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Develop Interactive Digital Enrichment for captive Capuchin monkeys that fosters their species-natural foraging behaviour and maintains their interest

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ABSTRACT

Compared to animals in the wild, animals in captivity do not have the same conditions of learning that nurture species-specific skills which are needed for their wellbeing due to less complex, stimulating and highly predictable environments in the captive settings. In order to bridge this gap and to reduce the negative effects of captivity, modern zoos provide enrichments to the animals that stimulate them socially, mentally and physically. Intelligent species, such as capuchin monkeys, can become accustomed to enrichments quickly, and once they have figured out the enrichment, they don't like to return to interact. These neo-tropical species prefer to stay indoors during the sub-zero winter months, while the lack of rich enriching habitat indoors breeds boredom and frustration them. This project therefore, aims to develop non-food based interactive digital enrichments for captive capuchin monkeys that promotes their species-specific natural foraging behaviour in indoor conditions and maintains their interest to interact and have a dialogue with the enrichment.

The project employed an iterative animal-centered co-design approach with the animal, animal welfare expert, caretakers and HCI design expert as stakeholders. The choices and preferences of the animals were considered using the caretakers as proxies. The project delved into the foraging behaviours of the capuchin monkeys, the factors that maintain interest in enrichments and other previous works of animal-centered methods that gave animals control over their environments through digital enrichment. Following ethical consideration to minimise harm for the animals, the final non-food based prototype that stimulated natural foraging behaviour of capuchin monkeys by producing lights and sounds of prey when interacted with was tested with white-faced capuchins at Apenheul Primate Park. Preliminary findings show that the animals were interested and displayed myriad foraging behaviours to interact with the device. Signs of frustration in animals over time when nothing came out of the device was also witnessed. It is plausible that digital interactive enrichments can be a potential form of engagement for the animals when coupled with small tangible rewards. However, due to the nature of the study, concrete conclusions cannot be drawn. This study is a significant step for a broader evaluation of digital enrichments for the capuchin monkeys, a small step towards understanding the capabilities and preferences of capuchin monkeys and a proof of concept for designing interactive digital enrichments in the future.

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1 INTRODUCTION

Capuchin monkeys, native to Central and South America, are known for their intellect, wit, and very dynamic behaviour, and are quite popular among scientists and public [1]. They have the biggest brain sizes with highest level of social intelligence amongst the New World Monkeys[2]. They have been documented to use myriad ways of tool use to get to foods that are not so readily available such as exploring into small crevices with modified sticks [3], extracting palm nuts through a series of sequential actions, catching oysters in low-tide[2] and many more. They live in societies with strict social hierarchies[4] and rely on social traditions passed down from generations to develop their unique foraging abilities[3].The social structure helps younger capuchins to learn the skills from their close associates through scrounging where there is significant tolerance to share food [3, 5]. Their tenacity and wit coupled with their societies that support scrounging have helped them to live in diverse range of habitats [2]. Unfortunately, today, many capuchin species are highly endangered because of habitat loss caused by human activities and the pet trade [2, 6].

Modern zoos and aquariums around the world offer safe habitats, nurturing and care for several endangered plant and animal species whose natural habitats are on the decline like the capuchins [7]. They also serve as centres for scientific research, conservation, education and recreation[8]. Although they provide naturalistic surroundings for animals to thrive, it is not always enough to excite their mental, social, and physical senses as in the wild [9], where they develop species-specific talents(cognitive, explorative, problem-solving, learning, spatial awareness), that ensure their survival and wellbeing [10–12]. Also, animals in captivity, have less complicated and more predictable environments aiding to less agency[12]. Therefore, animals are given *enrichments(*environmental, sensory, cognitive, nutritional, social) [13, 14], preferably mimicking their natural behaviour as much as possible [15], , to reduce the negative effects of captivity and stimulate similar opportunities as in the wild [16]. Enrichments give animals more freedom and choice over their environments, provide animals more autonomy and control over their surroundings, enhance their coping and knowledge acquisition skills, elevate their ability to deal with stress and learn new things, and hence improve their general health[17, 18].

Some zoos, such as Apenheul Primate Park, are closed to visitors during the winter months. The animals have access to outside enclosures unless the temperatures are below freezing. However, due to the lack of vegetation, the outside enclosures offer less exploration in winter than in spring or in summer[19].Non-native species that cannot adapt to freezing temperatures, such as the South American primates, are kept in controlled, closed environments to minimise seasonal changes [20]. Long durations of confinement indoors can result in animals developing aggressive and self-directed behaviours due to boredom[21, 22].

To mitigate the negative effects, enrichments pertinent to a particular taxon to challenge them in ways that are crucial for their welfare and wellbeing in enclosed environments are utmost necessary[16]. However, it is more challenging to provide enrichments to species with higher intelligence such as primates (capuchins) since they figure out the working of enrichments quickly and do not wish to interact with the enrichment device further, unless there is a reward attached[23].

Food rewards like fruits which have more sugar compared to wild fruits are discouraged by the zoo community to prevent obesity in captive animals[1]. Capuchins uphold a rigid social hierarchy like most primates, so highly desired food rewards are typically primarily available to those in the highest rank while the lower ranked individuals are devoid of the preferred food without the manual intervention by the animal caretakers[1]. Also, according to Apenheul animal welfare expert, "*the animals are repeatedly provided the same 'enrichment, and thus do not profit from the extra work put into food 'enrichment'. Furthermore, during winter time for capuchin species, when there is less vegetation (or insects) to forage, there is a need to find a way to keep their environment interesting for them to explore*". Thus, other intrinsic rewards such as satisfaction after completing the task are a preferred direction[24]. This presents a significant problem for the caregivers because they must always come up with new enrichment ideas and adaptations to keep the animals interested [1].

Digital enrichments have many advantages over traditional enrichment since they are easily adaptable and thus can be re-programmed to decrease habituation and bring in novelty [16], can cater to individual animal's preferences and can be easily tailored to age, gender, and species-specific individual preferences [25]. Furthermore, Animal-Centered Interaction(ACI) technology is also creating a huge impact in addressing welfare for animals by providing choice, control and relative freedom to them[12]. ACI technology is an interactive technology developed that is centered around animals using the User- Centered-Design (UCD) approach. The premise of ACI technology is that the characteristics, needs, and desires of the animals involved and the environments in which interactions occur, directly influence design processes and outcome generating a holistic enrichment for the animal[25].

One of the works based on ACI technology is "Kinecting with the orangutans"[14] which involved multiple games for orangutans using interactive projections at the Melbourne zoo. This included an ACI technology-based co-design approach [14]. Co-design entails learning directly from animals about their desires and requirements through observation studies and follow-up interviews and design sessions with zoo employees who are a proxy to the animal [14, 26, 27].

This project is a collaboration between the University of Twente and Apenheul Primate Park. Apenheul currently has two species of capuchin monkeys – the white-faced capuchins (WFC) and the yellow-breasted capuchins (YBC). The project seeks to produce a holistic digital enrichment for both these species that engages them while fostering their species-natural behaviour, drawing inspiration from the above mentioned ACI technology-based project -working with interactive projections as digital enrichment for orangutans [14]. The input of the proxies is limited to focus groups, joint observations, and post-intervention interviews due to the scope of this project and the time available from the caretakers. The project is explorative and iterative in nature broadly divided into lo-fidelity prototyping and experiential prototyping.

1.1 RESEARCH QUESTIONS

The primary research question of the project is:

> **HOW CAN WE DESIGN AN INTERACTIVE DIGITAL ENRICHMENT THAT IS ACI BASED, FOR CAPTIVE CAPUCHIN MONKEYS, THAT FOSTERS THEIR SPECIES NATURAL FORAGING BEHAVIOUR AND MAINTAINS THEIR INTEREST TO HAVE A DIALOGUE ?**

The secondary questions that help understand the context of this study are as follows:

1. *What constitutes the natural foraging behaviours of capuchin species?*
2. *How can prior work on interactive digital enrichments be applied to capuchin monkeys in captivity at Apenheul?*
3. *What factors of an enrichment maintain interest among captive capuchin monkeys?*
4. *How can the design process be animal-centered?*
5. *What is an ethical way of designing for the capuchin monkeys?*

In this project, maintaining interest refers to motivation to come back to explore and manipulate objects in their environment [28].

The above-mentioned research questions will be answered in two parts- (1)theoretically and (2) practically.

Chapter 2 covers Literature review summary and forms the basis for answering RQ1-4 theoretically. In this chapter, the foraging behaviours is detailed in sec. 2.1.4.1, which answers RQ1. RQ2 requires background on digital works which is detailed in sec2.2.1. Furthermore, sec. 2.2.3 elucidates the factors pertaining to maintaining interest in enrichment which answers RQ3. Sec. 2.2.2 delves into ACI based design methods. And finally, the ethics is covered chapter 4 which helps answer RQ5 theoretically.

After gaining the understanding of literature, the research questions will be further answered practically for the capuchin monkeys at Apenheul with the results and findings from the lo-fi and final prototype(s) detailed in chapters 6,10.

1.2 STAKEHOLDERS

The project involved inter-disciplinary collaborations from University of Twente and Apenheul (see Figure 1). The stakeholders primarily included the researcher and Human computer interaction technology supervisor from University of Twente; and Animal welfare expert and Animal caretaker department from Apenheul. Other departments, such as Apenheul' s technical team and nutrition eam, were consulted as needed over the duration of the study.

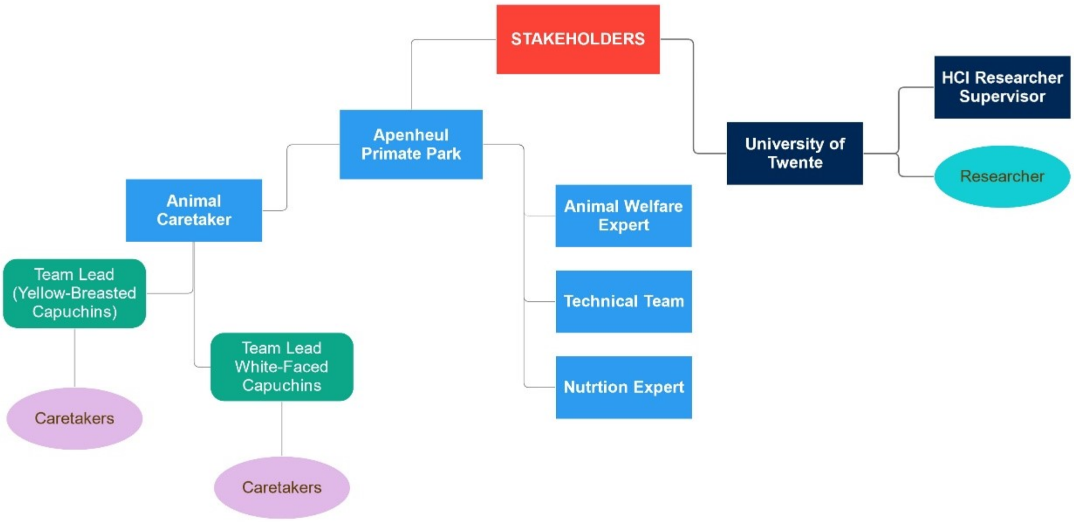

Figure 1: Stakeholders in the Project

Their background and specifics are as follows:

- *Animal welfare expert and Behaviour biologist:* Experience with research of and observing novel enrichments/interventions; experience with behavioural observations and primate behaviour.
- *Animal Caretaker Department*
    - Team lead (White faced capuchins), Team lead (yellow breasted capuchins)
    - Two Animal caretakers experienced with making enrichments for monkeys and apes, orangutans and Gorillas at Apenheul
- *HCI Researcher supervisor*: Experience with HCI studies with people with special needs and (young) children
- *Researcher* – Master thesis student

Going forward, this report will first focus on literature studies that encompass the topics mentioned above. This is followed by understanding the animal context in Apenheul and redefining the goals and objectives for the project in chapter 3. Before working with animals directly it is also vital to discuss the ethical considerations in place, which are addressed in chapter 4. In chapter 5, initial concepts are outlined, and in chapter 6, low-fidelity prototypes are testing is detailed. Based on the results obtained, an experiential prototype is designed and evaluated (chapter 7, 8, 9, 10). Finally, discussion and conclusion of the project is discussed in chapters 11 and 12 respectively.

2 LITERATURE REVIEW SUMMARY

To answer the research questions, it is first important to look into literature to discern the capuchin monkey- its senses, behaviour, skills, mental operation and also its limitations. This chapter therefore highlights the most significant capuchin monkey-related literature useful for this thesis project. In addition, this chapter focuses on earlier efforts on digital enrichments for primates, animal-centred design methodologies, and literature studies that focus on factors that keep enrichments interesting for animals. Most parts of this chapter are taken from and a more extensive literature review that has been detailed in the previously graded Research Topics Document of this project.

The focus of this project is limited to two capuchin monkey species – (1) White- faced capuchins (WFC) and (2) Yellow-breasted capuchins (YBC), which are also the species housed in Apenheul and the participants of this project.

2.1 THE CAPUCHIN

Among the two species, the YBCs are smaller with shorter limbs, tails, skulls, and jaws compared to their WFCs counterparts. They weigh an average of about 2.7kg while the WFCs weigh about 3.3kg[29]. They are more robust and spend less time on the ground. Both species are aerial, quadrupedal, and bipedal for brief periods, possess semi-prehensile and functional tails. However, the YBCs are more bipedal, have longer tails and are less terrestrial than the WFCs [30]. Furthermore, WFCs are viewed as extremely brash, obnoxious, tough, and disruptive while the YBCs are more gentle in comparison[2].

2.1.1 Food Habits

The food they eat depends on where they live and the time of year, but it is usually 50–80% fruit, 20–30% animals, and 10% other plants. The capuchins eat fruits, seeds, nectar, pith, stems, nuts, berries, flowers, and leaves, as well as bird eggs, insects, larvae and pupae, frogs, and small reptiles, birds, bats, and other small animals found in coastal environments [2].

2.1.2 Social Hierarchy

Capuchins are communal and social. Groups range from 10 to 27 (or more) individuals. The size of the group is determined by food availability. The sex-ratio favours females, however, it varies by species[1]. It is found that WFC females spent more time around and affiliated with females than males. Females establish a stable dominance social hierarchy[31, 32]. Males are often dominant but the order revolves around the females [32].

2.1.3 Body

2.1.3.1 Hands

Due to their pseudo- opposable thumbs the capuchin monkeys have developed both precision and power grips meaning they can grasp objects firmly using the entire palm in the case of power grip(Figure 2) and can also grasp smaller objects by using only their fingers – precision grip (Figure 3).

Figure 2: Power grip in capuchins. Photographs by V. Truppa and L. A. Marino, EthoCebus project[33].

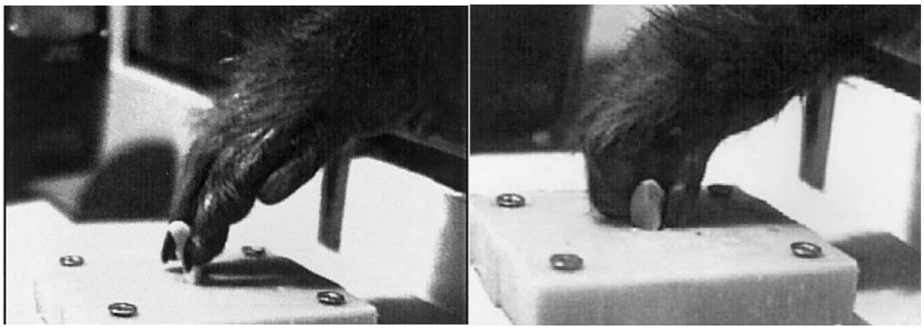

Figure 3:Precision grip in capuchins[34]

2.1.3.2 Vision

Capuchins have dichromatic and trichromatic vision. Individuals with trichromatic vision can see all colors like humans do while individuals with dichromatic vision are red-green colorblind. Generally, the females have the trichromatic gene while the males do not. In relation to this color differentiation, the fruit preference of capuchins is yellow, brown and orange[2].

2.1.3.3 Auditory Sense

They have a keen sense of hearing. They are most responsive to sounds between 7 and 10 kHz while having an auditory range between 1 and 45 kHz. They respond more to natural sounds than man-made sounds [29].

2.1.3.4 Tactile sense

The capuchins are very perceptive to both pressure and friction because they have many receptors in their skin and around the hair follicles, of their palms and soles [2]. YBC's haptic sensitivity is comparable to that of humans when differentiating food from non-food things using only touch and no sight or smell. The exploration is restricted to the graspable region, but the conclusion is comparable to that of humans[2].

2.1.3.5 Motor Skills

The capuchin monkeys demonstrate *combinatorial behaviours* by rubbing a fruit against a wall (first-order) or cracking a palm nut (second-order) (Tool Use, p. 9)[35].Zero-order relations refer to acting directly on the surface with the body, first-order to combining one thing with another, and second-order to combining one object with two others. These animals' strong hand-eye and hand-hand coordination allow them to manipulate food or utilize tools to extract complex items(See Figure 4) such as oysters, clams, palm-nuts, etc. by hitting or pounding [2, 36].

Furthermore, they can insert one cup into its spot in the midst of numerous serially ordered cups, demonstrating mastery over precision and pattern recognition [2].

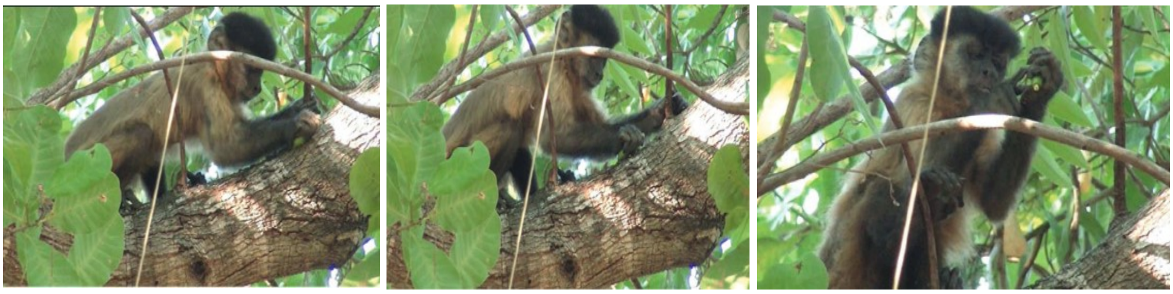

Figure 4:An adult female capuchin rubs a fresh cashew nut pod against the tree bark and uses her index finger to extract the kernel from the breached pod. Photographs by M. J. Fonseca de Oliveira, EthoCebus project. [33, 37].

2.1.3.6 Memory and perception

In short term memory studies, it has been shown that capuchin monkeys can remember objects or two-dimensional images they saw or heard many minutes ago. They can also recall where they were when a key event took place, even if it occurred in a different time and place[2]. They can respond better to visual stimuli[38] with delays as compared to matching auditory stimuli[39]. In long term studies, it has been revealed that the capuchins have strong long-term memory recollection up to years [40, 41]. Furthermore, they can arrange shapes in decreasing or increasing order [42] and can easily learn and implement transitive relations for a series [43]. When they see a branch, for example, they imagine it to be a part of the entire tree, even if the tree is not visible and so perceive parts as whole. They can also forecast the linear movement of the ball's position[2].

2.1.4 Behaviours

2.1.4.1 Foraging

Foraging behaviour is defined as seeking and finding food[44]. As mentioned (sec. 2.1.1), capuchins diet is diverse. Capuchins obtain protein and energy from eating fruit and insects. They spend nearly

50% of their time searching for food and insects or other small prey hiding beneath the leaves and within the branches' cavities[30].

Furthermore, food is sparse in the Neotropical jungles where capuchins reside. Favourable foods such as figs are only available in the rainy seasons between June and November. During the dry season, capuchins, thus, seek complex foods such as plants with spikes or thorns, nuts with hard shells, insects, beehives, wasps' nests, bird nests, army ants, termites, and small vertebrates [1]. In the dry season, it was found that a tufted capuchin consumed more than 60% animal matter in the form of ants and termites[45].

2.1.4.1.1 Foraging behaviours

Capuchin monkeys employ multiple techniques to forage for their food[2]. They rub the food against the branches(See Figure 4 and Figure 5), seek ripe fruits(Figure 6) and hunt small prey(Figure 8), search on ground and trees for insects(Figure 7), open tree barks for termites and insect larvae(Figure 9), use tails to access water in tree holes [46] (Figure 6) and even use stones to dig up roots[47]. They are thus known as extractive, destructive, arduous, extreme, and ingenious foragers with strong jaws that can bite, explore, and break tough surfaces [35, 48]. Furthermore, capuchins are persistent and determined to succeed at foraging, regardless of how long or unpleasant the process may be. When uncertain how to proceed with novel foods, capuchins pound and inspect them[29].

