mean duration	Median duration	SD of duration	Longest duration	Pre-Stimuli	Stimuli	Post-stimuli
P1	16	109	6.8	3.1	11.1	47.3	0.3	0.7	0.3
P2	36	180	5.0	3.2	2.3	11.6	3.3	0.6	0.4
P3	62	297	4.8	3.1	6.5	53.0	1.7	2.4	1.0

2). Nonetheless, most of the sakis’ interactive periods were short (median duration was three seconds for each monkey, Table 2).

Effect of Pre-Stimuli, Stimuli and Post-Stimuli

Table 3: The troop’s daily interactive periods during pre-stimuli, stimuli and post-stimuli conditions. Time and duration are in seconds.

	Interactive periods	Interaction time	Mean duration	Median duration	SD of duration	Longest duration
Pre-stimuli	5.3	27.3	5.2	3.2	2.5	11.6
Stimuli	3.6	19.5	5.4	3.1	8.3	53.0
Post-stimuli	1.7	6.3	3.6	3.1	1.2	6.4

The troop’s daily interactions decreased over the course of the study (interactive periods and interaction time, Table 3). However, the differences in interaction time between pre-stimuli ($M = 27.3s$, $SD = 21.7$), stimuli ($M = 19.5s$, $SD = 20.9$) and post-stimuli ($M = 6.3s$, $SD = 3.6$) were not significant (pre-stimuli and stimuli $p = 0.53$, pre-stimuli and post-stimuli $p = 0.07$, stimuli and post-stimuli $p = 0.13$; Table 7 in the appendix B). This result also indicates that the effect of the stimuli, presented by the difference between pre-stimuli and post-stimuli, was not major, implying that the option to trigger stimuli did not affect the sakis’ interactions with the system.

During the stimuli conditions, the sakis’ had a few longer interactive periods that led to a larger mean duration of interactive periods and greater variance compared with no-stimuli conditions (mean, SD and longest duration, Table 3). Most of the sakis’ interactive periods had the same minimum duration of three seconds (the median was three seconds for all conditions).

Audio vs Visual Stimuli

Table 4: The troop’s daily interactive periods comparing audio and visual stimuli conditions. Time and duration are in seconds.

	Interactive periods	Interaction time	Mean duration	Median duration	SD of duration	Longest duration
Audio	4.8	23.9	5.0	3.1	7.0	47.3
Visual	2.4	15.0	6.2	3.2	10.6	53.0

The sakis’ triggered audio stimuli twice as much as visual stimuli, which was also reflected in the time they spent interacting with the enrichment system during audio stimuli (interactive periods,

interaction time, Table 4). Yet, comparing the time the troop spent interacting with the device daily between the audio ($M = 23.9$, $SD = 23.3$) and visual stimuli ($M = 15.0$, $SD = 18.5$), the difference was not significant ($p = 0.18$; Table 8 in the appendix B).

Despite audio being more popular in frequency and total time, the sakis had a longer mean duration of interactive periods with visual stimuli (Table 4). The interactions with audio decreased over time, while the visual interactions increased over time (Fig. 6). Regardless, both stimuli types (audio and visual) had a few of these longer interactions (47- 53 seconds, Table 4). Most of the interactive periods were the minimum length of three seconds (median duration, Table 4).

Stimuli Content

The sakis triggered music the most frequently of all audio clips, with the total interaction time being twice as much as any other audio stimuli (Table 5). This higher value is explained by a few prolonged interactions leading to a higher deviation of duration for music audio (SD and longest duration, Table 5). However, the difference in the sakis’ interaction time between music and other audio was not significant (music and traffic $p = 0.43$, music and rain $p = 0.48$; Table 9 in the appendix B). Additionally, the median duration of interactive periods remained the same across all audio stimuli (3.1s, Table 5).

In terms of visual stimuli, the sakis triggered the underwater video the most frequently, with the total interaction time being two and a half times the amount of triggering of the two other visual stimuli (Table 5). Similar to the case with music audio, the underwater video was played longer on a few occasions than the other two visual stimuli. This resulted in the underwater video having a more significant standard deviation regarding the duration of interactive periods, while the median between the visual stimuli remained the same (longest, SD and median duration, Table 5). There were no significant differences between the visual stimuli content (underwater and abstract $p = 0.45$, underwater and worms $p = 0.43$; Table 10 in the appendix B).