Figure 5: Capuchin monkey opening clams at low-tide[49]

Figure 6: (a) Capuchin monkey foraging for fruit)Photo by Alexa Stickel [50]*). (b) Capuchin getting access to water from a tree hole*[46]

Figure 7: Capuchin monkeys foraging for insects in trees and ground @Apenheul

Figure 8: Vertebrate predation by an adult capuchin monkey and observed by a juvenile[51]*(Photograph by Tiago Falótico)*

Figure 9 Fishing for termites (a)Looking under bark [49] *(b) fishing for termites through sticks (Image credit: Camila Bione.)*[52]

Gender plays an important role in capuchin foraging. Males favour animal prey and hunt on the ground or in dangerous locations such as wasp nests. This may be because males are less likely to be consumed due to larger size compared to their female counterparts. Males are also more powerful and able to pull bark and pursue prey. Females instead pursue immobile prey and do less taxing tasks, such as stroking[53]. It is also likely that females do not take as many risks as males because they are the core of the social group(sec. 2.1.2) and are responsible for the upbringing of their children, among other things[2].

2.1.4.1.2 Tool Use

Capuchin monkeys are highly interested in manipulating objects whether familiar or novel[2]. They use stones to dig the soil for tubers and cut wood for insects and larvae, use sticks as probes to reach food or water in cracks, holes or insect nests[54, 55], use pieces of oyster shells to pound repeatedly on red mangrove oysters[56] and crack open hard-shelled fruit by hammering it against a hard surface[2].

Capuchins in captivity have been observed using sticks as tools (See Figure 10). They prepare and modify the branches to fabricate their tools. This is very significant and reveals a lot about their intelligence[2].The length of the branch is trimmed and sized, and then the excess branches and leaves are removed to make the final tool. Occasionally, proximal extremity thinning is noted as well. In addition, it has been observed that this behaviour is coupled with the successive use of stones to extract insects from dead tree trunks [57, 58].

Figure 10: capuchin monkeys using sticks to access small holes [59, 60]*(Photograph by Tiago Falótico)*

Moreover, capuchins have been documented to use tools to ***break palm nuts*** [2] (See Figure 11). Capuchins usually climb on the palm and consume the pulp of the fruit (*Syagrus romanzoffiana*) while leaving the seeds on the floor to dry before smashing and opening them up[49]. These seeds are frequently parasitized by *Coleoptera* larvae, and capuchins enjoy eating them. Many days later, they gather the discarded seeds and carry them in their hands and mouths until they find stones appropriate for an anvil and hammer (up to 1kg). They pound a single seed on the anvil and hammer with two hands until it splits open (See Figure 12). The larvae are extracted using their jaws and fingertips. If there are no larvae, they either discard or eat the seed [3, 61].

Figure 11: Stone aided palm nut cracking [58] *(Photograph by Tiago Falótico)*

Furthermore, it has been discovered that capuchins use the same process to break open cashew nuts (See Figure 12). They make use of their entire body to break open these nuts.

Figure 12: capuchins smashing cashews against stone "anvils" [59, 60]*(Photographs by Tiago Falótico)*

Factors influencing tool use

Tool-use depends heavily on individual's innate curiosity, acquired tool-use traditions, and social tolerances within the group[2] which are discussed in detail below.

Age: Until the third year of life, the proper synchronization of actions and placing of nuts, "hammer" stones, and "anvils" (any hard, flat ground) is not achieved [62].

Society: Capuchin monkeys have been observed to tolerate food sharing with infants in the form of ***scrounging*** (See Figure 13). Individuals develop time and space coordination through seeing the adult manipulate food. However, this depends greatly on the social hierarchy (on page9). A male with a mid-ranking is more willing to share clumped food than an alpha male [2, 63]. Also, the role of a mother is also crucial to the development of tool-use skills in the infant. children whose mothers died before they were three were less likely to utilize tools than those whose mothers survived [58, 64].

Environment: Tool use is dependent on seasonal resource reduction, abundance of embedded foods in dry season, predisposition to spend time on the ground, availability of stones and anvils, and low risk of predation[65, 66].

Figure 13: Scrounging among capuchin monkeys [58]

2.1.4.2 Anointing

Anointing is a characteristic capuchin behaviour in which they rub their body with pungent substances. (See Figure 14)[67]. Individuals can anoint themselves by themselves (self-anointing) or in groups of two or more (social anointing). It involves crushing and dispersing a foreign substance on the fur with the hands or feet [68].This substance could be derived from plants (leaves, fruits, flowers etc.) or from animals (ants, wasps, crickets, millipedes, worms, etc.). While YBCs anoint with animals and prefer to do it alone, WFC anoint with a wider range of plant substances with a preference for citrus fruits and onion and some animal substances such as millepede secretions and are more sociable[1, 69].

Figure 14: Social Anointing in capuchins with dishwashing detergent [67]

2.1.4.3 Grooming

Grooming (See Figure 7) in capuchin monkeys is both sanitary and sociable [70]. Grooming maintains the relations in the hierarchy and forms coalitions and is a pro-social behaviour. It is mostly directed from the lower ranked individuals towards the higher ranked individuals even though instances of relatives grooming each other have also been observed. The alpha male is a preferred recipient of grooming. Males groom less than females (but the examples of the reverse exist)[1].

Figure 15: Capuchin monkeys grooming[71] *Wikimedia Commons, (Image credits: Adrian Soldati)*

2.1.4.4 Play

Social play is primarily adapted by juveniles and younger animals in order to develop social bonds and acquire skills[72]. It is a non-agonistic behaviour having many physical components of adult behaviour, such as those utilized during aggression (but without immediate repercussions), and is dramatic, repetitive, and varied[2].

Figure 16: Cebus capucinus with restless parents displaying a threat face playfully and an infant blissfully sleeping © Jason McComb [73]

2.1.4.5 Effects of Captivity on Behaviour

2.1.4.5.1 Self- Directed Behaviour

A self-directed behaviour (SDB) is defined as any behaviour that an animal frequently and consistently directs toward itself in the absence of a major medical cause[74]. Poor housing, management styles, no coping options for the animals, and/or low stimulus environments all have an impact on the welfare of capuchin monkeys, causing them to become hostile, bored, apathetic, or to develop coping behaviours such as abnormal repetitive behaviours[75] such as pacing, scratching, all of which are signs of stress. In such circumstances, there is a decline in normal behaviours, such as social and manipulative interactions, coupled with an increase in periods of inactivity and stereotypical and self-directed behaviour[21, 22].

Self-directed behaviours, at higher rates, can indicate that the animal is stressed at the time. As is the case in the wild, brief, high levels of acute stress have no influence on the animal's welfare so long as the animal is able to cope with it. Animals are exposed to a diverse range of exposure scenarios, including sporadic, acute, and long-term, chronic environmental factors in the wild. Acute stress is functional for animals in the wild, as it aids in their survival. Similarly, short bursts of acute stress in captivity are not necessarily harmful to the animal unless the stress is persistent and the animal experiences high levels of stress for extended periods of time (chronic) and is unable to cope with it, which may have an impact on the animal's welfare.[75].

2.1.4.5.2 Contra-freeloading behaviour

Contra-freeloading is a behaviour observed in most animals in which, when presented with a choice between free food and identical food that demands effort, the animal prefers the latter [76](Jensen, 1963). Typically, in contra-freeloading, exploring, and acquiring a resource seems more essential than the resource itself. Adaptation to unexpected surroundings and uncertain rewards is a probable reason for contra freeloading [77]. This phenomenon was confirmed in Japanese macaques[78] and chimpanzees [79] in primates. Another reason why animals may actively approach or seek out characteristics linked with or predicting a positive outcome is that these factors are associated with or serve as predictors of a favourable outcome[75].

2.1.5 Activity-Time Budgets of Semi-free capuchins

Travelling (42%) and foraging (38%) dominate the activity budget of semi-free capuchins, followed by feeding (10%), social interactions like grooming and play (5%), and resting (4%) and other activities (2%). Besides feeding, additional activities vary by sex-age class and group [80, 81]. Social play and grooming make up 80% of capuchins' social interactions followed by agonistic (11%) and cooperative (10%) interactions. Sexual interactions are uncommon (0.4% of all incidents) and frequently include juveniles (45% of occurrences). Juveniles are the primary recipients of grooming, food sharing, and agonism, followed by the alpha male[2, 4].

2.1.6 The Capuchin – Summary

The literature points out findings about the capuchin monkeys that can be used to design enrichments for them. They have power and precision grips in their hands which enables pushing back and forth motion from their hands and fingers.

Both male and female capuchins can easily discern the yellowish to reddish spectrum and thus any use of colour in the enrichment must adhere to this spectrum for maximum visibility. Furthermore, they are most responsive to natural sounds within the range of 7-10kHz. This means the sounds used in the enrichment need to be familiar natural sounds in their hearing range.

They also have keen sense of tactile perceptivity which helps them in foraging an eclectic variety of food sources. This ability is largely supported by excellent motor skills (hand-hand and hand-eye coordination) and memory. Both the short- and long-term memories of capuchin monkeys are highly developed. However, research indicates that these animals retain visual stimuli more precisely than auditory stimuli in the short term.

Additionally, the capuchins can perform second order tasks as seen in the process of breaking palm nuts. This involved not just motor skills but also memory and long-term planning. The animals display a remarkable ability of foresight. This aspect may be used in the design of the enrichment such that when one thing can lead to another with some delay and overtime a third element can also be introduced (See Figure 17).

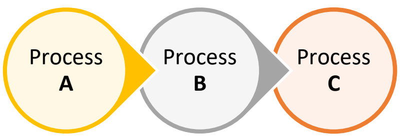

Figure 17: Sequential Process

There are pro-social behaviours displayed by the capuchins which help maintain the hierarchy of the group and establish new social bonds. These behaviours are social play and grooming. While grooming is hierarchical with the alpha male receiving the most grooming, social play is most observed among younger individuals in the group. Due to their importance in maintaining peace in the group, care must be taken to not disrupt these structures.

The enrichment design must also take into consideration of the self-directed behaviour shown by these animals when stressed. The design must not intentionally cause distress in an individual or the group.

Contra freeloading behaviour has been witnessed in primates such as Japanese macaques and chimpanzees. although there was no literature on contra-freeloading behaviour in capuchins, it is likely they would respond similarly. Apart from food rewards, anointment materials with strong smells are enjoyed by the capuchins. This can be a non-food motivator.

In the wild, these animals spend the vast majority of their time foraging. Literature underlines the multifaceted, destructive, and exploratory methods these animals use to obtain their food sources. Their determination to reach the food source, along with their ability to use tools, keeps them active and occupied. Therefore, an enrichment that promotes foraging behaviour in an indoor environment will be advantageous for both the animals and their caretakers.

In the next section, the literature will explore digital enrichments for primates and the design processes.

2.2 Enrichment And Design Frameworks

Animals in the wild develop species-specific distinct set of skills (cognitive, explorative, problem-solving, learning, spatial awareness) that guarantee survival and wellbeing [10, 11] , [12]. However, the same cannot be extended to captive animals due to often less complicated and highly predictable captive settings. Thus, **enrichments** are provided for the animals to obtain similar mental, social and physical stimulation as they would have in the wild [15].

Enrichments provide animals with a greater degree of autonomy and choice over their environment, enhance their coping skills and information acquisition[17, 18].

There are multiple types of enrichment. Environmental enrichment entails the introduction of new resources in the animal environment including physical structures (trees, vines, perches) and alternative materials. Cognitive enrichment is cognitive stimulation by positive reinforcements. Feeding enrichment involves presenting the animal's usual diet and new foods in novel ways, often combined with other forms of enrichments such as puzzle feeders (cognitive + food) and scattered food (environmental +food). Sensory enrichment includes visual, olfactory, tactile, or auditory inputs. And finally, social enrichment includes altering animal groupings to promote stable social groups. [14, 82].

Social enrichment does not fall under the purview of this thesis project and thus is excluded from literature study. The research topics document delves into details of all enrichment types but here in this report the focus is limited to only digital enrichments implemented with primates.

2.2.1 Digital Enrichment

Digital enrichments have many advantages over traditional enrichment [24, 83]. Digital technologies are easily adaptable and thus can be re-programmed to decrease habituation and bring in novelty[16]. They can cater to individual animal preferences and can be easily tailored to age, gender, and species-specific individual preferences[25]. In addition to being intrinsically rewarding, they are a viable alternative to food-based enrichments[84]. And lastly, they can also log the animals' responses to enrichment automatically and, therefore, assist in enrichment evaluation, without the intervention of a caretaker. This increases accuracy, reduces observer bias, and reduces processing time. And alternatively, this gives greater autonomy, privacy and freedom to the animals and thus are engaged for longer periods. [85, 86].

In contrast, the impact of digital technologies on the stereotypical and self-directed behaviours is inconclusive. While there was a positive effect in rhesus macaques [87], there was increased anxiety in orangutans [85, 88], and there was no adverse effect observed in Sulawesi macaques[89]. More research is required to minimise the negative effects of digital technology [73]. The next section discusses some examples of digital technology implemented with primates categorised by the type.

2.2.1.1 Visual

Different coloured lights were placed in chimpanzees' enclosure. This resulted in diverse effects on the animal. The red light exacerbated the animals' hostility, and they showed self-directed behaviours such as higher rates of pacing (sec. 2.1.4.5.1). However, blue and green lights decreased anxiety[90].

In another study, captive white-faced sakis' were provided with an interactive screen enrichment (See Figure 18) that they could trigger themselves. Saki monkeys in the device didn't always face the screen. They kept their backs to the screen in the device's centre and peripheral. The frequency of interactions did not differ between control and stimulation settings, suggesting that some primates(sakis) do not always engage with screens as humans hypothesized[91].

Figure 18: Setup view from google nest and Raspberry Pi cameras [91]

2.2.1.2 Auditory

Digital music and sound have been used as auditory enrichments for the animals. The responses of primates to music vary by genre. While light jazz music enhanced the social bonding behaviour of rhesus macaques, classical music decreased their stereotypical behaviour[92, 93]. Music also reduced restlessness and aggression in chimpanzees while enhancing their social, play, and active exploration behaviours [94].

Playing species-specific habitat sounds (forest sounds) and the vocalizations of conspecifics to some captive primates, however, showed mixed results. The sounds of bonobos played to gorillas increased their stress-related behaviour [95] , but gibbon duet calls played to Lar gibbons resulted in an increase in activity and vocalization[96].

Captive white-faced Saki monkeys were given an interactive audio device that they could use as a trigger to play sounds. *The monkeys preferred traffic sounds over silence, rain sounds, zen music and electronic music*[97].

2.2.1.3 Interactive Games – Kinecting with Orangutans

Figure 19: Interactive projections for Orangutans : in clockwise- Burst; Sweep; Painting; Match and Gallery [26, 27]

The Kinecting with Orangutans initiative at the Melbourne Zoo provided orangutans with interactive projections (See Figure 19). The Kinect and projections were an effective combination since the hardware could be positioned beyond the animal's reach while stimulating multiple senses (visual, tactile, aural)[98].

Five games- Burst, sweep, painting, match, and gallery were built with Microsoft Kinect (Figure 19). The *burst* application projected a 5cm coloured dot around the cage. It flashed when touched. *Sweep*'s red and blue tiles disappeared when touched. When the animal touched *Painting*'s white screen, coloured marks appeared. The colour of the marks was changed using buttons on the screen's edge. Matching and touching coloured shapes in *Match* created aesthetically pleasing feedback (Figure 19). Higher levels required form or colour matching [20, 21]. Images and videos (of food, animals, orangutans, and Zookeepers) were shown on a 2x3 grid in *Gallery*. A touched photo filled the screen. Water ripples enabled picture interactivity [26, 27].

The project used a ***CO-DESIGN*** approach which involved cross-disciplinary collaboration team involving a game designer, a programmer, and an expert in animal behaviour [14, 27, 98]. The Orangutans in Melbourne Zoo prior to this project had access to digital technology in form of touch screens. The interaction was limited to using fingertips. The project enabled greater choice, freedom and control over their environments and the interactions could be explored by the animals in novel ways triggering body movements such as- roll around, hang from ceiling, and could "touch" using whole hands, feet, faces, and objects [26].

The project generated emphatic responses from the visitors since there was now greater visibility of the orangutan's bodily movements which were very "human-like" thus providing a deeper sense of reflection on animals' cognitive processes and affective states [26].

Figure 20: A young visitor looking at one orangutan interacting with burst application[27]

2.2.2 Design Methods

To develop enrichments for animals, multiple design methods exist, including the 4-Outcome model of Intrinsic motivation, the five new freedoms, and the ACI- ethical framework. This report will focus on the ACI- ethical framework and co-design, a subset of this design methodology while briefly addressing the other models.

2.2.2.1 ACI-Ethical Framework

The fundamental tenet of the Animal-Centered- Interaction Technology(ACI) or Animal-Centered Technology(ACT) is that technologies, their development methods, and their ethical foundations should be animal-centered, meaning that the characteristics, needs, and desires of the animals involved and the environments in which interactions occur should directly influence design processes and outcomes [99]. This follows an ethical framework described below:

> 1. **Understand the interaction** between animals and computing technology in contexts where animals live, are active, and socialize with other species, including humans.
>
> 2. **Developing Technology** must be able to *improve* the animals' life quality or expectancy by meeting their physiological and psychological needs, *support* animals in their activities and legal functions by minimizing negative effects and maximizing positive effects on life expectancy and quality; and *foster* interspecies relationships if applicable by enabling communication and promoting understanding.
>
> 3. Follow **User-centered approach,** an iterative design process, to design technology for animals, based on their needs and preferences, to involve them in the design process by considering animal users as *legitimate stakeholders or co-designers* and design contributors throughout the design process and beyond.

There are challenges associated with including animal users as design collaborators in interaction design. The user-centered design methodology entails designing solutions to become closer to the end consumers. However, the ultimate challenge for ACI research is soliciting the needs of non-human users and capturing their perspectives [14].

To comprehend and appropriately address the needs of animals, ACI must define robust measures to (1) identify animals' needs and (2) incorporate them into the design process [100]. The former can be facilitated by using human caregivers as proxies, as this helps to discover the animal's needs and desires (in)directly [99, 101, 102].

One way to respond appropriately to the needs of animals is to incorporate them into the design process [100]. This is accomplished by including the animal as an authority on its own experiences. Nonetheless, it remains one of the greatest obstacles, as it necessitates the interpretation of animal demands and the countering of anthropocentric design methods [14, 93, 103, 104]. In addition, the key to acquiring a comprehensive understanding of the wants and needs of animals in their current habitats is to give equal weight to the concerns of all stakeholders [105].

Co-design is a design method that embodies this characteristic.

2.2.2.2 Co-design for Animals in Captivity

Implementation of co-design approach is the creative collaboration of designers and non-designers in the design creation process[100]. It is based on a participatory design approach which has its roots in politically driven and rights-based ways of including people in design practices and also draws on Research through Design [14].

As per this approach, since it is uncertain if non-humans are capable of conscious "*creativity*" and if they can be defined as "*collaborating*" with human designers, so, the bigger goal of co-design projects that focus on animal needs is to involve the animal as an expert of its own experience learning directly from animals about their wants and needs [14].

According to Webber [14], the co-design process begins with an analysis of the context of usage, which includes the prioritized needs of animals and caregivers as well as the restrictions and obstacles driving the present enrichment. This is followed by interviews with zoo staff, keepers, other stakeholders, and animal welfare experts, to learn more about the animals' preferences, motivations, and seasonal fluctuations. The results are utilized to build mock-up prototypes that can be tested with the animals targeting a specific goal behaviour. If the enrichment meets the standards, it is validated[14].

Many enrichment programs are based on this paradigm. Bonobos and chimpanzees can navigate 3D desktop Virtual Reality (VR) settings on a large, fixed monitor using animal-activated VR [106], and elephants(See Figure 21) at Columbus Zoo utilize an elephant-activated shower to moisten dried hay before eating it[12].

Figure 21: Elephant taking shower in Columbus Zoo [12]

2.2.2.3 Other Design Methods

The 4-Outcome Model of Intrinsic Motivation

Based on this model, there are four welfare outcomes in relation to the skill of the animal and the level of challenge provided by the enrichment (See Figure 22) [107]. When a task is well-matched to the individual's skill, the individual becomes absorbed in the task and experiences a state of ecstasy, pleasure, or satisfaction known as "*flow*". Unchallenging tasks result in *boredom* in case of higher skill and or *apathy* in case of lower skill, while challenging tasks result in *anxiety* if the individual lacks the necessary skills [24, 107].

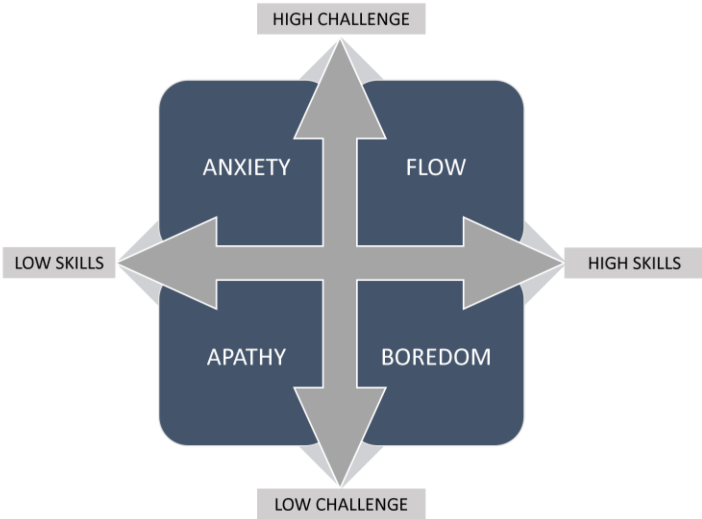

Figure 22: The four outcome model of intrinsic motivation [107].

The 5C's or the Five New Freedoms

In accordance with this view, it is necessary to consider animals' life in an integrated and holistic manner to promote their welfare [14, 24, 108, 109]. It emphasizes that animals must be provided with the "Five New Freedoms"- *choice, control, challenge, change, and competence* [12, 110]. The animals must have choice, autonomy, and control over their settings, as well as with appropriate challenges of their capacity. This can alleviate the majority of behavioural and physiological issues [1]. This model focuses on assisting animals not only to cope but also to thrive[111].

2.2.2.4 Evaluation Methods

Separating the effects of enrichment from other variables linked to the environment, social group interactions, and seasonal changes can be difficult, particularly in zoos and animal shelters [26]. Despite that quantitative, qualitative, and physiological measures can be implemented to effectively assess the impact of the enrichment on the animal.

Quantitative method includes usage counts. The higher the count of interactions, the higher the efficacy of the enrichment. This provides insight into the value of the enrichment to the animals and is a pre-requisite to its effectiveness [112, 113].

Qualitative analysis incorporates the data on the count, duration, and quality of interactions. This provides insights into patterns of habituation and demonstrates how the various stimuli affect usage [95]. To improve the overall performance of the enrichment, the impact on the animal's behaviours indicative of positive welfare indicators (such as play behaviour, positive social interactive conduct, etc.) or negative behaviour (such as stereotypical behaviours) is measured[114].

Physiological measures, such as the animal's level of stress-related hormones, and the caretaker's ratings of the mood of the animal and well-being, are utilized to evaluate the intervention's impact on animal wellbeing. These factors give an insight into the quality of the interaction [114].

Separating the effects of enrichment from other variables such as environment, social group interactions, and seasonal changes, for example, can be challenging, especially in zoos and shelter environments [96].

2.2.3 What makes Enrichment- Enriching

It is equally important to consider what interests an animal in returning to interact with the enrichment when developing enrichments for animals. Enrichments frequently lose their appeal and thus become another aspect of an uninspiring environment. Loss of interest as a result of repeated or extended exposure to the object reflects habituation[115]. This is especially crucial for cognitive animals like capuchin monkeys and giant apes, who avoid interacting once they've overcome the challenge or become habituated to enrichment [116]. This poses a significant challenge for caregivers because they must constantly come up with new enrichment ideas and adaptations to keep the animals interested for extended periods of time [117]. This section discusses the factors that contribute to and maintain interest and value in enrichments.

According to previous studies [16, 24],animals are susceptible to the habituation of their environment, which can lead to a loss of interest and, if no action is taken, boredom and self-directed behavior ensues in some of the animals. This is a significant concern for the animals' well-being [118]. Thus, the **novelty** of an object is a crucial factor in initiating and maintaining exploration [93]. It stimulates and renews the animal's interest in the enrichment [113]. Novelty can be achieved by modifying objects or changing the animal's habitat [119], by varying schedules for the introduction of the enrichment [1], and by introducing novelty into the diet[89].

Novelty in food can be further improved by **increasing the processing time** by making the animal work for it. This is accomplished by scattering food across numerous locations into substrates (wood wool etc) or by providing food items requiring extensive processing such as coconuts [89, 120, 121]. Increased time spent foraging has been linked to decreased inactivity, aggressiveness, and inappropriate stereotyped behaviour [89].

Another way to reduce the abnormal stereotypical behaviours and increase positive excitement in the animal is to give challenges that meet their individual competence. When this is coupled with agency, studies indicate overarching benefits in animal wellbeing. **Competence** refers to the range of cognitive skills such as inspective exploration, problem solving and response to novel situations that an animal uses to deal with current novel challenges. And **agency** is the animal’s ability to gather knowledge and enhance skills for future use which then transpires to competence[24]. Together, competence and agency are intrinsically rewarding behaviours, that are performed without an external reward such as food and have been linked to increased physical health in the long run [122–124].

Moreover, the **aesthetics** of the enrichment have a key part in attracting and retaining the interest of the animals, since it influences the enjoyment, they derive from the enrichment. This can be made possible by making the enrichment multi-sensory(visual, tactile, auditory, olfactory, gustatory) and experientially appealing (temporal, vibro-acoustics or electro-magnetic fields) to the animals[125, 126].

Primarily observed in animals with strict social structures, **monopolization** of enrichment is a frequent problem. The dominant individuals monopolize or have preferential access to resources preventing lower-ranking individual access[24]. In fact, moments preceding the feeding times, there has been highest levels of aggression observed in captive primate groups due to the monopolization [127]. Thus, to prevent aggression in animal groups, enrichment design must account for monopolization and include different versions of the enrichment or multiple access points [127], [24].

It's also been found that highly salient stimuli in terms of how they affect the animals' environment as a whole or how different they are from the existing environment are likely to cause a stronger response and *slower habituation*. This is especially relevant to the introduction of non-naturalistic stimuli (such as computerized installations) into naturalistic environments, such as those of zoo animals [128].

2.2.4 Summary

The literature highlights the flexibility of using digital enhancements and their wide applications for primates. However, no studies involving capuchin monkeys in captivity were found. Consequently, there are numerous unknown factors pertaining to the capuchin species interaction with enrichments.

In terms of preferences, the literature reveals that there is likeness towards traffic sounds (on page20) and interactive projections (on page21). Furthermore, the animals often interacted with the enrichments in many surprising ways such as Saki monkeys spending time around the device setup and orangutans interacting with projections with their mouths. Therefore, it is necessary to keep in mind to give the animals freedom and control to interact with the enrichments in ways unaccounted for.

The ACI- Framework highlights the need to gain animal perspectives through proxy (caregivers and animal welfare experts) and through experiences of the animal itself(observations). Furthermore, there is emphasis on iterative design process to understand the animal's preferences, context, and technology of use. Lo-fidelity mockups can further be used to learn deeper insights into the preferences and modes of the capuchin monkeys. The resulting findings can be used to design a functional prototype that can interest the animals. The prototype must be novel, aesthetically interesting with interactions that are catered to the animals' competency and agency. Multiple access points or multiple devices must be installed for testing to prevent monopolization. Other factors mentioned (on page26) can be included to slower habituation. Long-term non-food reward enrichment interactions aren't confirmed by studies. It is unsure if non-food rewards can keep animals interested in longer periods.

The next chapter will delve into the understanding the animals at Apenheul Primate Park.

3 APENHEUL PRIMATE PARK

Apenheul Primate Park is a non-profit foundation that works for the conservation of primates and their habitats founded in 1971. It houses nearly 35 different species of primates out of which nearly 18 roam freely among the visitors. The primate themselves live in large natural habitats that stimulate their natural behavior [129].

Apenheul houses two species of capuchins – the white-faced capuchins (WFC) and the yellow-breasted capuchins (YBC). The WFCs have a larger outside island (See Figure 24)and a group of seven individuals. In contrast, the YBCs are divided into two groups of four individuals each. Group-1 has access to an exterior. Group 2 has no access to the exterior island but has access to outside part of the enclosure. They are not visible to the visitors.

3.1 WHITE-FACED CAPUCHINS (WFC)

Figure 23: Two individuals of the white-faced capuchins group at Apenheul (Photograph by Snigdha Guntuka)

The WFCs housed at Apenheul are a very energetic group of seven individuals. They are known to entertain the visitors with their ever-busy activities. We gathered the following information about each member to the extent known or applicable: name, birthyear and month, gender, father and mother, and offspring. Seven females and two males constituted a family of grandparents, a mother, two uncles and two grandsons. Their ages were 35, 34, 21, 16, 13, 15 and 10 respectively.

The outside enclosure of these animals is one of the first islands the visitor sees on arrival into the park (See Figure 24). The outside and inside enclosure of WFCs is shared by the howler monkeys and sometimes other species as well. The WFCs in Apenheul are incessantly foraging for food from the food baskets, inspecting crevices in the tree trunks, and are quite interested in grooming.

Figure 24 : Outside Enclosure of White-faced capuchins

3.2 YELLOW-BREASTED CAPUCHINS (YBC)

Figure 25: Two individuals of the yellow-breasted capuchins group-1 at Apenheul(Photograph Snigdha Guntuka)

On the far end of the park reside the yellow-breasted capuchins (Group-1, David). They are smaller compared to the white-faced capuchins and prefer to stay on a height. Group-2 also called as the "**Xanta**" group are not visible to visitors. Group -1 island is close to the Gorillas. Their inside and outside enclosure are exclusive for them.

Figure 26 : Outside Enclosure of Yellow-breasted capuchins- Group -1

For this group we also gathered information about each member including their name, birthyear and month, and gender. Subgroup-1 consisted of three females aged 38, 12, 7 and one 31-year-old male. And subgroup-2 consisted of three females aged 28, 12, 11 and one nine-year-old male.

3.3 Understanding Context

Understanding the environment in which animals live, operate, and interact with other species, including humans, is essential to the animal-centered design approach (on page22). This is achieved by direct video observations of both WFCs and the YBCs in their outside enclosure, followed by focus group discussion comprising of animal welfare expert, caretaker team-leads of both species, human-centered interaction expert and the researcher.

3.3.1 Video Observations

Video recordings of the outside islands was made for 3 days spanning 1 hour each. General behavior and overall dynamics of the group was recorded. Some of the individuals were followed to note their unique behaviors and interactions with the rest of the group.

Both species were usually busy seeking food sources. There were play behaviors observed in both species. The outside enclosures were fitted with puzzle feeders and food baskets. Some of the food was scattered across the enclosure. The animals spent a lot of their time either moving around, manipulating some food items or grooming. The animals were largely peaceful, and a distinct social hierarchy was observed. However, it was difficult to identify the individuals without the help of the caretakers.

3.3.1.1 White-faced capuchins (WFCs)

The WFCs were very active and constantly running around, playing or looking for food. In numerous instances, the animals were bipedal and stood alert on the ground. They often dug through the grass, towards the water's edge, and searched under plant leaves. Even though there was food in the food basket, they preferred to stay and seek food on the ground. While they groomed each other frequently in the afternoons, they were sighted high up on the trees in the evenings. These individuals were more aggressive than the YBCs. WFC's enclosure is viewed from the side, thus all the animals couldn't be observed at the same time. Hitting, rubbing, and pounding behavior was not observed.

3.3.1.2 Yellow Breasted Capuchins

YBCs were significantly smaller than WFCs, preferring to stay on a height rather than the ground, less aggressive, and could walk bipedally for extended periods of time. They had a smaller enclosure that could be viewed from above, allowing visitors to get a much closer look at the animals. YBCs, like WFCs, were very active and vigilant, involved in eating, grooming, and play. The enclosure included a puzzle feeder as well as two metal surfaces where the animals enjoyed manipulating their food. They frequently rubbed, hit, and pounded on the food item before eating it. They were stubborn (on page13) and spent over 2 minutes continually breaking open a bamboo stick. Similarly, when a visitor dropped a soda bottle by accidentally, one of the individuals attempted to open the bottle and managed to bite through it before the caretakers removed the bottle from the enclosure. This interaction lasted about 6 minutes (Figure 27). Scrounging (on page13) was observed on several occasions. These creatures were also seen looking for insects under plant leaves. Many times, one individual was seen hanging in the air at the border of the enclosure, supported only by his/her tail, searching for insects through plants' leaves.

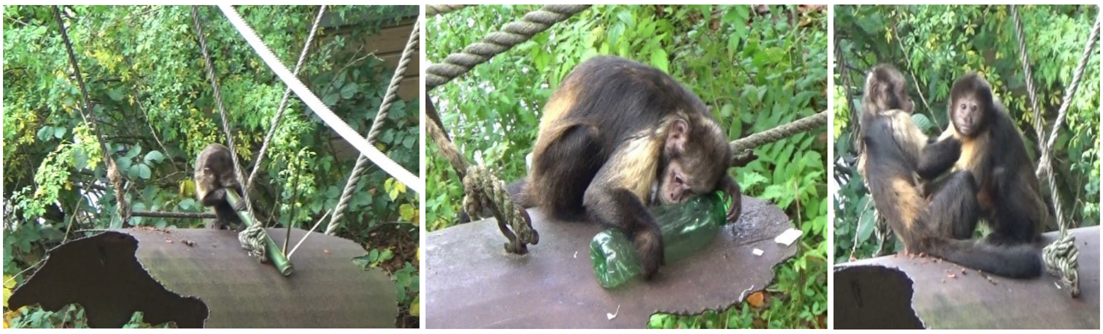

Figure 27: Objection Manipulation and Play Behaviour on metal surface (a) bamboo (b) soda bottle dropped accidently by a visitor (c) play behaviour

3.3.2 Focus Group Discussion – Summary

To gain a deeper understanding of the two species at Apenheul and their individual characteristics, focus group discussions were held with an Animal welfare expert, HCI Researcher supervisor, Animal Caretaker Team leads for both species, caretakers with experience in making enrichments for primates, and a researcher.

The objective was to learn more about the animals at Apenheul. Comparing and contrasting the similarities and differences between the two species in terms of enclosure settings, behaviour patterns, and challenges. In addition, the food distribution system at Apenheul was discussed, along with enrichments that had already been tested. Any additional interesting details about capuchin monkeys and initial brainstorming ideas was also discussed. The focus group discussion lasted a total of 60 minutes and was held at Apenheul. The meeting was recorded for analysis purposes and to formulate the objectives and opportunities of the project going forward. A brief summary is provided below.

3.3.2.1 Enclosure Settings

The WFC's inside enclosure is a new building with more space for animals and dynamic lighting that follows the sun. It has five males and two female white-faced capuchins. The animals have two entrances to the inside enclosure. Their enclosure has a camera to monitor their behaviour. The animals always have inside and outside enclosures.

There are two groups of YBCs with four members each (on page29). Group-1 has inside and outside enclosures like the WFCs. Group-2 or Quarantine group has no access to islands or outside enclosures. They get sunlight, but it's not a free-roaming enclosure like the islands. Due to social disturbances with the group 1, this is a temporary arrangement.

3.3.2.2 Behaviour

In general, both species enjoy making noise and a mess. They are social animals that rely on maintaining social hierarchy, so they engage in frequent play and grooming. They engage in playing, hitting and measuring something with stones. *Both species enjoy rubbing themselves with aromatic plants.* They rub heavily with onions but dislike other herbs. Tobacco is their favourite anointing agent. While the YBCs are laid back, the WFCs are high on energy. Outside islands are always accessible to the animals. They only stay inside when the temperature drops below freezing. Boredom is high during the winter months because the park is closed to visitors and thus there are fewer distractions for the animals. There is no infighting because there are no newcomers to the group, and they all grew up together. Except one male, the other in the group are castrated. This however doesn't impact the fighting behaviour in the group.

The majority of the WFCs are on the ground. Five of them barely climb a tree. They have been seen climbing trees in the evenings, but only two of them. It is possible that they're looking for the keeper. They are never bored and are always busy. They were previously one of the free roaming monkeys. They enjoy carrying and playing with the stones. They also enjoy torturing and playing with frogs found near the island.

"*the white-faced capuchins used to walk free with the public especially the female white-shoulders. They loved to play with stones always. They had a normal children slide on the island. There were little holes inside the slide and we would throw some rocks- one female capuchin would go out and run and catch them. She would carry the stones the whole day. We loved to watch and play with them*" – Animal caretaker team lead

The YBCs on the other hand are rarely on the ground. They show hitting and pounding behaviour constantly on the outside enclosure. In the inside, they are mostly seen rubbing stuff on a wall.

3.3.2.3 Food Distribution

Each species works with 3-4 keepers. The animals are fed three times a day in multiple ways. Food is spread and hidden around the island when the animals are inside foraging for insects or are provided with snacks. Insects are given when still alive in the inside enclosures only. Bicycle siren is a sound that they hear to know that food has arrived. *Highly favoured food items given are fruits and locusts while low priority foods are seeds.*

3.3.2.4 Challenges:

Food Distribution

Because the animals are so close to visitors, throwing food is prohibited at Apenheul. When the animals are inside, food is instead placed in food baskets or scattered on the island. Some animals, such as "Oemie," who are more shy and vulnerable (pg.28-29), refuse to come inside when there is too much activity among the other animals. These animals are fed separately. Because these animals have a social hierarchy, lower ranked individuals may otherwise not always get enough food, especially when it comes to more preferred and limited foods like locusts, because higher ranked individuals may steal the reward. Food rewards are restricted in order to protect the animals' health. As a result, any food enrichment must have multiple access points for all individuals of all ranks, be strong enough, and be able to store large quantities to ensure that everybody gets the food.

Puzzles

These animals are extremely intelligent. They can solve puzzles, but once they figure it out, they quickly lose interest and stop interacting. There is a need for puzzles that are not too easy, that can be easily changed, that they enjoy, and that the animals have control over. As a result, there is a push for digital technology. Furthermore, the inside of the puzzle should be easily cleanable. *There are no digital enrichments in Apenheul for the capuchins.*

3.3.2.5 Social Hierarchy

Higher ranking individuals steal the food because they are sometimes simply lazy. Mid and low rankers are more creative and try to solve problems. The lowest rankers take a step back and carefully choose their battles. They must work harder for their food. Age does not imply higher rank. In most cases, the oldest are more likely to be ranked lowest. They are ranked higher if they have a lot of family support like Oemie (WFC). Group 1 and Group 2 YBCs do not collaborate with each other and thus require separate housing islands/housing facilities.

3.3.2.6 Enrichments in Place or tried out so far

Videos can be used. They either love or hate children’s films. Sounds can also be used. However, use of dolphin sounds was a big mistake.

All enrichments on the outside enclosure must fit to the theme of Apenheul which means they are made of or look like natural and nontoxic materials. A big box with small holes filled with sawdust and sunflower seeds in there which is in the outside enclosure of YBC (pg.29). There was a puzzle which is now removed with big balls put in a wrench which the YBC solved but WFC did not. But there is some confusion of which species was using it.

These animals are adept at manoeuvring multiple steps to reach food, such as pull, push, and shift toys. The animals learn from one another, and they see and observe one another. The difficulty of solving the challenge is determined by the personality of each monkey. The enrichment must strike a balance between complexity, object strength, and cognition level. They will give up if the challenge is too difficult. They will first destroy the puzzle if it is delicate. And if it's too simple, they'll figure it out and lose interest.

Some Spider monkeys learnt to break coconuts with the end of a screw. Hanuman langurs loved the rolling wood enrichment.

3.3.2.7 Brainstorming Initial Ideas

Based on the findings of the literature, some initial ideas were discussed and mentioned done with the focus group, which revealed more insights into the design aspects to be incorporated.

The emphasis was on rewarding the animal for various behaviours, such as smashing something and then releasing food. More steps could be added in between to cognitively challenge them and make them respond more naturally. *Multiple release points away from the activation point can distribute food, allowing access to all ranked individuals.*

"*Small food rewards such as nuts, mealworms, and insects can be used as food enrichments, but without is preferable."* - Animal welfare expert

Because South American primates cannot see all colours, shapes/figures are an alternative. By producing sound cues, the enrichment can encourage animals to climb and forage. Only testing can determine whether the animals will cooperate or not.

3.3.2.8 Enrichment Expectation

Finally, the objectives and expectations for the enrichment were discussed. The goal was to create an enrichment that could be extended to both capuchin species and orangutans (if possible) such a way that the enrichment implements interactive technology which entails a bi-directional dialogue between the enrichment and the animals It should challenge the animals cognitively and bonus if it can elicit empathy in visitors[27].It must cater to both inside and outside enclosures, with an emphasis on the latter. When the keeper is not present, the enrichment would be used in the interim. The animals must be able to interact with the enrichment and be rewarded without the assistance of a caretaker or any other prior training. To keep the animals interested, the enrichment should be easily changeable. The enrichment design must be cost effective so that parts can be funded by crowdfunding.

Small seeds can be utilized to promote foraging, but it would be ideal to develop an alternative that does not entail food rewards. This is due to the fact that capuchin monkeys are highly driven by food, their foraging behaviours are eventually linked to food, and they are accustomed to food-based enrichment. However, the animals are not accustomed to other sorts of enrichment (tactile, auditory, olfactory, etc.), and it would be interesting to determine what motivates these animals without food.