Table 5: The troop’s triggering of audio and visual stimuli. Time and duration are in seconds.

	Audio			Visual		
	Music	Rain	Traffic	Abstract	Underwater	Worms
Interaction no.	24	15	16	9	12	8
Interaction time	112	52	51	28	81	25
Mean duration	4.7	3.5	3.2	3.2	6.8	3.2
SD of duration	6.1	1.2	0.4	0.0	12.6	0.0
Longest duration	32.1	7.7	4.6	3.2	46.7	3.2

7 DISCUSSION

In this paper, we used a novel computer enrichment device over several weeks to allow white-faced sakis to choose between audio and visual stimuli in their zoo enclosure. The findings on how sakis used this system are relevant in two domains: the first regards how we can build interactive devices for choice (RQ1), while the second regards what stimuli sakis prefer when given this choice (RQ2).

7.1 Monkeys' Interactions with Computers RQ1

The sakis' interactions with the enrichment device were mostly short, lasting only a few seconds and often being triggered by a saki walking or running through the system, sometimes pausing inside. Their short interactions and interaction times mirrored the animals' interactions in their everyday space, which has been seen as key for non-food enrichment [8]. Occasionally, the monkeys' interactions were longer, especially during the stimuli conditions, where the saki would sit inside the device.

Suggestion 1: Typically, monkeys have short interactions with computer enrichment systems.

The monkeys' interactions decreased towards the end of the study, declining rapidly post-stimuli, though not significantly. This decrease may indicate two things: the sakis became habituated to the device and/or the initial high number of interactions was the overall novelty-effect induced by new enrichment. Reflecting on novelty and habituation, Hirskyj-Douglas and Webber [23] have recently advocated plotting an animal's usage of systems over time, as we have done here. However, this plotting alone does not indicate how or what factors affected the monkeys and whether, in essence, the interaction was meaningful to them. Nonetheless, our findings unearth that computer enrichment has a long-lasting effect on the sakis' usage of the space even after the stimuli are removed. We propose that while novel computer enrichment systems in zoos may offer a temporary increase in the value of the environment for animals, there is a need to look at the after-effects to balance any temporary value with long-term effects to ensure overall welfare. This is especially essential in zoos where space is limited and at a premium [5]. Augmenting the enclosure itself (rather than something that can be removed, e.g. [62]) could have long-lasting detrimental effects on the animal's space usage. However, beyond this study, prior work has not measured the impact and after-effects of computer enrichment interventions on primates. This highlights a need to scope studies to pre- and post-stimulus to get a fuller picture of the effects and after-effects to ensure computer systems have positive, long-lasting benefits.

Suggestion 2: There is a need to balance the short-term benefit of novel computers for enrichment with monkeys against long-term effects.

7.2 Monkeys' Preferences for Visual and Audio Stimuli RQ2

While not significant, the sakis' daily interaction time over the test cycles followed a zigzag pattern (Fig. 6). While overall the results indicate that they showed more interest in audio stimuli, the frequency of them choosing audio – while initially triggered more – decreased, whereas interactions with visual stimuli increased over time. With most prior enrichment systems for primates being predominately visual (e.g. [46, 64, 68]), our findings highlight the potential of audio-based strategies in monkeys as well as visual ones and that monkeys interact with these modalities differently over time.

Furthermore, we speculate that the interaction modality of audio may have a simpler feedback loop over visual. In the study, the sound was instantly immersive, whereas the screen was placed to one side of the tunnel; to view the screen, the monkey had to direct their attention and position themselves towards the stimuli. Prior studies with visual-only interfaces with primates have balanced screen placements to reduce this variable [26, 29], but this is not possible across modalities. We propose that while audio is triggered more often by monkeys, this could be in part due to the system layout and audio as a modality being more easily accessible and immersive. More studies on visual placement and immersion are needed to investigate how they affect a monkey's affordance of enrichment.

Suggestion 3: There is no significant difference between monkeys choosing between audio and visual stimuli.