3.4 SUMMARY

The capuchins at Apenheul Primate Park are active, alert, always on the search for food, and enjoy making noise. While the WFCs forage mostly on the ground, the YBCs prefer to stay on a higher level. Both species are bipedal, with YBCs being bipedal for longer periods of time. YBCs have been observed to engage in more hitting and pounding behaviour than their WFC counterparts. Both engage in grooming and play behaviours and enjoy anointing.

WFCs have much larger enclosures (both inside and outside), as well as indoor lighting that follows the sun's pattern, whereas YBCs do not. Apenheul has a three-time feeding schedule in which the carers feed the animals while also scattering/hiding food on their islands. The YBCs in Group -2 do not have access to an island.

The animals could get more bored with less external environmental enrichment. The need for enrichment is for the intermittent periods between the feeding times.

The enrichment must be able to encourage the animals' natural foraging behaviour while also encouraging them to interact with it multiple times with a dialogue between the enrichment and the animal. The enrichment should be easily changeable and able to be used both inside and outside of enclosures. Furthermore, the challenge should not be too easy or too difficult, and it should be tailored to their abilities so that no prior training is required. The enrichment must appear natural and be able to withstand various types of animal interactions while remaining non-harmful to the animals. Food rewards should be kept to a minimum. It must be accessible to all individuals and should not cause disruption in the group. Furthermore, it should be simple to install, with no wires within the animals' reach. Finally, the enrichment should be cost - effective and modular.

Summarising the objectives from 3.3.2.8:

3.4.1 Objectives

1. Promote natural foraging behaviour of the capuchin monkeys
2. Must enjoy interacting
3. Easily changeable (can fit both inside and outside enclosures)
4. Cater to competency of animals
5. Monkey proof for at least the duration of the testing and natural materials
6. Non-harmful to animals
7. Minimal to no food rewards
8. No disruptions to social hierarchy
9. Easy installation
10. Low-cost and modular

Bonus: Challenge cognitively and elicit empathy from visitors

Later in further meetings, testing participants were decided as WFCs and the group -2 YBCs.

4 ETHICS

Animal-centered design approach necessitates the need for an environment that fosters animals' autonomous participation in the design process as legitimate stakeholders and design collaborators [99]. An ethical committee can help in directing and improving research plans towards a more ethically sound approach. The primary objective of an ethical committee is to ascertain if the proposal of the study falls within the ethical framework determined for the target participants[130]. Here in this study the target participants are capuchin monkeys.

UT research ethics policy depends on under which ethical framework it falls, to this end we first verified that to verify that the study does not fall under the law of animal experimentation. To do this first via the UT's internal animal welfare body, the researcher together with Ethics Committee Computer & Information Science (EC-CIS) contacted UT's independent animal welfare officer under the law for animal experimentation. It was determined that the proposed research did not involve animal experimentation, but rather experimentation with animals where the caretakers take the role of proxy to the animal just as caregiver is the proxy when working with vulnerable people with limited capacity to express themselves.

This research is in compliance with the Dutch laws and in agreement with international and scientific standards and guidelines. The proposed study does not meet the definition of an animal experiment as outlined in Article 1 of the Dutch "Experiments on Animals Act" due to the strictly non-invasive nature of the research and the absence of any potential discomfort or distress. Therefore, Apenheul Primate Park's Zoological Manager, Curator, Head of Caretaking, Veterinarian, and Research & Animal Welfare coordinator waived the need for approval from the Dutch Central Commission on Animal Experiments (Centrale Commissie Dierproeven).

Based on EU Regulations on animal research[131] and ethical guidelines of Apenheul based on ethical standards for zoos and aquariums[132, 133], literature sources and the ethical committee review, resulting in a positively assessed research under ***RP 2022-12***, "*under the assumption that, as promised, the people with that expertise approve the plans as they unfold from an animal welfare perspective*", (personal communication with ethics committee CIS, 18-02-2022). In the end the following principles and guidelines were outlined for this project:

- **Objective of project must benefit the animal**
  The study's primary purpose must be to benefit the animal. Animals may only be used in research in the EU when there is a strong scientific rationale, when the anticipated benefits of the research outweigh the potential dangers in terms of animal suffering, and when the scientific objectives cannot be accomplished using methods that do not include animals. Only projects that meet these criteria are permitted [131].

- **Experts**

  To ensure animal welfare, research on animal-computer interaction must be conducted with experts with adequate animal knowledge. Animal welfare experts must approve both the research concepts and the final prototype. It is not enough to ensure "universal" requirements for well-being (such as the absence of suffering); capuchin-specific criteria must also be met.

- **Enabling consent: Walking away**

  Animal-computer interaction research applies consent principles comparable to those employed for vulnerable human subjects. It is proposed that those responsible for the animals' well-being provide consent on their behalf. They should have extensive knowledge of the animal's behaviour and well-being, as well as familiarity with the animal. In addition, they must comprehend the welfare consequences and hazards associated with the prototype [99]. Consent is therefore twofold: mediated (through a competent caretaker) [134], and contingent (by an animal welfare specialist and through competent reading of the clues from the animal throughout the experiment) [135]. Thus, the proposal has to demonstrate that the researchers have capabilities to estimate both. The researcher should also be able to judge the animal behaviours while constantly monitoring the observation and if further training is required, the caretaker should be able to respond instantaneously if need arises.

  Furthermore, the animal should have the "*freedom to interact*" and the opportunity to stay or walk away at will during the entirety of the study. This means that the animal must have the space and the ability to assess the environment and can chose to engage./disengage [99, 134]. And no form of coercion applied to ensure interaction with the prototype. They will always have options available to retreat or avoid test objects and/or researcher(s) in their enclosure.

- **Support natural behaviour without training in a safe environment**

  Research methodology should be inconspicuous or natural [99], should not inhibit the animal's freedom of expression beyond what is caused by their environment (if in a zoo) [99], should involve positive reinforcement [135], and animals should not be trained to use the system [134]. The study must ensure that the knowledge about what stimulates or inhibits natural behaviour is known. The experiment shouldn't change/alter animal behaviour.

- **No Harm and distress to animal** [134]

  The study must take into account about different forms of harm to the animals which can be in different forms- physical, psychological and threats to social wellbeing. Thus, no aversive tools should be used [135], technology and procedure should be least disruptive [135], non-invasive to animals [135]. More specifically, in the offered technologies showing distress footage or sound, should be avoided to ensure that animals should have no existing / prior emotional behavioural problem [134].

- **Animals should have no existing/ prior emotional behavioural problems** [134]

  The animals who will be introduced to the prototype should have had no atypical emotional or behavioural concerns. Prior to introducing the enrichment, however, care must be taken to ensure that the animals are not agitated. Only when the animals are in a "non-stressed" state, the enrichments can be introduced.

- **Other considerations** [132, 133]
    - The animals are never separated from their social group for this study unless for husbandry or veterinary reasons, and only after consent by the head of caretaking, veterinarian or zoological manager.
    - The animals are only positively reinforced and only after discussion and consent by the head of caretaking, veterinarian, animal welfare coordinator, training expert and zoological manager.
    - The animals are never to be deprived of food or water at any stage of the study.
    - The animals are never to be handled or manipulated in any way shape or form.

There will be careful monitoring of the behaviour and welfare of all the animals. Any abnormal, self-directed behaviour, aggression or injury observed by the researcher must be reported to the (head of) caretaking and research supervisor immediately (by phone or verbally).

5 INITIAL IDEAS

Six preliminary ideas were developed based on previous work on enrichment for primates and literature on capuchin monkey, focus group discussions and YouTube videos and documentaries that showcased enrichment, particularly for primates in zoos today.

Each concept stimulates one or more of the capuchin monkeys' natural behaviors of interaction, which, when repeated until a certain *threshold* is achieved, activates **the feeder system** responsible for seed dispersal (Figure 28).

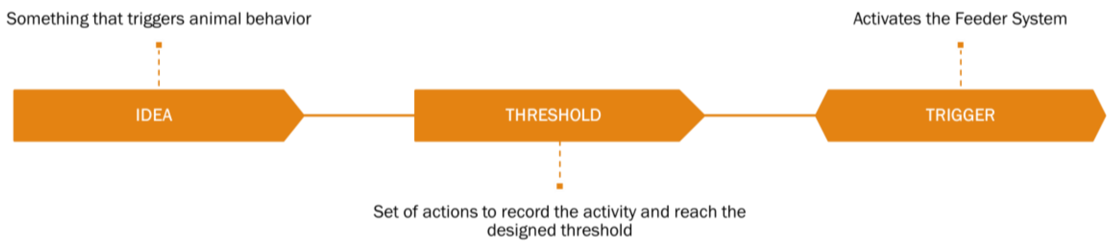

Figure 28: Conceptual Design Flow chart

Use of Minimal Food Rewards

As already described in sec 3.3.2.8, the expectation from the enrichment was to know what other types of enrichment (tactile, auditory, olfactory etc.) besides food motivates capuchin monkeys. However, for keeping the animals interested for longer durations[136], low-priority food rewards such as seeds(sec.3.3.2.8) were used as part of the concepts in the initial ideas.

5.1 CONCEPTS

5.1.1 Rattleway

This concept was inspired from rattle walkway enrichment made for macaques (Figure 29). The strength of this concept lies in the random motion of the rattle walkway making it unstable and unpredictable for the animals and thus engaging for the animals[137].

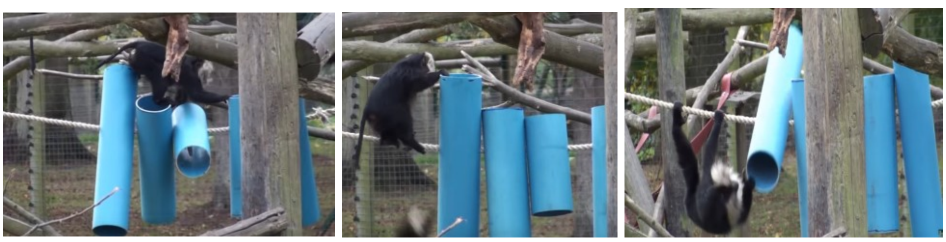

Figure 29: Macaque rattle walkway enrichment [137]

Concept: This concept makes use of hollow bamboo tubes (A-E)) (Figure 30) each of which is equipped with a motion sensor. The tubes freely rotate on the axis, which is the rope on which the monkey walks.

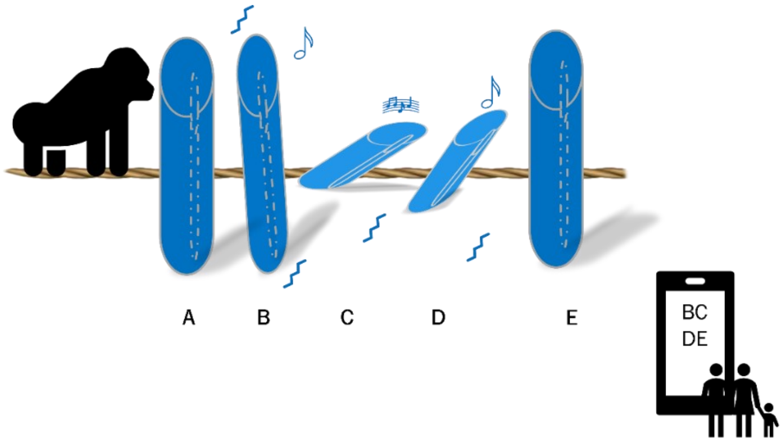

Figure 30: Concept 1 – Rattle-way

The capuchins like to explore into hard to reach place(2.1.4.1 above), like to make noise(3.3.2.2 above) and rolling wood enrichment for hanuman langurs has good engagement (See 3.3.2.6 above). When a tube rotates, the sensors in it trigger sound/vibration. Furthermore, the caregivers can pre-program a trigger sequence that activates the feeder system upon reaching a threshold. For instance, in Figure 30, the sequence BCD is rotated by the animal, and if E is likewise rotated, it fits the pre-programmed trigger-sequence, and the feeder is activated.

Control Element: Sound and lights can inform animals when the system is working or not. At other times, the walkway will simply rotate without music or sounds.

5.1.2 Hit The Tiles

This concept was inspired by a video of a capuchin monkey playing with a ball (Figure 31). The animal engages in ball play, with behaviors such as hitting and pounding observed [138].

Figure 31 : A capuchin monkey interacting with a ball [138].

Concept: This concept includes pressure-sensitive tiles and a ball (Figure 32). The tiles glow randomly at a set frequency and turn off when pressure is applied. The animals can use their natural destructive behaviours, such as hitting or pounding (2.1.4.1.2 above) on the tiles, to turn them off. When bounced "x" times, the ball activates the feeder. Tiles can be placed horizontally and vertically around the enclosure. The system complexity can be increased by tapping into short term memory capabilities

(2.1.3.6 above) of the capuchin monkeys, and/or increasing the rate at which the lights glow prompting faster responses from the animals. Also, social cooperation can be tested in this concept by triggering the feeder when two distant tiles are turned off at the same time.

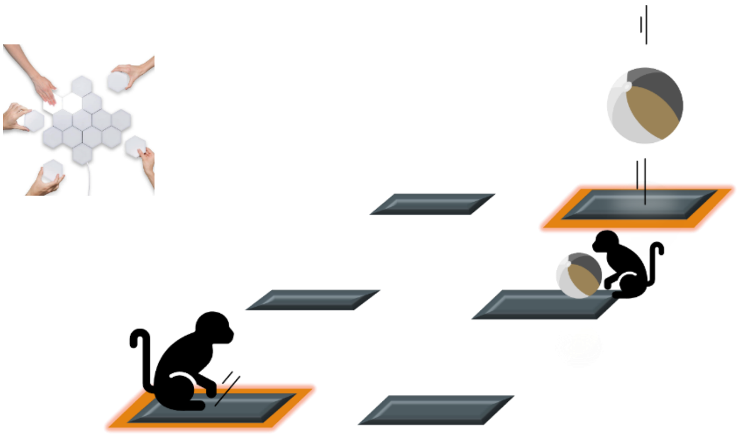

Figure 32: Hit the Tiles Concept

Control Element: The lights can tell the monkeys the system is active. Vibrations or sounds can also indicate system operation. When off, pressure isn't registered.

5.1.3 Trampoline Play

This concept was inspired from the trampoline walkway enrichment made for baboons[139] (see Figure 33).

Figure 33: Baboons playing with trampoline walkway[139]

Concept:

This concept is based on animal play and taps into stubborn determination to reach their food and tool use capabilities of the capuchin monkeys (on page 13on page 16). The animals can only reach a collapsible shelf by trampolining (Figure 34). The bench is retractable when not in use. The bench/shelf can hold a hanging basket of food or a puzzle feeder with tubes to reach honey with sticks. Trampoline pressure sensors will detect play and trigger the feeder system. Multiple setups (using other play enrichments like hoops) in between to reach the final reward can increase complexity.

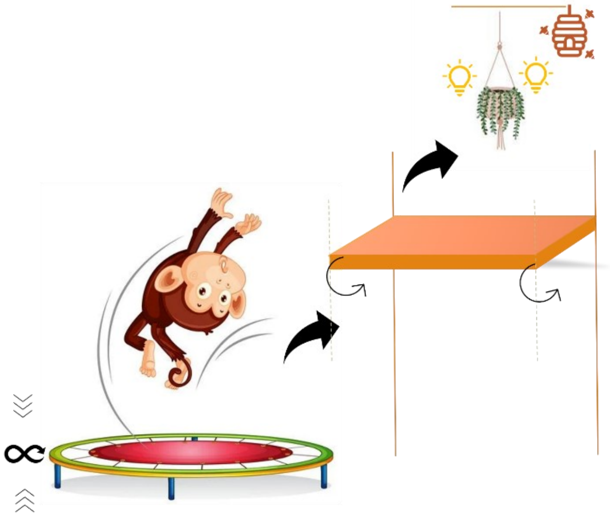

Figure 34: Trampoline Play

Control Element: The retractable shelf if collapsed discourages the animal.

5.1.4 Laser Targets

This idea was inspired by pet videos that use laser pointers to move animals and also ACI workshop[136]. Mostly for cats. Most animals(Figure 35) think the laser point is an insect and follow it[140]. Capuchins can also be included because they eat insects and bugs like reptiles (2.1.4.1 above).

Figure 35: Bearded Dragon chasing laser pointer

Concept:

A projector projects movable laser points from the Kinect sensor (they are visible in the daylight in the outside enclosure). When capuchins interact with the dots, they vanish, and an interaction is recorded. The feeder system is activated when "X" number of interactions is reached. This system can be made more challenging by introducing more complex projections[27]

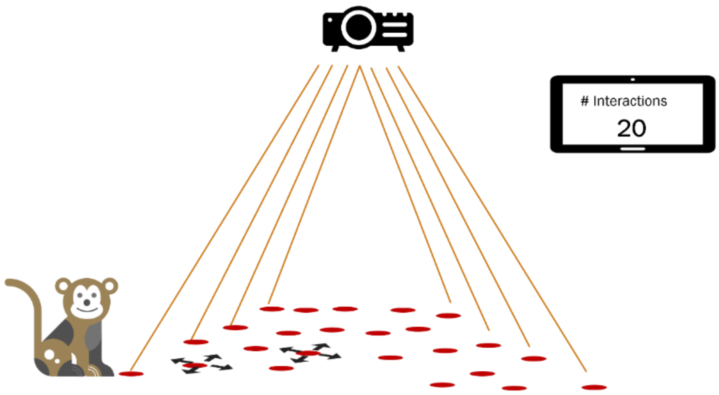

Figure 36: Laser Targets

Control Element: Sensor "On" Time

5.1.5 Foraging in Water

This concept replicates the natural foraging behaviour of the capuchins hunting for clams[141] (2.1.4.1 above) .

Figure 37: White-faced capuchin fishing for clams in low-tide [141]

Concept:

The idea is to simulate low and high tide in a shallow pool which the animals are made aware by sounds/lights. The reward (puzzle box or other foods) is accessible only during the low tide by hanging by the tail (3.3.1.2 above).

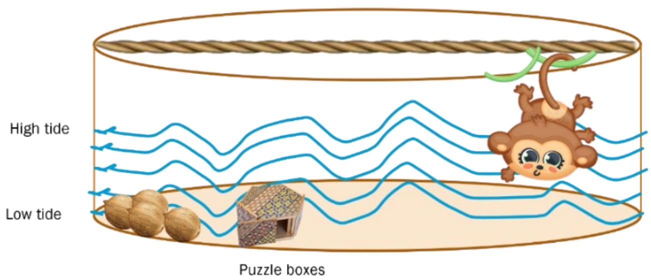

Figure 38: Foraging in Water

Control Element: Water level

5.1.6 Precision Picture

Capuchin monkeys have a powerful and precise grip (2.1.3.5) that may be employed to turn knobs. They also have excellent short-term memory (2.1.3.6) and pattern recognition abilities(2.1.3.6), as well as problem-solving abilities (2.1.4.1.2). This concept takes into account the animals' abilities mentioned above and involves matching the shape on a screen by correctly turning the knob. With the combination of every shape in the sequence, a portion of the image appears, and, at the end, a video is played (2.2.1.3). The sequence can be set by visitors and the system creates a database of inputs given and the complexity can be increased by increasing the number pf variables or using other games with this concept.

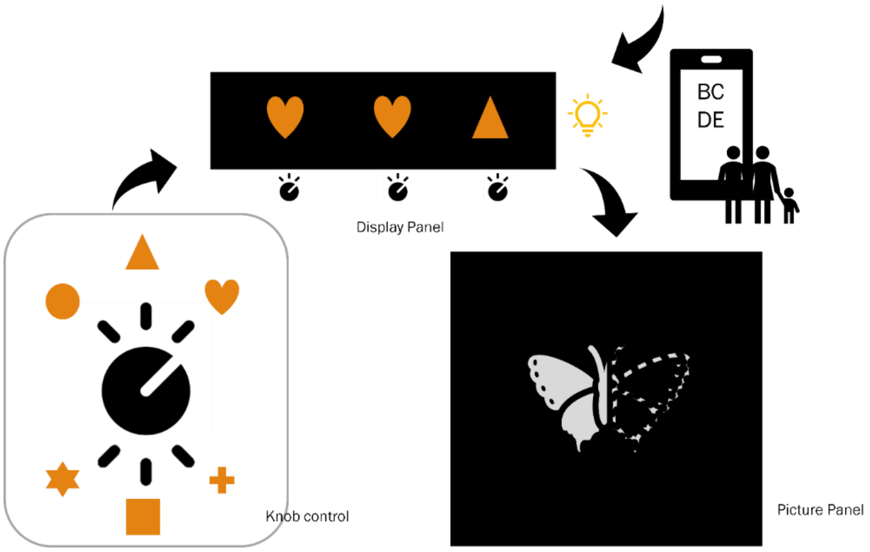

Figure 39: The precision control concept

Control Element: Lights and sounds to indicate the status of the device

5.1.7 Projections

Since capuchin monkeys are intelligent[1], interactive projects(2.2.1.3) can also be implemented if we know how capuchins respond to projected images and images inspired from the work of Webber.et.al[27].

5.2 FEEDBACK

The initial ideas were well-received by the stakeholders. Concept -6 Precision picture was discarded because it did not encourage natural foraging behavior, as observed in the wild or in captivity. Other concepts 1–5 and 7 were finalized for exploration using low-fidelity prototypes to learn more about the preferences, interaction methods and engagement.

6 LO-FIDELITY PROTOTYPING

Although the concepts were inspired by previous works or existing enrichments in other zoos, none of these concepts or sections of them were previously tested with the Apenheul WFCs or YBCs. The table depicts the breakdown of the concepts into low-fidelity prototypes that were then tested.

CONCEPT	PROTOTYPES	DESCRIPTION
C1- RATTLEWAY	Rattle	mechanical sounds - wood, metal chain and coca cola can with stones electronic sounds such as traffic sounds, African music
	Way	PVC Tubes walkway
C2- HIT THE TILES	Ball	Basket balls,
	Lights	Hexagon pressure sensing lights
C3- TRAMPOLINE	Trampoline	Toddler trampoline
C4- LASER PLAY	Laser pointer	Laser pointers were shown around the enclosure
C5- FORAGING IN WATER	Pool	Shallow sandbox filled with warm water
C6- PROJECTIONS	Projections on floor	Videos of slow-moving transitions and top view of grass footage

Table 1: Breakup of the lo fidelity prototypes derived from the initial concepts

6.1 LO-FIDELITY CONCEPTS

In Concept 1, the Rattleway was divided into two parts: (1) the walkway and (2) the rattle. The walkway was built with 4mm PVC tubes (see Figure 40). The rattle was made from a wooden bar and a metal chain. The capuchins were tested with traffic sounds (2.2.1.2) preferred by Saki monkeys and African music [2, 97] preferred by chimpanzees.

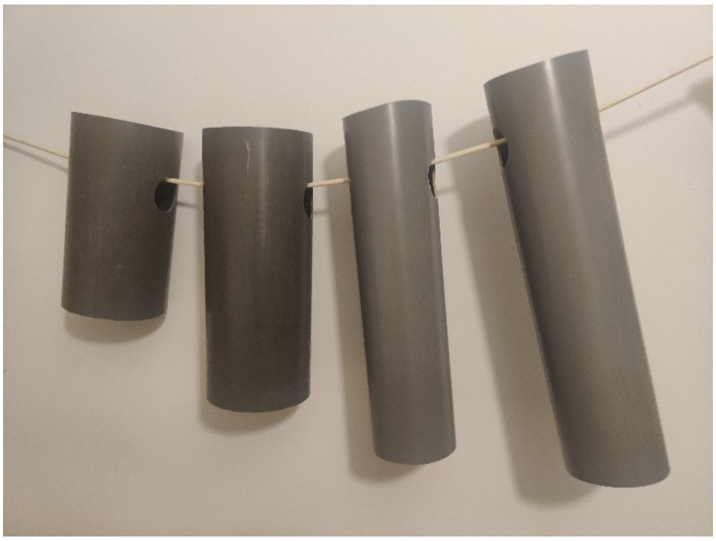

Figure 40: Rattleway with PVC tubes

Concept 2 was divided into two low-fidelity prototypes: (1) balls and (2) pressure-sensitive lights (LED hexagon panels - Figure 41). A total of three balls were used. Two basketballs and one football.

Figure 41: LED hexagon touch lights and balls used to test conceptt2

To test concept -3, a toddler trampoline (Figure 42: Trampoline) with effective endurance that could support the average weight of capuchins was used (See 2.1). It was tested at various heights with 3 kg and 4 kg weights. The rebound level was adjusted to accommodate the animals' weight and force.

Figure 42: Trampoline as lo-fi prototype for concept -3

Laser pointers were used as low-fidelity prototypes to study capuchin monkey responses to moving dots. And for concept 5, it was necessary to see if the animals would approach water. To accomplish this, a sandbox (Figure 43) already available at Apenheul was chosen and filled with warm water. The animals had previously been exposed to the sandbox as part of their enrichment.

Figure 43: Sandbox at Apenheul

Finally, two projection videos were chosen for concept 6 with the projections: (1) grass video footage (Figure 45) from a top view of 1.5m (average height of the capuchins) and (2) low speed, slow transition of multiple colors and abstract shapes video (See Figure 44).

Figure 44: Multicolour lava lamp transition video

Figure 45: Snip from the video of grass

6.2 LO-FI PROTOTYPE TEST SETUP

In February, group-2 YBCs and WFCs tested low-fidelity prototypes. First and second day of testing was 30 minutes long. Four prototypes were tested on each day. On day three, only the top three low-fidelity prototypes were retested for 60 minutes.

Day 1: Tubes, sounds, Balls, Lights

Day2: Trampoline, Pool, Projections, Laser dots

The monkeys were housed indoors with no access to go outside but they were free to go away from the room to the neighboring rooms. The days were mostly rainy with some thunderstorms which was maybe cold for the monkeys and the park was closed for visitors at that time. While the WFCs inside enclosures were well-lit, bright, with wood shavings on the floor, the YBCs enclosure was smaller dimmer and darker. There were no wood shavings on the floor. One google-nest camera was fitted to observe the interactions. Some interactions with the ball could not be captured.

On day three, only the top three lo-fi- prototypes that resulted in maximum interactions and also had highest interest among both the species were tested with white-faced capuchins.

Day-3: Rattleway, balls, lights

6.2.1 Evaluation

To evaluate the results of observations on day -3, the interactions with the lo-fidelity prototypes were categorized into three parts.

- **Interact** - A long interaction with the device for more than 20 seconds
- **Touch** - A short interaction with the device for less than 20 seconds
- **View** - Looking at the device without touching it

One **interaction count** used in this project is the duration between walking up to the device with an intention to touch and then walking away. A threshold of **20 seconds** is used to distinguish between long duration interactions (*Interact*) and short duration interactions(*touch*). This number is the average time duration spent by the animals in one interaction count.

6.3 TESTING

Both WFCs and YBCs had access to other enclosures during the entirety of the pilot testing.

6.3.1 Day-1-2

Rattleway

The Rattleway did not move as unpredictably as it did with the inspiration concept with the macaques (sec. 5.1.1). However, the Rattleway was interesting for both the YBC and WFC. They approached it with curiosity. Looking into it from the top, from the side, from the bottom and walked on it several times.

Sounds

Sounds on the other hand had mixed results. While the wood rattle had a neutral effect on the capuchins. It was not distressing or caused much of interest, the metal chain sounds when clanked with the tubes, was frightening for the capuchins.

Traffic sounds were sudden and loud. The animals showed distress signs when they were played and therefore the session was discontinued. Indian flute music and African music were not tested.

Lights

The animals repeatedly approached the lights and tried to touch the panels in multiple ways. They interacted with their hands, mouths and tongue. The change of colors did not deter their interaction. They came back many times but briefly. Although there was response to this enrichment, the lights did not pique interest for longer durations as compared to Rattleway or balls. They approached the reddish hue (red, pink) more than the other colors in general. The lights were flashing sometimes which kept the animals at a distance but after some time they figured out that the lights were harmless and approached the lights again.

Balls

The basket balls elicited some response from the animals on day 1. There were observations of play, social and attack behavior on day 1. In some instances, two or more individuals interacted with the balls at the same time. However, when the balls were reintroduced on day 3, the animals did not exhibit the same level of interest. They displayed attack behavior towards the balls. The basket balls had the highest duration of continuous interaction spanning up to roughly 3 minutes and 45 seconds. The animals pushed a ball nearly 56 times in one interaction count. Two individuals simultaneously interacted with the ball while a third individual closely observed before lifting the ball and throwing it with force across the floor. Furthermore, there were multiple instances of *hitting and pounding* behaviors observed with the balls

YBC:

In case of the YBC, they were rather reluctant on day 1 and did not touch the balls at all. However, on day 3 when one ball(basketball) was put into a food basket, there were repeated interactions noted. There was no interaction with the balls on the ground.

Trampoline

There was minimal interaction with the trampoline. WFCs approached the trampoline three times in a group while showing a threat face. They did not jump on it. The YBC did not interact with the trampoline at all.

Laser Pointers

Both the WFC and YBC followed the laser pointers. Multiple individuals followed the laser dots together with cooperation. They tried to catch the laser dots and eventually looked for the source of the laser.

Pool

There was very little interaction with water in the pool. Although warm water was provided, the capuchins did not want to get into the pool. While the WFC perceived the water as drinking water, the YBC stayed away the whole duration of the observation. “Possibly in summer, in high temperatures. Not for winter” say the animal welfare expert.

Projections

Projections of videos (pg.- 46) was shown to the WFCs. The Camera couldn't capture the reactions to the projections. Brief interactions of 2-3 sec were noted. But the animals came back again and again. The projections could not be projected into the enclosure area for the capuchins to interact with them due to the limitation of the space and safety of the projector. The projector could not project into the enclosure of the YBCs. Videos on laptop was shown instead.

6.3.2 Day-3

The top three most interacted lo-fi prototypes were tested again with the WFCs and the YBCs. While the test results of the interactions of the YBC were noted as observations, they are not quantitatively evaluated since the next iteration was carried out only with the WFCs.

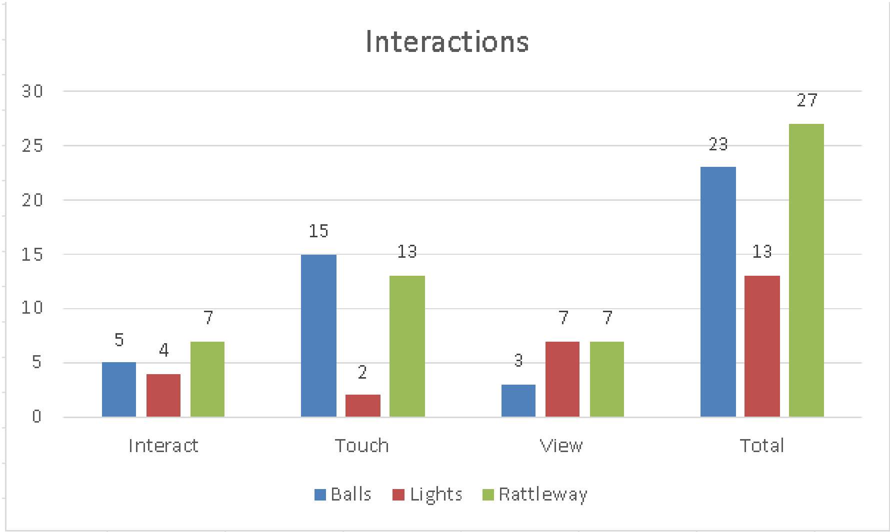

Figure 46 : Count of Interactions of white-faced capuchins on day 3

The count of interactions with each of the three prototypes is depicted in Figure 46. The Rattleway had the most interactions with a total of 27, followed by the ball with 23 and then the lights with 13. Moreover, the Rattleway was the most intriguing, with seven counts of interactions lasting longer than 20 seconds with a total duration of *4min 29 sec*, and there was considerable curiosity in exploring it from above, sides and the bottom. The balls had the second-highest number of interactions with the highest number of "touch" interactions.

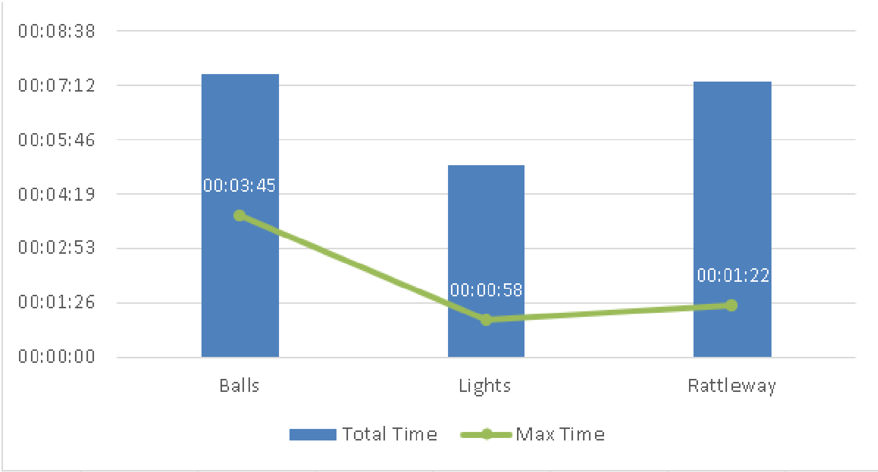

Figure 47: Comparison of Duration: balls vs lights vs Rattleway

In addition, when considering the time spent with each interaction, the data indicates that although Rattleway had a greater number of interactions, the time spent is not equivalent. The balls reported a maximum engagement length of over 7 minutes, with the longest encounter lasting 3 minutes and 45 seconds. This encounter entailed 56 pushing movements.

6.4 Lo-Fi Prototyping- Stakeholder Feedback

The feedback from animal welfare expert and the caretakers for the different lo-fidelity prototypes tested is summarised in the Table 2 below:

LO-FI PROTOTYPE	YBC	WFC
Balls	Engagement only after ball in food basket. 1st day approach to the ball was with fear, maybe approached it as a novel item. No interaction with bright yellow football.	Approached with caution at the beginning. One individual was very sure about the ball and bounced it around the enclosure. Hit/pound was also observed. Oemie the eldest capuchin perceived it as threat and approached it only when her daughter was with her. Nevertheless, there was interaction with the ball.
Light	On Day1 they did not approach at all. But on day 3, there was interaction with lights. They tried touching the different lights. Kept coming back.	Good interaction on day 1 and 3. the bright light did not deter their interaction.
Rattleway	One or two individuals interacted with Rattleway	Many individuals occasionally looked into the tubes to see what is inside from top, side and bottom. There was little interest to interact persistently.
Laser	Highly interactive response to moving light	Highly interactive response to moving light. There was social tolerance observed. Three individuals worked together in order to catch the laser point.

Projected videos	curiosity observed. They popped up often to see what is happening - but it was a brief visit of 2-3 sec. But kept coming back	curiosity observed. They popped up often to see what is happening - but it was a brief visit of 2-3 sec. But kept coming back.
water sandbox	No interaction	Mistook it for drinking water
Trampoline	No interaction	Interacted once - but did not jump.
Music	stressful	did not test

Table 3 : Lo-fidelity Testing Feedback Summary

6.5 DISCUSSION

In day1-2 testing, the Rattleway - did not move as unpredictably as the macaques in the video (This could be due to the fact that capuchin monkeys are much lighter than macaques. As a result, the PVC tubes were able to maintain their balance. However, Rattleway elicited numerous exploratory behaviours in the animals. The balls elicited animals' play, social, and threat behaviours. It is possible that the animals perceived the random movements and texture of the basketball as a predator. laser pointer piqued the animals' interest, and there were instances of social tolerance observed. Looking directly into the laser source, on the other hand, can be harmful to the animals, and additional research shows that long exposure to laser targets causes anxiety in animals. This concept was rejected due to the potential for animal harm. Pool and trampoline showed no interest among the animals while. While projections elicited some positive intermittent response from the animals, due to space and installation limitations, the projections were not considered for future iterations.

On day-3 WFCs showed considerable interest in all three prototypes – Lights, Rattleway and balls. There was undeniable interest in the lights, which explains why it has the most "view" interactions. But persistent participation is low. There were long sustained interactions noted for the Rattleway and the balls. Balls recorded the highest number of "touch" interactions which could be due to its unpredictable nature. As soon as it is touched, it immediately moves.

The monkeys displayed myriad natural behaviours involved in foraging while engaging with the Rattleway. They explored inside, outside, from the side, walked on the rope to see through to interact with the Rattleway. Although it was a see-through prototype, the monkeys kept coming back to interact with this enrichment. Furthermore, there was no aggressive behaviour observed during these interactions. With the balls, although there was a quite a strong element of engagement and play behaviour was displayed with multiple individuals engaging with it together, the monkeys also possibly perceived it to be a threat and responded accordingly by throwing, hitting and pounding. It is also possible that due to its resemblance to orange food items, the animals tried hitting and pounding them. There were also more occurrences of social cooperation in interacting with the ball. However, YBCs did not interact with the balls unless they were placed in the food basket at a height.

Based on observations and prior experience with the animals by the stakeholders, it was concluded that the YBCs were slower to approach with new enrichments and are more delicate in their interactions while WFCs showed a much more active and aggressive approach which is also supported by literature (2.1) and focus groups(3.3.2.2). This means that the threshold to interact with final enrichment design would be higher for the YBCs compared to WFCs. Also WFCs are more disruptive than YBCs[2], therefore if the enrichment can withstand interactions from WFCs, probably it can be extended to YBCs as well.

Furthermore, the caretakers noted that the lo-fi prototypes were interesting but not rewarding to the animals. As a result, future iterations must take into account what the animal gets as a reward for interacting with the enrichment.

Based on lo-fi tests, feedback from the stakeholders and revisiting the project objective to cater to both species (3.4.1), it was concluded that the Rattleway was the preferred direction for the future iterations. Lights and sounds were not rewarding enough yet. So, the future iteration concepts must also have some kind of reward for the animal for interacting. The prototype needs to be strong and sturdy to withstand the destructive interactions of the animals even if it is just for one session.

7 Experiential Prototype

Based on the previous chapter, this chapter covers the process of developing an experience prototype. Answering design questions unique to the Rattleway and natural foraging behaviours is part of the creative process. This is followed by a discussion of how to make these concepts appealing to capuchins over the long term, and the preferable route is determined by the stakeholders' feedback.

7.1 Ideation Process

Based on the lo-fi user tests it was decided to continue from the Rattle-way. Meaning a tubular shape that can be rotated by the animals, hanging in mid-air and which can be look at /in is a reasonable starting point. Also, natural sounds like wood rattle (sounds. 49) had a neutral effect on the animals which is also supported by literature (2.1.3.3).

Figure 48: Rattleway with PVC tubes

7.1.1 Design Challenges

From the previous section, three important takeaways and questions are as follows:

- *Natural behaviour* – what is the natural behaviour of interacting with the rattle-way and how to link these to natural foraging behaviour of the capuchins?
- What is the *reward for the capuchin monkey* when the individual interacts with the enrichment?
- How to *maintain interest* such that animals come back to interact multiple times?

7.1.1.1 Natural Behaviour

Figure 49: WFC looking for insects inside a flower(photograph by Amanda D. Melin[142]*) and looking beneath leaves(Photograph by Voshadhi*[143]*)*

There are various natural foraging behaviours observed with the Rattleway(6.4) that are also observed in the wild capuchins (Figure 49)(See 2.1.4.1.1) such as looking what is inside from top, bottom and sides . And exploring around it.

The foods that capuchins consume can be classified into plant-based sources and animal-based sources after reviewing literature (sec.2.1.1, sec.2.1.4.1) to understand their food habits and how they manage to procure these foods in the wild.

Plant based sources can be broadly classified into wild fruits and nuts while the animal-based sources can be broadly classified into honey, termites, ants, wasps, larvae, insects, clams and other small prey. Table 4 summarises the foraging behaviours associated with seeking each of the food sources from (sec.2.1.1, sec.2.1.4.1).

FOOD SOURCE	ASSOCIATED FORAGING BEHAVIOUR	DESIGN CONSIDERATIONS
WILD FRUITS	Manoeuvring through spikes and thorns [2].	We do not want to hurt the animals in any way. And therefore, not a preferred option
NUTS	Planning and foresight	Can be used. But how to give the animal cues?
NUTS	Hitting and pounding	Can be used. What materials can be used that are safe and durable enough for repeated hitting and pounding action
HONEY/ ANTS/ TERMITES	Use of sticks as tools	Sticks can be used to poke each other – and can cause harm during fights. So not a preferred direction

WASPS, BIRD NESTS, SMALL VERTEBRATES	Grab and run	What can be grabbed? and what will motivate this behaviour?
CLAMS	Hit and rub	Can be used
INSECTS	Look under the leaves	Can be used
INSECTS	Sifting through gravel	This is a ground activity, and we are looking for an arboreal activity. So not a preferred direction

Table 5: Foraging behaviour based on food sources

7.1.1.2 Reward for Animals

From sec.3.3.2.3, it is known that low priority food like seed mix can be used to encourage interaction with the device to begin with. Also, the animals enjoy anointing themselves which can also be an alternative to food rewards (sec.3.3.2.2,sec. 2.1.4.2). From the lo-fi user testing, it was seen that there was a lot of interest in lights (6.5) and there was some interest in sounds(sounds, pg49) which is also supported by literature (2.1.3.3).

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7.1.1.3 Maintaining Interest

Initial brainstorm with stakeholders (3.3.2.7) looked into using multi-step cognitive challenges to access rewards such that the animals were rewarded for various behaviours. Another approach would be to make the concept *exploratory* such that it can tap into simple behaviours with repeated actions for longer duration to gain rewards. However, there needs to be a surprise element for the animal to be motivated to do repeated actions.