7.3 Computers for Choice with Monkeys RQ1

Overall, in this study, the troop spent less time inside the device than sakis spent with prior enrichment systems: six seconds per day each here, 560 seconds per day each for visual enrichment [17] and six seconds per hour each in audio enrichment [47]. The prior studies afforded the monkeys the choice of turning the system on/off, but not the choice between options. This difference in usage indicates that when building interactive systems for choice, a binary on/off system is preferred by sakis over a system where they can choose between multiple options. Additionally, in this version of the system, the monkeys did not sleep inside the system as they had done prior in [17, 47]. Reflecting on this system as one for choice, the usage of the zones indicates that the sakis did not learn to use the individual zones. As such, from the sakis behaviour and interactions, we deduce that having three zones based on space usage does not work for sakis with regard to choosing between stimuli content. Instead, we put forward that future choice systems for monkeys need to account for their everyday walk-throughs and other typical behaviours to allow for the mobility and physicality of monkeys.

Taking the approach of interaction time as a measurement of preference is a frequent procedure in animal-computer enrichment systems [10, 17, 21, 47, 51] and was built upon in this research. Nonetheless, this approach comes with the assumption that the longer or more frequent the animals' interactions are, the more meaningful and engaging the system is. Especially for systems for

choice, more weight is placed on the animal's decisions as measures of intent [26]. This is indicative, as we as humans expect that if animals benefit from interacting with a device (especially when given the freedom to do so), they will exploit the opportunity and use the device for more extended periods and more frequently. Yet, as our data proposes, while usage time gives an indication of an animal's choice, it does not comment on their quality and experience of the interaction. To peek into an animal's user experience and meaning-making, many researchers use their own experiences, as well as animal behaviour specialists and trainers, to make guesses (as humans) through subjective behavioural analysis [51, 62, 66, 70]. This interpretation is based on the assumption that all animals, including us, co-exist somewhere on the same spectrum of understanding when interacting with computer systems [41]. Indeed, in animal cognition, a large area of research involves employing touch screens to investigate an animal's agency and cognition on multiple levels [28]. Yet, it is conceivable that an animal's spectrum of understanding (when interacting with computers) may be far removed from, or noncomparable to, the spectrum of humans or may be on another dimension altogether. As such, it could be that the measures we use to evaluate an animal's user experience and the quality of interactive devices for choice are beyond our own grasp. This would make our trials in trying to understand and measure a monkey's interactions beyond something that we can really succeed at as we cannot adequately observe nor quantify their experiences. Thus, while the work here found that monkeys can use systems for choice autonomously when given the opportunity to do so, more work is needed to bridge this with the human understanding of how animals access and experience computer systems to identify objective measures of engagement. By working towards what meaning and relevant experiences a monkey can have with computer systems, we can begin to understand their usage patterns and how to design devices for them. This in turn applies to all animal-computer systems where the end goal is to enrich animals' lives and well-being [20].

Suggestion 4: New methods are needed to measure an animal's meaningful engagement and interactions with computers beyond frequency and timing alone.

Reflecting further, as the system in this study gave monkeys access to stimuli when they chose, it provided them autonomy and agency over their lives – a rarely held commodity in a zoo animal's toolkit. While, as humans, we do not fully understand to what degree a monkey understands this agency, the monkey's usage of the system indicates that they did control it. However, it could be possible that the act of triggering the stimuli told more stories about monkeys' use of computers than the preference for content. The monkeys could have triggered the device and used the system to exercise their agency and choice rather than play the content. As so few systems exist that give primates (or animals more broadly) control over their lives, we cannot comment on what system factors caused the monkeys to trigger stimuli or how having the option of choice impacted their interactions.

Suggestion 5: Having a choice could influence the monkeys to use systems for exercising the option rather than for the enrichment they provide.

7.4 Lessons from ACI to HCI

It remains unspecified what interactivity means for zoo animals [41]. While we begin to uncover what systems for choice look like for monkeys, how they learn and choose and their understanding of their interactions, many unknown factors remain. Part of building and designing systems with and for animals (and humans in HCI) is recognising what we don't know and taking small steps to acknowledge that another user's experiences may be beyond our own. The small advancements couple together to tell stories about how users use computer systems and, in this paper, how a monkey may use a system for choice when given the opportunity to do so.