7.1.2 Design Concepts

Building on the above-mentioned elements regarding natural foraging behaviour, providing rewards and maintaining interest, three concepts based on Rattleway were created: (1) Flower Tubes, (2) Modular Discs and (3) sounds. Both concepts (1) and (2) offer food rewards which can be prevented from monopolisation by having multiple of them which would encourage movement among the animals often seen during foraging (2.1.5). These concepts were discussed with the stakeholders to determine the course of action for the next iteration.

7.1.2.1 Flower Tubes

The first concept is flower tubes (Figure 50) is based on exploratory approach. The targeted natural foraging behaviours are (1) Looking under the leaves for insects and (2) planning and foresight. Upon interacting with the system, animals are initially rewarded with lights and sounds, followed later by low-priority foods such as seeds or anointing materials such as garlic. Instead of a physical rattle as used in the lo-fi tests, natural insect sounds will be triggered.

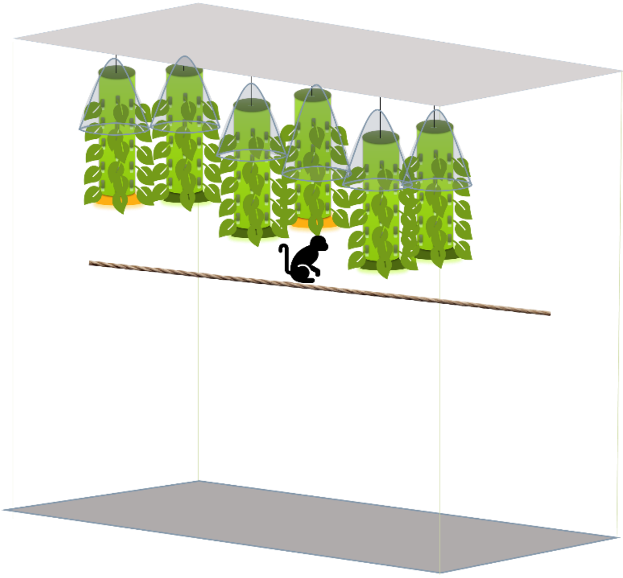

Figure 50 : Flower Tubes concept

Multiple tubes covered with leaf flaps suspended from the ceiling dispense grains or garlic, depending on the type of feeder (see Figure 52 and Figure 54), when animals interact with it when the light below the tube is orange (Figure 50). The light below the tube slowly turns from green to orange representing the blooming of a flower, which becomes a cue for the monkeys to start looking for any food in these tubes. They can access the tubes only from the ropes below. Approach from other directions can be limited by using cones as shown (Figure 50). To make it more challenging for the animals, these tubes can further be interconnected to create a more complex cue (sec. 7.1.3). The sounds are triggered when the animals lift the leaves to look inside (6.4) while the flower tubes rotate freely from the point of suspension like the lo-fi Rattleway prototype.

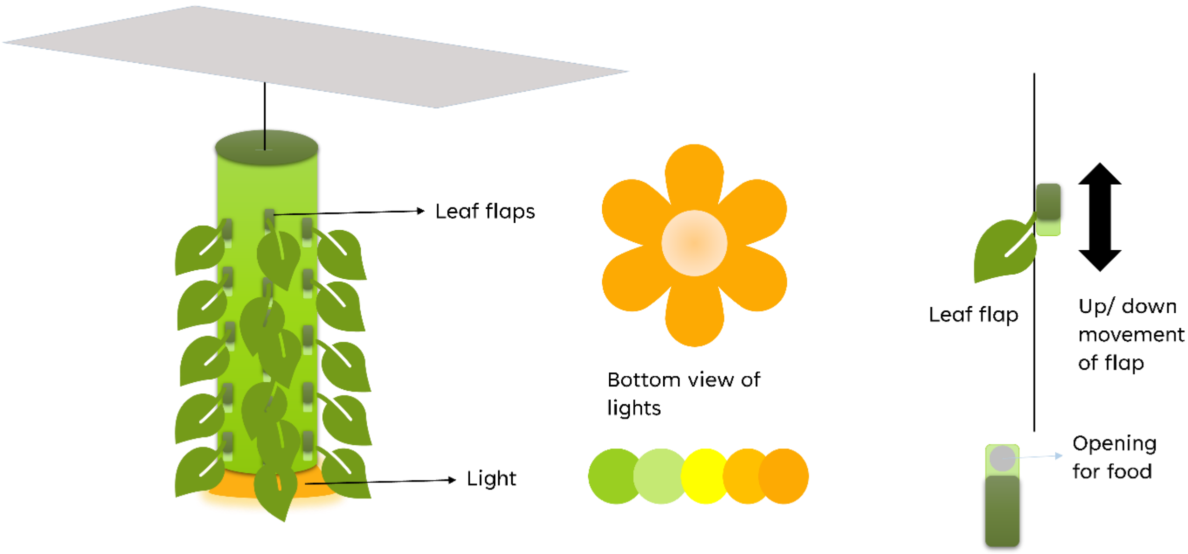

Figure 51: Flower Tubes – Detail

7.1.2.1.1 Feeder Systems

Two feeder subvariant notions are conceptualized, one for low-priority foods such as seeds and the other for substances used for anointing, such as garlic pods. The food rewards are dispersed when “x” number of interactions are registered by the feeder system.

7.1.2.1.1.1 Feeder Subvariant -1 – Seeds

This feeder subvariant (Figure 52) stores small seeds in bulk in an inaccessible compartment inside the tube, while randomly releasing a small number of seeds in few of the access points. This can encourage foraging behaviour in the animals.

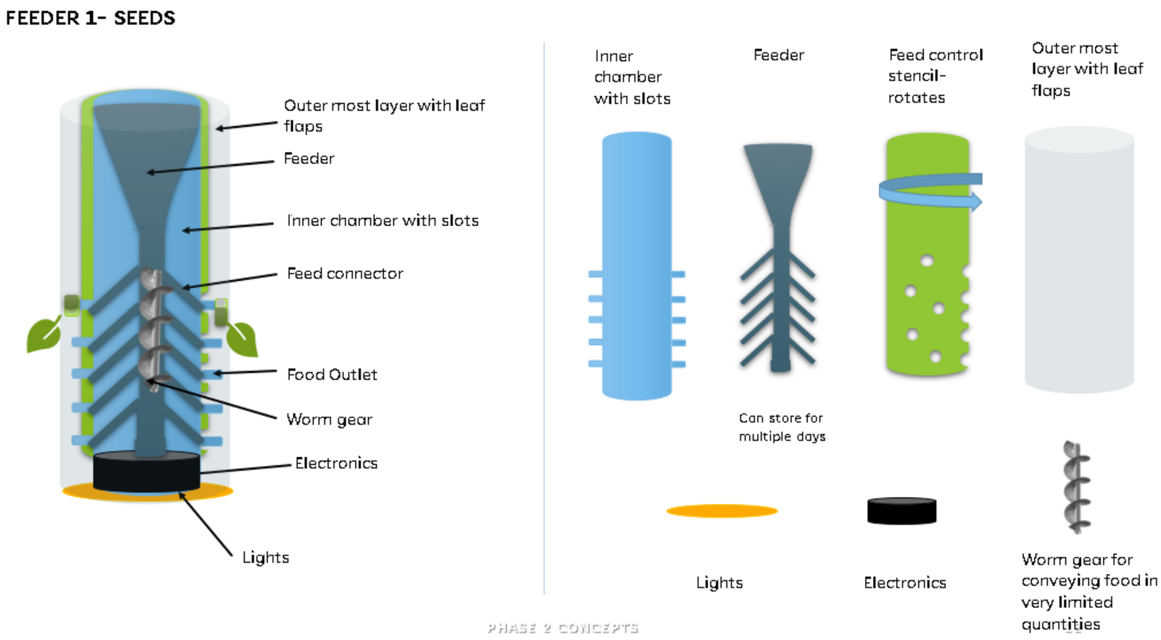

Figure 52 : Subvariant -1: Seeds

7.1.2.1.1.2 Feeder Subvariant -2 – Garlic

This feeder subvariant (Figure 53) stores garlic pods in bulk in an inaccessible compartment inside the tube, while randomly releasing a small number of them from a central release, which is dispersed over larger area on the floor due to the release height. This may allow all group members to access the reward.

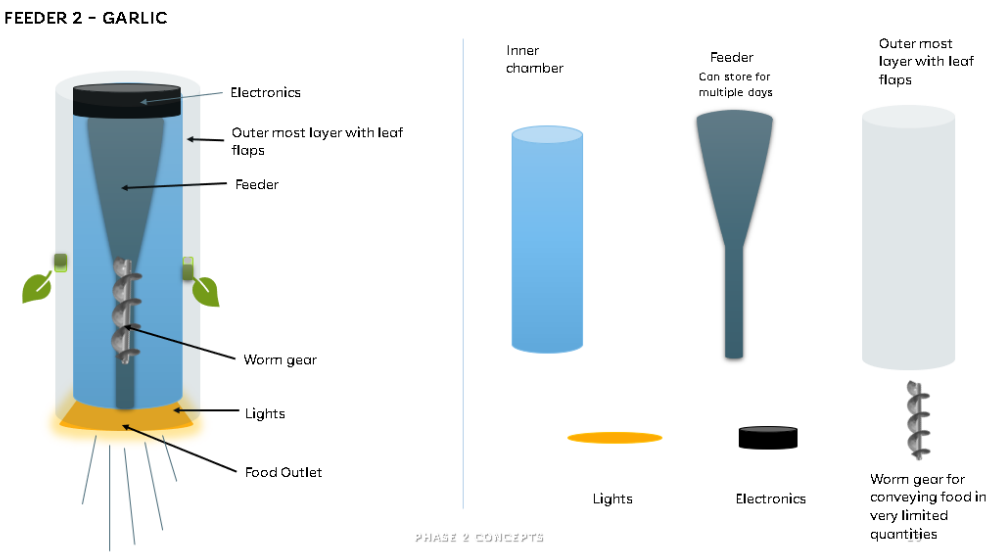

Figure 54: Subvariant -1: Garlic

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7.1.2.1.1.3 Multiple Access Points for Food Dispersal

Lo-fi testing with balls, observations of YBCs manipulating piece of bamboo (3.3.1.2 and literature (2.1.4.1.1) points out that the capuchins are persistent. To ensure that all the individuals gain access to food, after feedback from stakeholders, the feeder subvariants were further modified to provide multiple access points (sec 2.2.3, sec. 3.4.1for animals of all ranks to reach the food rewards.

In Subvariant 1 with seeds, multiple access points are provided in the tube itself where only a few of them have food at a given time. In Subvariant -2 with garlic, food is scattered as much as possible by adding multiple heights below the feeder dispersion (Figure 55).

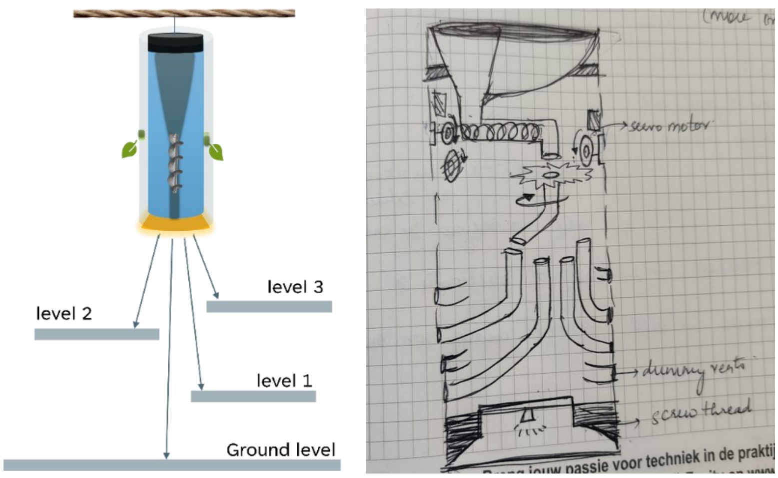

Figure 55 : Multiple access points for Feeder subvariants: (a) Garlic (b) Seeds

7.1.2.2 Modular Discs

The second concept is modular discs that stack up to a tube (Figure 56). It is based on cognitive approach. Capuchins forage for shelled animals (2.1.4.1.2) in the wild using their wit and hands (power and precision grips, sec. 2.1.3.1). This is also the target behaviour in this concept. Lights and vibrations are cues to the animals to interact with the system and they are rewarded in return with low-priority foods such as seeds or anointing materials such as garlic. Like Rattleway in lo-fi user testing, the system is freely suspended. And when multiple of these systems are installed, then monopoly of a single device can be mitigated.

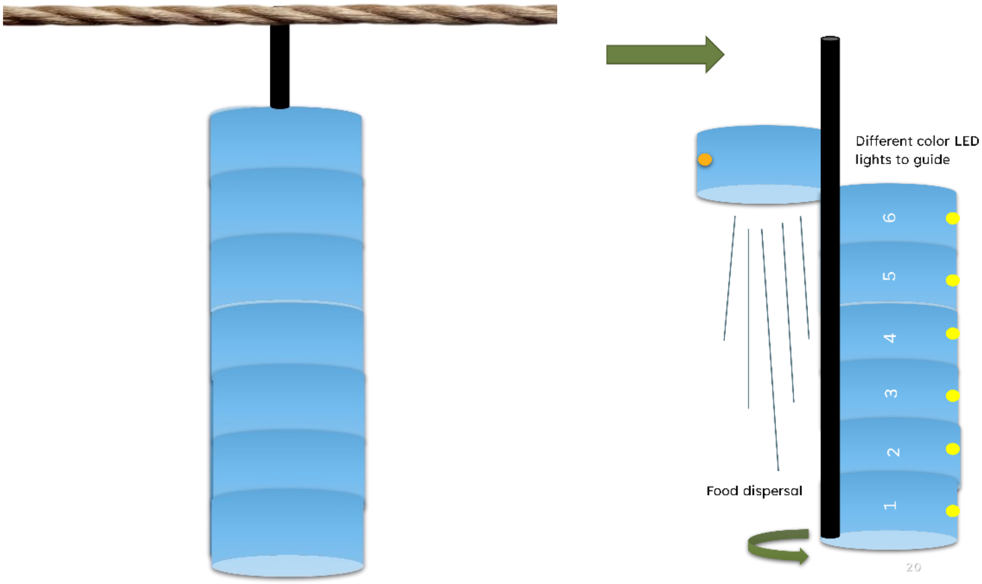

Figure 57: Modular Discs

The animals have to figure out the sequence of rotating the modular bits to release the food. For instance, to release rewards in the first compartment, the sequence to be followed is 1-2-3-4-5-6 which will be guided by lights. This can further be made more complex by changing the opening sequence.

The limitation to this concept is that this concept uses partially exposed mechanical parts that can be broken overtime.

7.1.2.3 Concept 3 – Sound Concert

The third concept Sound Concert (Figure 58) is based on exploratory approach and is non-food rewarding. According to Apenheul' s carers, capuchin monkeys like making noise (3.3.2.2), which is also the desired behaviour in this concept.

Hollow bamboo tubes/metal tubes of varied thickness and length can be used to create a natural sound making a xylophone. Or PVC tubes can be used instead with digital electronics. When the tubes are hit or looked into from top or bottom, lights glow, and a natural sound is produced. Looking inside and exploration behaviour is supported in this concept.

In case of PVC Tubes, digital sounds can be used mimicking the nature sounds such as flowing water, rain or sand. A ball can be hung nearby to be used to strike the tubes (building on the reasonable interest in the orange basketball in the lo-fi prototype session, (Balls, pg. 50)), as well as to protect the electronics.

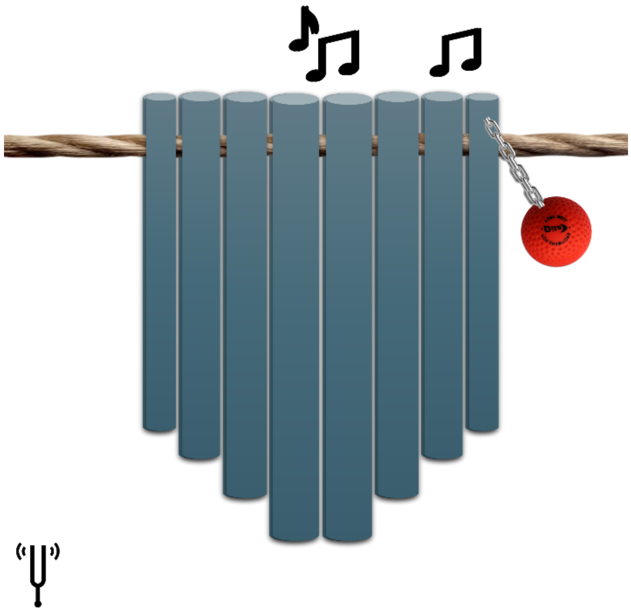

Figure 59: Sound concert

7.1.3 Maintaining Interest – Fruiting tree concept

When searching for food in the forest, monkeys move from one fruiting tree to another. Nature is plentiful. Everything is accessible at the appropriate time. A fruiting tree emits a scent that draws monkeys to it. Not every fruit is mature enough for consumption. Thus, tree resources are not depleted overnight but gradually over time. Using the same logic, it is possible to inform intelligent capuchin monkeys that if they perform a particular action, a certain consequence will ensue.

Several devices all with same concept or each with different concept, can be installed throughout the room to create a more engaging concept that is dynamic and interesting for the animals, like the fruiting trees in nature (Figure 60). This adds dependencies between devices that might trigger social behavior and prevent monopolization (Figure 61).

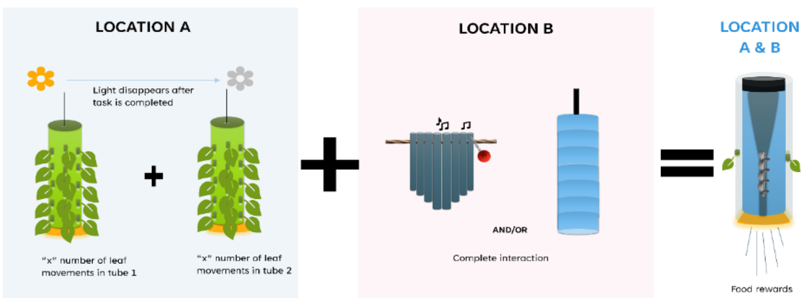

Figure 62: Rattleway – Long term engagement concept

For instance, in an example scenario shown in Figure 63 , when the animals engage with tube 1 and then tube 2 at position A, the devices at location B are activated. Food rewards will be released from a feeder at both places such that all individuals have access to food when they engage with either of them for "x" threshold duration or longer.

7.2 Feedback From Stakeholders

The three concepts based on Rattleway i.e., Flower tubes, Modular Discs and Sound concert were introduced to the stakeholders by giving a presentation through video and slides.

Flower tubes was the most well-received concept among the stakeholders of the project. Since it is based on an explorative approach involving many simple natural capuchin monkey foraging behaviors and can be easily modified independently to maintain interest in the animals for longer durations. This concept was the final chosen direction for the experiential prototype.

The second most favored concept was Sound concert. *"Would the monkeys actually use this to make and create sounds?"*. It is unknown so far and would be interesting to see if they would. However, the sounds should be acceptable to both the caretakers and the capuchins as well.

Modular discs received the least favored response. This is partly because this concept has the risk of injuries for the animals while rotating. Furthermore, it has the limitation of exposed electronics which is deterrent for the goal of the project since it means it cannot be placed in the enclosure for longer periods of time as stated by animal welfare expert.

8 SETUP DESIGN

The chosen concept, flower tubes as mentioned in the previous chapter has two main parts: (1) A sensing and triggering sounds system and (2) a feeder system. Due to time constraints the latter part, was foregone. Together with stakeholders, the decision was made to build the sensing and triggering system first in order to test the interaction and interest in animals. If time permitted and adding food would benefit the concept the most, the feeder would be built at a later point.

This concept has one part that can be in contact with the animals which is the leaves. Therefore, it was important that these were made of non-toxic or otherwise dangerous materials. The main design considerations were regarding the sensing, leaves materials, the lights, and the sounds. The remainder of this chapter will first go by each of these. Then how these parts were combined and realized is described. Finally, the chapter ends with a description of a pilot test and subsequent needed revisions to the prototype.

8.1 ELEMENTS

This section investigates into the most suitable sensing technologies, the optimal leaf material that can be employed, and the sounds that will attract capuchin monkeys.

8.1.1 Sensing Technology

Multiple options were explored to find the right technology that facilitates “lifting of leaves” interaction (sec 7.1.2.1). When number of leaves lifted reach a certain threshold, lights and sounds are triggered. Three test categories were explored: (1) Capacitance, (2) Mechanical and (3) Electronics sensors.

Capacitance

Simple capacitance (Figure 64)was tried. By having a conducting sheet with a wire abridged between two leaves, it was possible to detect touch on the leaves. However, the presence of a wire external to the device can cause harm to the animals if other safety measures would break down and therefore this option was ruled out.

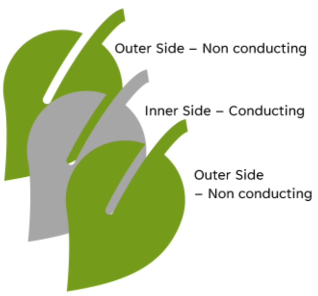

Figure 64: Capacitance contact

Mechanical

Two methods (1) weight-based contact (Figure 65) and (2) spring-based contact (Figure 66), were tested that were mechanical in nature. This method rules out the presence of wires externally and in this respect is safer than the capacitance method mentioned above.

In both the systems, the idea is that in stationary position, the circuit remains open. When the leaf is pulled, due to the force applied, the circuit of the system is completed and the this can be registered in the system through a counter.

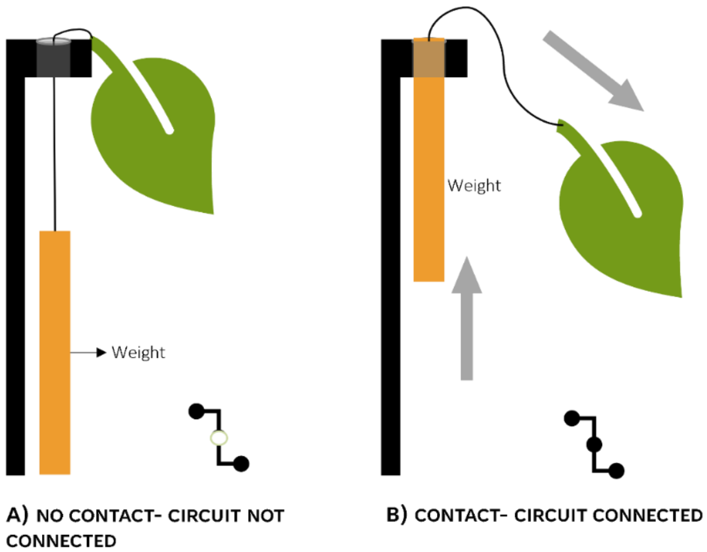

Figure 67: Weight-based contact sensing

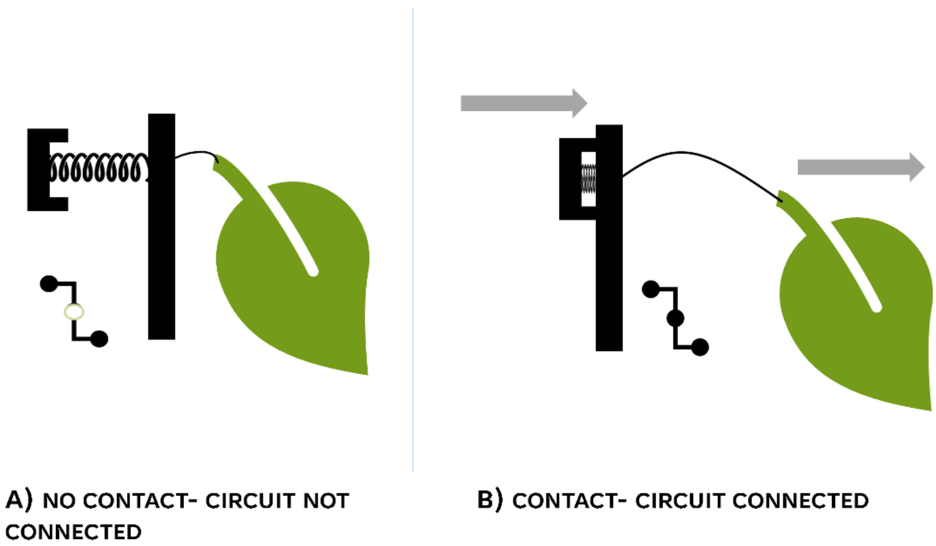

Figure 68: Spring-based contact

In both these systems, although there are no electronics on the outside, the downside is that it does not replicate the action of lifting the leaves which is the main prerogative of this design. Getting the sensitivity to fit this kind of interaction would require quite some additional work, and therefore this was also not chosen.

Electronic Sensors

Finally, other relevant electronic sensors such as proximity sensors, light detecting diode sensors, light dependent resistance sensors and several others were explored. The task was to find the most cost-effective solution while giving the most reliable results. After evaluating these sensors, Light dependent resistors (LDR) were seen as the most promising direction as they do not need direct contact, can facilitate "lifting of leaves" interaction and are the most cost-effective among the other sensors investigated.

Although the photodiodes also showed similar characteristics, the LDRs gave better performance with more robustness to change of weather and temperature. According to the experience of the HCI technical expert, the photodiodes were more unpredictable under different light conditions which is undesirable because it can lead to unwanted food releases if this system is combined with a feeder.

8.1.2 Leaves

Next it is important to look into appropriate materials for leaves that can aid this sensing system. There are many considerations from 3.4.1 for choosing the material for the leaves outlined below:

- *Non-toxic* – to ingest or lick or bite
- *High Strength* – should not tear off on biting or pulling
- *Flexible* – Since the interaction is to lift the leave and look underneath them, the material needs to be flexible with high tensile strength so that it doesn't tear or break off easily.
- *Smooth edges* – to ensure animals are not hurt during the interaction
- *Look* – aesthetically pleasing to interest the animals
- *Opacity* – medium to high opacity to enable the sensors to detect the interaction
- *Low cost* – since multiple leaves are needed which might have to be replaced in regular intervals, the material needs to be cost effective

Multiple materials were explored to find the most suitable option for use. Table 6 shows the materials investigated for the use of prototype evaluated against the parameters with a colour code that ranges from black (Highly likely) to White (Most unlikely).

MATERIAL	USE CASE	Non-Toxicity	Strength	Edges	Look	Flexibility	Opacity	Low Cost	REMARKS
Plastic	Terrariums and aquariums								Although safe for terrariums and aquariums, they are not tested with primates and therefore may cause problems on ingestion
Flexible Resin FLFLGR02	Bendable and compressible 3d material								Chronic aquatic hazard - unwise to use with animals
Starch based	Animal chew toys								Most products are made up of corn starch which high in sugar.
PLA and PVA	fast prototyping 3d printable material								Easily broken into tiny bits which is potentially dangerous for ingestion

Silicone	For medical implants								It can easily be broken down into tiny bits when the material is bitten which is potentially dangerous for ingestion
Silk based	Artificial Plants								The dye used for the colour of the leaves is toxic
Natural leaves	All the trees								Although they can break down easily, since they are non-toxic without any other side effects, this is the best option

Table 6: Evaluation of different types of materials for making leaves.

Colour code range: Black (Highly Likely) to White (most unlikely)

Since a suitable material that satisfies all the conditions was not found in this research and considering the time constraints, the prototyping proceeded with natural leaves which would need replacement. Upon further research into native (Netherlands local region) leaves which are also non-toxic on ingestion, white chestnut leaves are chosen for this study. They are abundant, long, soft, safe and are reasonably opaque, don't tear easily and easy to obtain. Due to these reasons, the white-chestnut leaves were chosen for this project. In a follow-up, a durable material that is similar to natural leaves is preferred for future uses.

Figure 69: White Chestnut leaf and branch@ Hengelo

8.1.3 Sounds

Lo-fi testing revealed that traffic sounds were distressing to the capuchin monkeys (6.3.1) even though they were preferred by Saki monkeys(2.2.1.2), and capuchins showed a neutral effect to natural sounds made by the wood rattle(Sounds, sec 6.3.1). Therefore, going back to literature (2.2.1.2)[2], natural insect and prey sounds were implemented instead.

The sound files included the sounds of crickets, bugs, frog, mosquito, wasps, grasshopper, bees and so on. A total of 24 sounds of 10-30 sec duration were shortlisted to be played. These sounds were played to the HCI expert and the Animal welfare expert and the caretakers before testing with the animals.

8.2 BUILDING THE SETUP

The enrichment must be able to sense the lifting of the leaves and then activate the sensors. Then after “x” times, it should be able to trigger sounds and lights. Literature points out that capuchin monkeys perceive parts as a whole (2.1.3.6) and therefore it is likely that they would perceive the leaves to be part of a tree and therefore be interested to interact with the enrichment. However, it remains unknown how they will react to digitally produced sounds of insects and prey.

This section delves into building the components of the flower tubes from the elements described in previous section.

8.2.1 The Sensing system

To do as mentioned above, the sensing system was developed in four iterations.

1: Basic circuit of LDRs with Arduino which was tested for “lifting the leaf” interaction

2: Combining the circuit with lights and sounds

3: Adapting the circuit for changing light and weather conditions

4: More than one sensing at the same time

8.2.1.1 Basic LDR Circuit

The basic circuit with six LDRs (Figure 70) was tested for “lifting leaves” interaction by using small pieces of tape to control the amount of light falling on the sensor. When the small piece of tape is lifted away from the sensor, the sensor triggers the LED in the circuit.

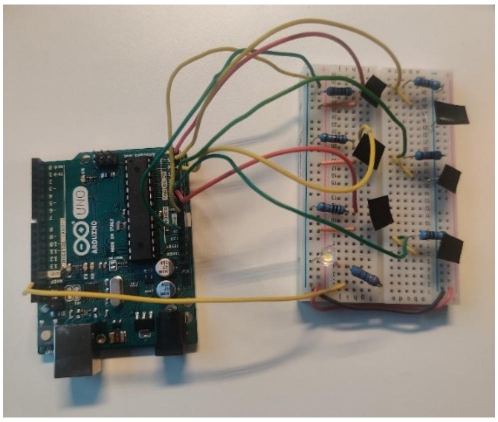

Figure 71: Iteration -1 - LDR Circuit

8.2.1.2 *Adding lights and sounds*

In this iteration feedback (Figure 72) in the form of sounds (up to 10 s) and lights (up to 10 sec) was added to the previous setup to measure the lifting of a "leaf". Furthermore, it was noticed weather conditions (cloudy, sunny, indoor light and so on) influenced the amount of light on the sensor which influenced the sensor output. For instance, when the weather was cloudy the sensors did not respond in the previous iteration. To mitigate the influence of weather, threshold for each weather condition was measured and multiple test conditions were incorporated into the program.

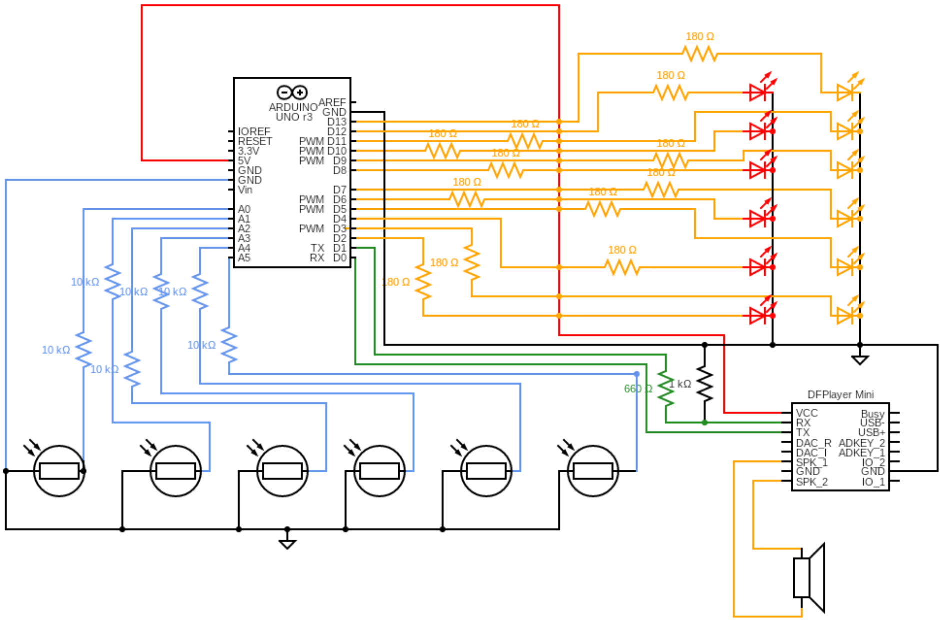

Figure 73: LDR Circuit with lights and sounds

When a leaf flap (black tape) is lifted, it activates the sensor. The program looks for specific weather condition, and when the condition is matched, the sounds and lights are triggered. The threshold of each LDR however, is dependent on the quantity of light passing through. This makes the sensing system weather and time-dependent which means that the sensing system will be able to respond to the interactions only when a certain weather and time condition is met. This is not desirable since the one of the objectives (3.4.1) of the project is to develop enrichment for both indoor and outside enclosures which interests the animals for longer durations.

8.2.1.3 *Adapting to changing light and weather conditions*

To remove time and weather dependency, two methods were investigated out of Method-II was implemented in the program.

Method -1 necessitated one sensor to be measure the time and weather condition. This means this sensor must always access the external conditions and should not be covered which is not very practical for enrichment design for animals. Method -II uses continuous comparison of sensor values and measured the difference between the present and the former state in this project. When the difference between states exceeds a predetermined threshold, it indicates that the leaf is lifted.

Based on multiple manual trials, a threshold of 170 is chosen and implemented into the code. So, the sensing system now does not detect when the weather condition changes, indoor /outdoor condition changes, individuals pass by and only responds to lifting of leaves.

8.2.1.4 Triggering multiple sounds and lights simultaneously

The sensing system is unaffected by time and weather conditions as mentioned above. However, at any instance, only one interaction is registered which triggers the sounds and lights for ten seconds, during which time no other interaction is registered by the sensing system.

This problem was solved in this iteration by removing the delay from the program and registering up three simultaneous interactions. The number three was selected following numerous trials. When the first one fades away, the fourth one can begin, allowing for immediate but not excessive feedback.

This was accomplished by adding hardware to the sensing circuit, including additional sound players, a separate battery unit to power them, and upgrading the Arduino to Arduino Mega.

In short in this final iteration a leaf could be lifted, which is sensed in such a way that the weather has little influence. Each lifting of the leaf, triggers lights and sounds. However only three sounds and lights can be played at one time. The first started feedback is stopped after the third simultaneous interaction (less than the about 10s sound loops) and instead a response is given to the last trigger.

8.2.2 Leaves

Due to the project's use of natural leaves, the original design was adjusted to include branches with leaves rather than only leaves. Real leaves lose their shape when torn from their branches. To prevent this, the project employed branches instead of leaves. The branches must be secured in such a way that they cannot be pulled away easily and the clamps do not do any harm to the capuchin monkeys.

8.2.2.1 Clamps

Different branch holders were designed adhering to the following design decisions:

- Easy to put in and take out by caretakers
- Difficult to come off even when pulled by the capuchins
- Clamps material should be safe for the animals.

Multiple designs were made using PLA which is non-toxic. But finally, after assessing the risk of breaking the clamps into bits if bitten, it was deemed unsuitable for further development. Instead, clamps were designed that can be placed inside the device itself such that only the branches are out.

One limitation resulting from this choice is that more light shines through on the sensor as the branches cannot align to zero-degree w.r.t the side walls (See Figure 74).

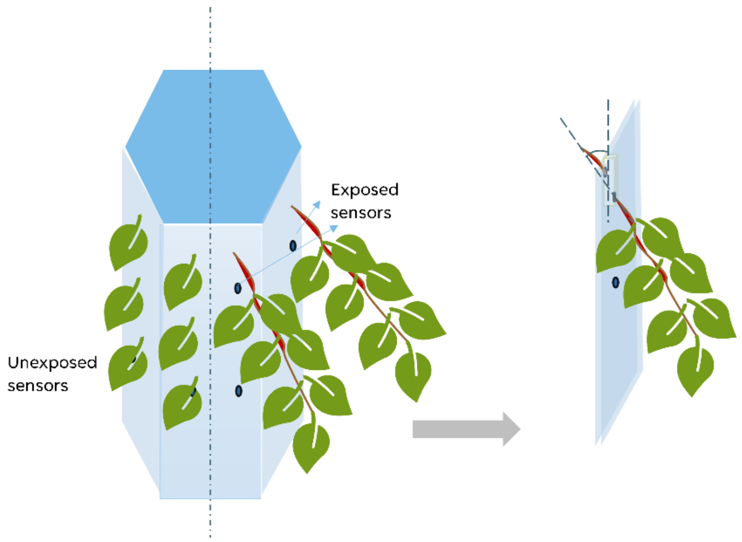

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Figure 74: Comparison between use of leaves and branches

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8.2.3 External shell

The animals have maximum contact with the exteriors of the enrichment. Therefore, the external shell must be safe for them and cause no harm (3.4.1). Furthermore, the enrichment much look natural and aesthetically pleasing for the animals to interest them as stated in sec. 2.2.3.

Taking into account of the aforementioned requirements, the external shell was made with wood of 10mm thickness since it is natural, nontoxic and is strong. It can also be laser cut easily into desired shapes. For parts to fit easily, a hexagonal shape was considered. For more strength, the box was made from 10mm wood with finger joints which aids in greater strength to the box and can withstand lateral forces much more resiliently. (See Figure 75). The edges were sanded down to remove sharp corners.

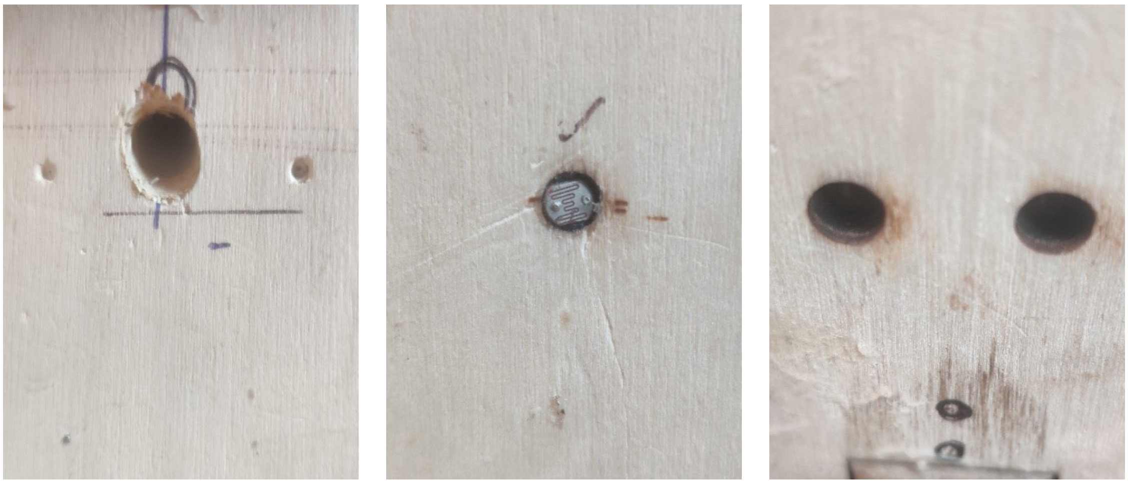
Figure 75: External box. Left to right: (a) top view (b) finger joints (c) smooth corners

The box can be opened from the top for keeping the branches and charging the battery. The bottom could also be opened in case the electronics housed within, have to be repaired or otherwise replaced during or in between the test sessions.

8.2.4 Assembly

Most of the external components like the LDR sensors, the LEDs and the branch clamps were fitted to the device by making appropriately sized holes such that there is no direct contact with these items from the outside. The LDR sensors were enclosed in the sides of the device as shown. The LEDs were enclosed at the bottom of the device as shown.

Also, speakers were attached at the bottom lid with holes for the sound to come out. (Figure 77). The top removable lid was fitted with a chain to hang the device.



(a) branch (b) LDR sensor (c) LED

Figure 76: External component placements

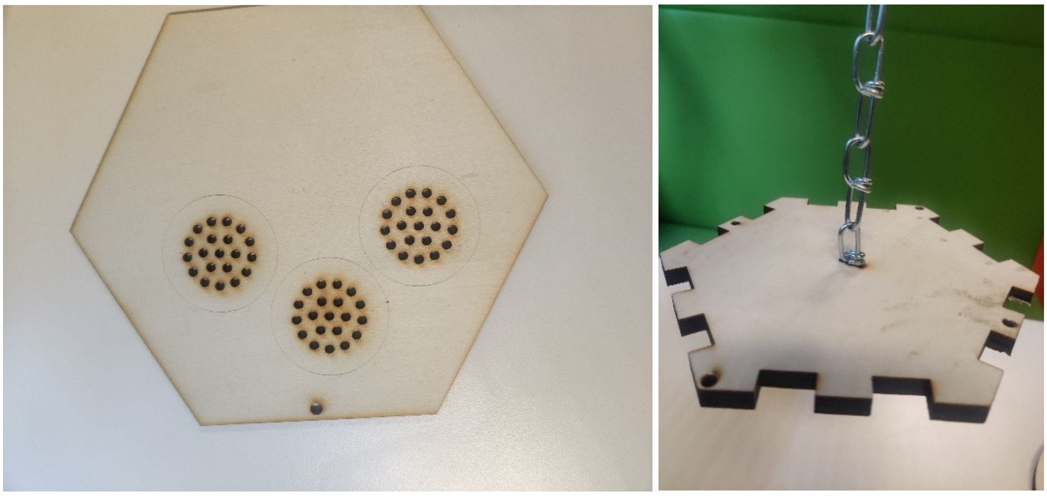


Figure 77: Bottom lid and the top lid

All the electronics were attached to the bottom lid of the box such that they can be removed to repair in the future.