Nevertheless, there remain difficulties and knowledge gaps in how users beyond our vantage experience create meaning from interactive systems and what a user can perceive as possible in using a computer system. In HCI, these aspects of interaction are encompassed in the theoretical framework by Norman [40] as 'the gulf of execution'. This gulf is the ease with which a user can understand the current state of a system and in essence the difference between the intentions of a user and what the system facilitates the user in doing. In this paper, while we captured users' interactions, the gulf of execution remains unknown; what a monkey experiences with a computer system, their understanding of how it works and what meaning they derive from it are unclear. These knowledge gaps regarding creating systems that are usable for users are some of the main difficulties in working with users who give feedback and communicate in different manners.

For the HCI community, this paper has taken a standard approach to interaction times, designed interaction devices and adapted this to non-human users. This method alteration is common when working with certain human users, such as in child-computer interactions and with those with special abilities. We have learnt from animal-computer methods here for HCI by using requirements for non-verbal users to create and investigate interactive systems using typical interaction design principles. This method paves new ways for designers to think about interactive systems, forcing us to investigate beyond our own biases and uncover ways of developing more inclusive technologies.

8 LIMITATIONS AND FUTURE WORK

Due to the limited number of participants (three), having a small sample size restricts the findings within their place and time and the analysis we were able to use, although this troop size is still representative. While it would have been ideal to incorporate more study participants and a control group, these are simply the limitations of working in a living zoo environment. In future work, we plan to test these systems with different monkeys in other zoos to make further generalisations regarding monkey-computer interfaces and species differences. As animal minds are not blank slates, recent work has highlighted personality dimensions in primates affecting their free choice (individuals with high openness and low

assertiveness engage more) [39]. Personality dimensions could be another factor of future research on stimuli preference.

It is unknown how much the monkeys understand their interactions and how they learn to use computer-enabled devices that trigger stimuli with systems for choice; for the sakis to choose between multiple stimuli, they have to understand that different options exist. Furthermore, to understand how to trigger certain stimuli, the monkey has to understand the feedback loop to some extent (that different zones trigger different stimuli). Though necessary for experimental parity, changing the zones of the stimuli across phrases could have hindered the sakis' learning.

Reflecting on our interaction design decisions, without prior examples, we made some decisions that influenced the monkeys' learning and understanding to gain an idea of (1) how many occurrences of interactions the sakis needed to have to learn that a zone was associated with the presence of stimuli, (2) how many zones and thus choices the sakis had and (3) what the *minimum duration* that the stimuli should play for was. To assist the animals' learning of using systems, we suggest that future systems for choice with zoo animals should play around with these three factors. For instance, as the sakis mostly used the outer zones (Zones 1 and 3) a two-zone binary choice would be more suitable in the future. To further support this, while we involved the zoo keepers and the zoo's research director (an expert in animal behaviour), we could involve primate behaviour specialists to add further nuance to the results.

Looking at the sakis' usage of the system, pre- and post-stimuli provided a way to see a bigger picture of how computer stimuli impacted their lives beyond the usual study remits. However, we speculate that our method of collecting data (presenting the device to the monkeys without it being interactive by playing audio/visual stimuli) may have disorientated the monkeys' understanding of the system and that it triggered events. In essence, each monkey had to re-discover the system and its interactivity when, to them, nothing physical had changed within their enclosure to give them an indication of the change. As each monkey's initial interactions are often exploratory, these early investigative behaviours may not be repeated once the system becomes interactive. Thus, there is tension when creating systems for animals that offer autonomy and agency that arises from having comparable data while also using the animal's initial investigative behaviours to assist them in learning about the interactivity of a system.

9 CONCLUSION

The idea of giving animals choices and the freedom to access computer systems when and where they want to improve their welfare in zoos is not a new concept. However, beyond touch screen devices, computers have yet to be implemented with monkeys with regard to choosing between multiple options. In this paper, we explore with white-faced sakis how we can build interactive devices for choice and what preferences monkeys have for audio and visual stimuli when given this choice. Studying one troop of monkeys over several weeks, we implemented a device that automatically captured, measured and recorded the monkeys' usage and the choices they made between three different visual and audio stimuli. Analysing the results, we found that monkeys triggered audio twice as much

as a visual stimulus, though non-significantly, pointing to the need for more audio-based devices for primates. Furthermore, measuring the monkeys' activity with the device pre- and post-stimuli helped build a larger picture of how the stimuli affected the monkeys and the impact of the enrichment system. The fact that the monkeys used the space significantly less after the stimulus was stopped highlights the need to balance any short-term benefit gained from computers with long-term space use to prevent mitigating the animals' welfare. Regarding this, our method provides one way to measure a monkey's choice. Yet, looking at our data in context highlights a need for measuring engagement beyond frequency; we postulate that the act of having choice itself could influence the monkeys' using of the system for this choice alone rather than the stimuli. As computer devices for choice weave further into zoo enclosures to facilitate animals having agency, it is imperative to determine how these devices augment an animal's life and the impact their use will have. By looking at how to build interactive devices for choice and how monkeys choose, we draw and engage in a new understanding of what computers for choice mean for monkeys. This conversation inherently pulls at threads of how humans use computers, bringing new understanding to how we look, build and engage with computers and use devices to make choices for animals and humans alike.

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A APPENDIX

Table 6: Visual stimuli used.

Video	Details	Source
Worms Visual 1	Cut of 18 s	https://www.pexels.com/video/earthworms-burrowing-under-the-compost-soil-3046307/
Worms Visual 2	1:18 - 1:21	https://www.youtube.com/watch?v=ux3vd0zlg78
Underwater Visual 1	Cut of 14 s	https://www.videvo.net/video/school-of-barracuda/4072/
Underwater Visual 2	Cut of 18 s	https://www.pexels.com/video/a-group-of-jellyfish-swimming-underwater-at-display-in-an-aquarium-3297378/
Abstract Visual 1	Cut of 10 s	https://pixabay.com/videos/tunnel-wormhole-abstract-art-43781/
Abstract Visual 2	Cut of 20 s	https://pixabay.com/videos/tunnel-yellow-abstract-background-12904/

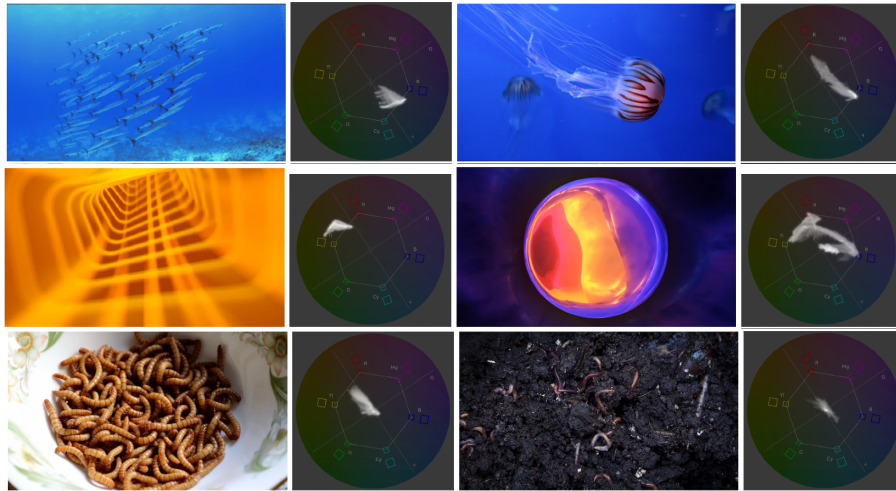


Figure 8: Stills of the videos played to sakis including Adobe Premier Pro vectorscope of hue and saturation. Rows 1: Underwater video, 2: Abstract video, and 3: Worms video. (Source: [17])

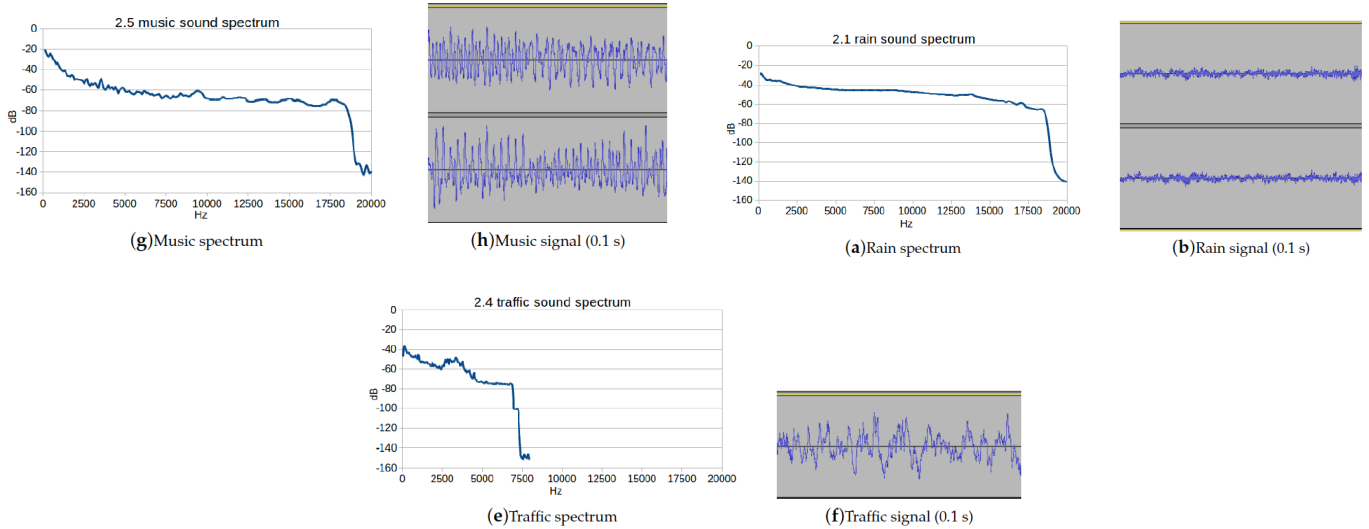


Figure 9: Spectra of audio stimuli. (Source: [47])

B APPENDIX

The statistics and results for Wilcoxon rank-sum tests used to assess the significant differences in sakis' interactions between different conditions. The tests were conducted using R Studio IDE software using the library rstatix (v0.6.0).

Table 7: Wilcoxon rank-sum test comparing the sakis' daily interaction time between stimuli conditions.

Condition 1	N	Mean	SD	Condition 2	N	M	SD	Test	W	p-value	Effect Size	magnitude
Pre-stimuli	7	27.3s	21.7	Stimuli	18	19.5s	20.9	two-sided	74	0.53	0.13	small
Stimuli	18	19.5s	20.9	Post-stimuli	7	6.3s	3.6	two-sided	37	0.13	0.43	moderate
Pre-stimuli	7	27.3s	21.7	Post-stimuli	7	6.3s	3.6	two-sided	33	0.07	0.36	moderate

Table 8: Wilcoxon rank-sum test comparing the sakis' daily interaction time between stimuli.

Condition 1	N	Mean	SD	Condition 2	N	M	SD	Test	W	p-value	Effect Size	magnitude
Audio	9	23.9s	23.3	Visual	9	15.0s	18.5	greater	51.5	0.18	0.23	small

Table 9: Wilcoxon rank-sum test comparing the sakis' daily interaction time between audio stimuli.

Condition 1	N	Mean	SD	Condition 2	N	M	SD	Test	W	p-value	Effect Size	magnitude
Music	9	12.5s	18.3s	Traffic	9	5.7s	5.0	greater	43	0.43	0.05	small
Music	9	12.5s	18.3s	Rain	9	5.8s	7.2	greater	41.5	0.48	0.02	small
Traffic	9	5.7s	5.0	Rain	9	5.8s	7.2	two-sided	39.0	0.93	small	

Table 10: Wilcoxon rank-sum test comparing the sakis' daily interaction time between visual stimuli.

Condition 1	N	Mean	SD	Condition 2	N	M	SD	Test	W	p-value	Effect Size	magnitude
Underwater	9	9.1s	17.4s	Abstract	9	3.2s	3.2	greater	42.5	0.45	0.04	small
Underwater	9	9.1s	17.4s	Worms	9	2.8s	3.3	greater	43	0.43	0.05	small
Abstract	9	3.2s	3.2	Worms	9	2.8s	3.3	two-sided	43	0.86	0.05	small

Table 11: Wilcoxon rank-sum test comparing the sakis' daily interaction time between interaction zones.

Condition 1	N	Mean	SD	Condition 2	N	M	SD	Test	W	p-value	Effect Size	magnitude
Zone 1	18	7.8s	12.8	Zone 2	18	1.3s	1.7	greater	238	0.006	0.42	moderate
Zone 1	18	7.8s	12.8	Zone 3	18	10.4s	13.0	less	125.5	0.13	0.19	small
Zone 2	18	1.3s	1.7	Zone 3	18	10.4s	13.0	less	51.5	0.0002	0.6	large