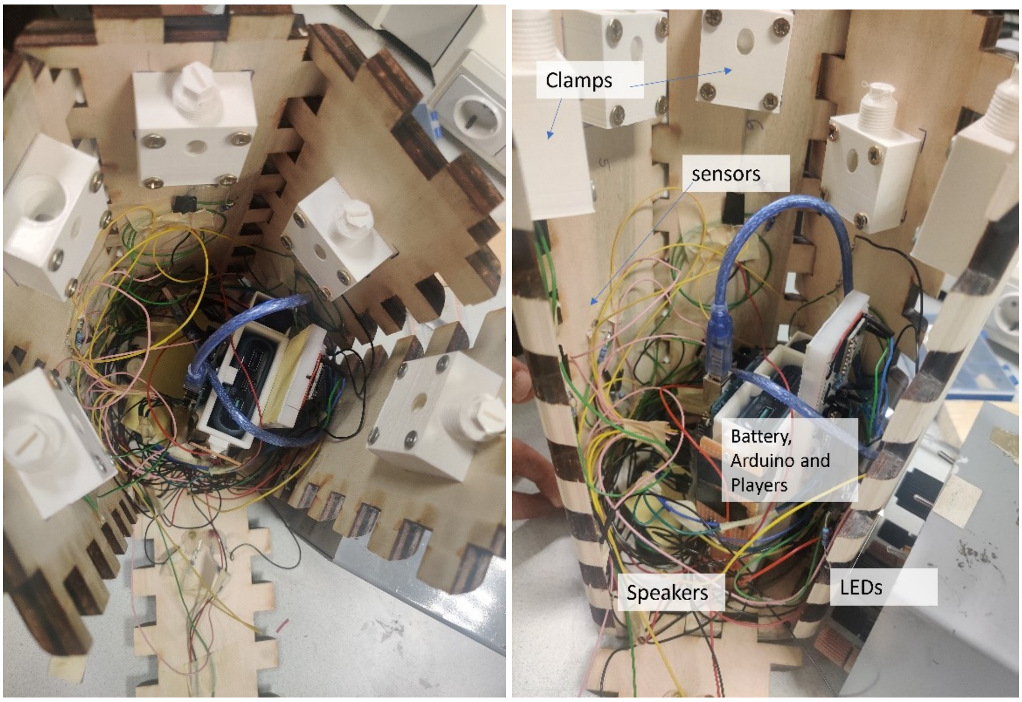


Figure 78: Electronics inside the device

Figure 79: Pilot Prototype

8.3 PILOT PROTOTYPE TESTING

The Pilot prototype was tested with the white-faced capuchins for 20 min under the supervision of the caretaker and animal welfare expert. The pilot prototype was ethically authorized by Apenheul and caused no discomfort or pain to the animals, in accordance with the ethical guidelines (chap 4). The animals had access to other enclosures during the entirety of the pilot testing.

The prototype was setup to hang from a height that was reachable both from the ground and from above. The animals interacted with the prototype in multiple not anticipated ways. There was curiosity in the device. They sifted through the branches multiple times causing the device to trigger sounds. The animals ran away immediately but came back to the device again to interact. As time went by more brazen interactions were witnessed. On multiple occasions, the animals lifted the device by the chain and tried to throw it, they tried biting the top and bottom of the device, pulling and swinging the device more than anticipated and many more detailed in chap 10.

The pilot test revealed that in order to protect the device and prevent any possible harm to the animals (we realized there might have been a chance that a finger would get stuck), the chain should be replaced with a snap hook which is used to fasten food baskets at Apenheul. Furthermore, the removable parts of the device which are the top and the bottom should be reinforced to withstand stronger interactions from the animals. As the device was hanging below an accessible rope rather than above the rope from which it could be accessed the caretaker mentioned the situation in which monkeys might urinate on the device which can be detrimental to the animals and the device itself.

8.3.1 Reinforcement

To address the above-mentioned potential fallouts, the lid was redesigned with a larger spanning surface that extends outside the device to give it protection from water from the above. This also gives protection against biting.

Furthermore, the lid had two layers – one that's fitted to the device itself and the second one that covers the device and is secured by 6 screws from the outside. The nuts for these screws are placed in between the two lid layers to avoid injuries to the animals (See Figure 80)

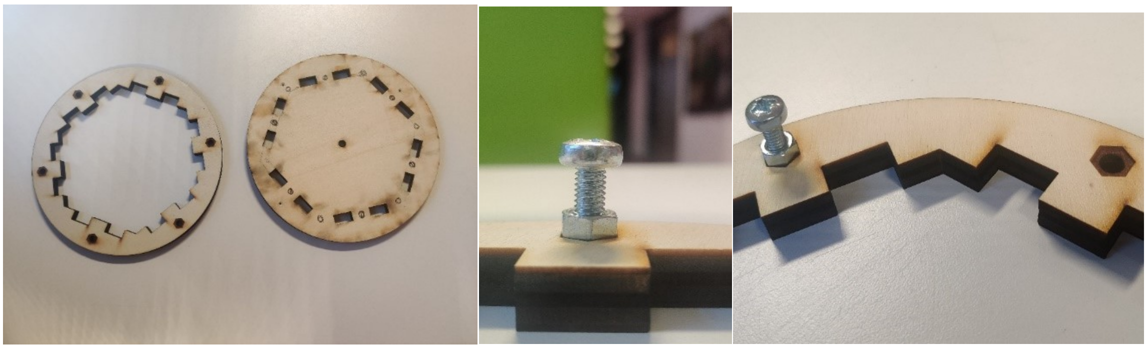


Figure 80: Reinforcing the lid – Redesign

Also, the chain was replaced with a snap-hook that limits the amount of displacement of the device from the rope. The prototype was tested for endurance and strength before testing with the animals. The final prototype is as seen below:

Figure 81: Experiential Prototype

9 TEST SETUP

The final prototype's safety and sturdiness were evaluated after reinforcement by the stakeholders. All the below mentioned experimental procedures were ethically authorized by Apenheul and caused no discomfort or pain to the animals, in accordance with the ethical guidelines (on page36).

9.1 PARTICIPANTS

The participants in the study are the seven white-faced capuchins (WFC). They were selected for the final tests based primarily on the availability and the tendency to earlier on explore an intervention.

9.2 PROCEDURE

Two conditions were studied to test the engagement of the device. Condition A is the baseline condition with no enrichment and Condition B is with enrichment in two sessions. Throughout the experiment, the monkeys have the freedom to walk out to outer enclosure or stay in the inner enclosure or interact at their own will.

9.2.1 Baseline condition: No enrichment

The no enrichment condition observes the behaviour of the WFC in their inside enclosure during a regular day for a duration of 60 min. The observation room has existing enriching elements such as a hoop and a ramp.

9.2.2 Condition 2: With Enrichment

In this condition, animals were observed in the same setting with an enrichment device present. The animals had the option to interact or not interact, to engage with something else in the room, and to occupy the space of their choosing. The animals had access to both the interior and exterior enclosure throughout the whole observation time, in accordance with ethical requirements. (On page36).

To lessen the impact of novelty, the experiential prototype (EP) was first introduced to the animals for 30 minutes prior to the observation study. There was a gap of 3 hours between the first introduction session and the observation session.

To reduce the effect of novelty, the experiential prototype (EP) was introduced to the animals for 30 minutes in the pre-observation session. After a gap of 2 hours, 60 minutes, observation session was carried out in the same settings as the baseline condition.

9.2.3 Data Collection

This study used qualitative analysis as pointed out in [114] and the ACI evaluation methods discussed in literature (on page25). A mutually exclusive ethogram [26] to document positive and negative behaviours (See Table 7),count of interactions with enrichment (enrichments in room / experiential prototype), and quality of interactions were measured. Scan sampling method at every 10 sec[144] was used to quantify behaviours and continuous sampling [144] was used to record the quality of interactions.

BEHAVIOUR	CODE	DESCRIPTION
STANDING ERECT	St	Standing upright, bipedal or quadrupedal, and stationary
SITTING	S	Just sitting (no additional activity), head held high, immobile
LOCOMOTION	M	moving from one location to another /walking/running/climbing
FORAGING	F	food manipulation
SITTING AND EATING	SE	seated while eating
GROOMING	Gr	Physical contact with the hands, teeth, or tongue, or close visual proximity
ENRICHMENT USE	E	Interaction with swing or hoop
SOCIAL	So	Cooperation between two or more individuals
SOCIAL PLAY	SP	Nonaggressive interaction with another capuchin including wrestling, rough and tumble play, chase play
AGGRESION	Ag	Directed at another individual/object, facial threat, object shake, or slapping, grabbing, biting, wrestling
PACING	P	Repetitive, rapid movement around the top level of the enclosure, with frequent head-rolling in the middle of the course
OUT OF VIEW	OV	Not in view of the camera
SCRATCHING	Sc	Scratching one's body

Table 7: Ethogram of capuchin behaviours [26]

It was difficult to recognize each individual on the footage without the assistance of the caretaker, resulting in the inability to calculate the length of these behaviours for each individual. Instead, group behaviour was measured.

Quality of interactions were measured in two ways- time wise[26]and behaviour wise. Time wise coding (See Table 8) involved three categories: view, touch, and interact[26]. *View* when an animal approached the enrichment, looks at it, and sits near it without touching it. *Touch* encounters are those in which the animal made brief, intentional touches and intentional touches which were not brief touches were coded as *Interact.* Clark[145] notes " there has never been a duration or proportion of time proposed as an 'acceptable' level of enrichment use". However, for the purpose of this study, a 20 sec time window is used to distinguish between *touch* and *interact* in case of repeated brief interactions by the same individual as used for lo-fi analysis (sec 6.2.1).

Interaction type	**Description**
View	Looking at the enrichment, sitting near it, no touch involved
Touch	Brief touches with the enrichment and walk away immediately
Interact	Deliberate intentional touches with the enrichment,

Table 8: Time-wise Interaction coding[26]

Behaviour wise coding corresponded to a sub-ethogram of behaviours directed towards the experiential prototype only. These behaviours were unique to the interaction with the experiential prototype and hence do not apply to the in-house enrichments. The definitions are included in Table 9 below:

ENRICHMENT USE BEHAVIOURS		CODE	DESCRIPTION
DESTRUCTIVE	Facial threat	Ft	Showing facial threat
	swinging	Sw	sway / move the object back and forth non- aggressively
	lifting object	Lo	Lifting the object by rope/ hands
	biting	B	biting the object
	attack	At	jumping towards the object/deliberately throw
	hit	H	slap with hands /kick the object
EXPLORATION	explore side	Es	investigate the leaves, sensors and sides of the enrichment, looking into branch clamp inlets
	explore top	Et	investigate the top of the object - look around it from top.
	Rotate sides	Ro	Rotating the object to observe
	explore bottom	Eb	investigate the bottom/ looking for sounds/ looking near LEDs

Table 9: Enrichment use behaviour ethogram

9.3 ANALYSIS

Not all behaviours listed in the ethogram(Table 7) were observed during the study. The ethogram behaviours were regrouped into broader categories to provide more meaningful behavioural summaries inspired from literature findings [26].

REFINED LIST OF BEHAVIOURS	CODE	BEHAVIOURS INCLUDED
RESTING	R	sitting, lying
FOOD RELATED	FR	eating and food manipulation
ACTIVE	A	locomotion,
ENRICHMENT USE	E	Interaction with enrichment
SOCIAL	So	Cooperation between two or more individuals, social play, grooming
ALERT	SA	Standing erect and being vigilant of the surroundings
PACING	P	Pacing in ritualised, distinct unchanging pattern within the enclosure
SCRATCHING	Sc	Scratching
AGGRESSION	AgI	Contact and non-contact aggression towards conspecifics: Jumping forward to attack, object shake, or slapping, grabbing, biting, wrestling, showing facial threat
	AgE	Rough exploration behaviour towards device: Jumping forward to attack, object shake, or slapping, grabbing, biting, wrestling, showing facial threat - Directed at the enrichment (coded as per Table 11)

Table 10: Refined list of behaviours

Furthermore, post-implementation interviews were held with the animal welfare experts and the caretakers to qualitatively assess the entire study.

10 RESULTS

This section describes the results of the two observed conditions.

10.1 BASELINE CONDITION: NO ENRICHMENT

The animals' behaviours in the no-enrichment condition which is also the baseline condition were coded from sec.9.3. Here the behaviours and interactions with the environmental enrichment in place is coded into the enrichment- use. A total of seven individuals were observed. Figure shows the behavioural time budge results for the baseline - no enrichment condition.

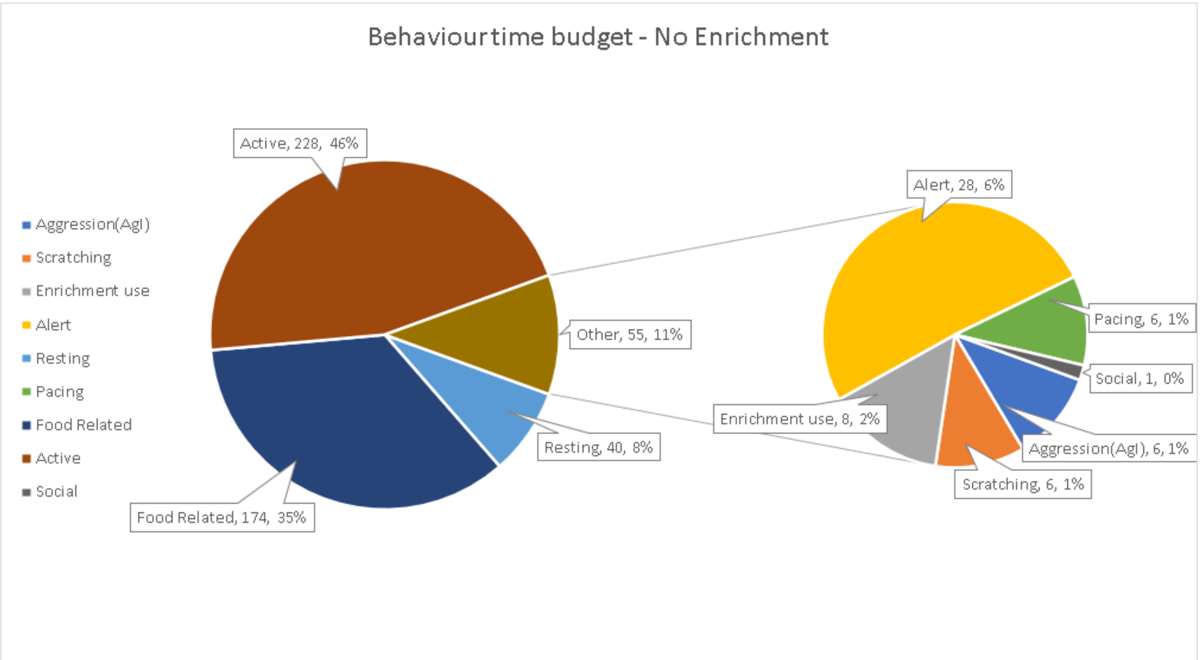


Figure 82: Behaviour time- budget results - No enrichment condition

The majority of time (46%) was devoted to active behaviour that entailed locomotion. Following this, 174 instances (35%) of animals eating and/or manipulating food were observed. Resting which included sitting and lying down was prevalent, accounting for 8% of the time. The remaining 11% consisted of alert behaviour (6%), which is when the animal is standing erect and is vigilant, in-house enrichment use (2%), scratching, pacing and aggression towards another individual (1%) and social behaviour was less than 1%. Grooming and social play were not observed. Many times, it was observed that the animals liked to view outside the enclosure through the window the room while eating.

There were eight instances of enrichment use, of which five were to obtain food from the ramp and two were to move around the room for a duration of three to four seconds each. The hoop was only *touched* once.

During the observation period, there were many external sounds some of them were loud banging sounds heard from outside the observation. The animals responded to these sounds in aggression (such as use of facial threats at each other, jumping towards another individual), scratching, pacing behaviour and showed multiple signs of alert behaviour. On an average, 1.509 individuals out of seven individuals were present in the observation zone.

10.2 CONDITION 2: WITH ENRICHMENT

Following the introduction of the experiential prototype in the first session preceding the observation study, the animals became familiar with the device for 30 minutes and began biting off branches 20 minutes later. Within 3 minutes of beginning the observation study, the animals bit the branches off.

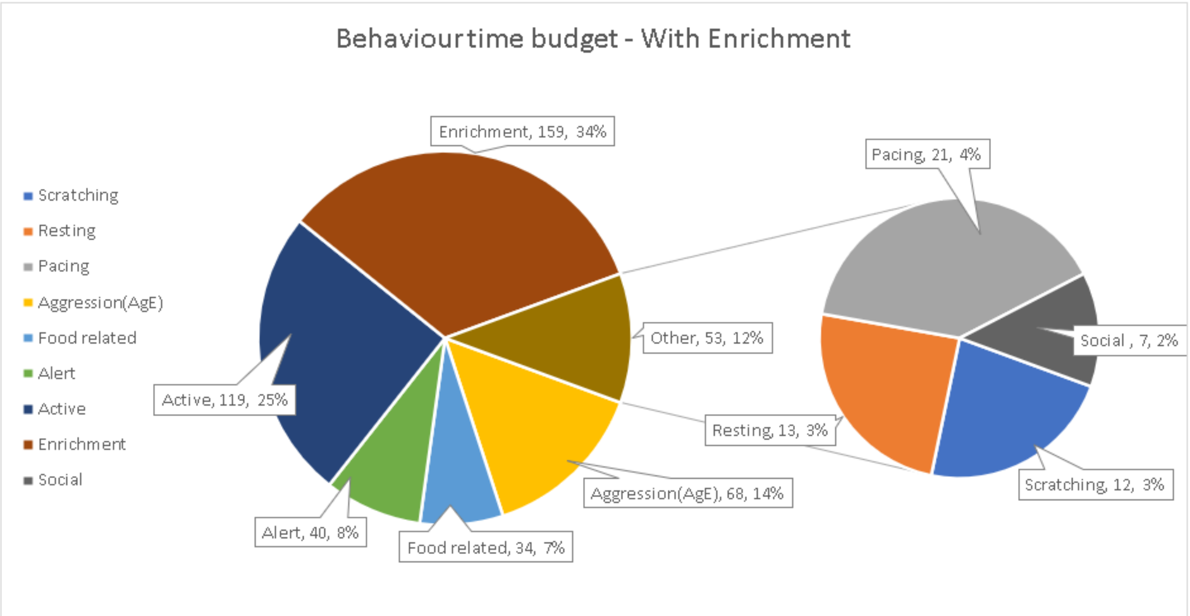


Figure 83: Behaviour time-budget results - With enrichment condition

Figure 83 shows the behavioural time budge results for interactions with the enrichment. The time budgets in this condition are different from those in the baseline condition. Animals spent most of the observation time in enrichment use (34%), locomotion (25%), standing /sitting in attention (9%) and depicting aggressive behaviour (15%) towards the enrichment (experiential prototype) and no instances of aggression towards other individuals were observed. Food related behaviour and resting behaviour which occupied most of the time budget in baseline condition reduced to 7% and 3% respectively while self-directed behaviour such as pacing, and scratching increased to 4%and 3% respectively. Social behaviour increased to 2% with the enrichment where multiple individuals worked together to figure out the device, however no instances of social play and grooming behaviours were observed. There were 7 instances when two individuals tried to look and figure out the enrichment together.

Of the 68 instances of aggression (AgE) where rough exploration behaviour was observed, all of them were rough exploration towards the enrichment and none were a directed at another individual. Furthermore, there were loud sounds and commotion heard during the observation which was out of view. There was a fight on the outside island at the start of the observation period and some of the individuals like “Oemie” could not enter the observation room because of this. The fight did not seem to be related to the enrichment device (personal communication with caretaker). Therefore, the number of individuals observed was six instead of seven in the condition 2.

The camera angle was slightly off in this observation and some parts of ground activity and activity near the far-end window could not be observed. On the average, 1.337 individuals out of six were seen in the observation zone during the condition 2.

10.2.1 Interaction with Experiential Prototype

The interaction with the experiential prototype was typically ad-hoc and intermittent rather than a focused activity. There were a total 56 instances observed where the animals approached the device and interacted (touch, view, interact, sec 6.2.1) with it. The animals *interacted* with the device for 25 min 35 sec with a maximum continuous interaction of 2min 46 sec observed, touched for two minutes and *viewed* for 1min 21 sec. Figure 84 below shows the enrichment use behaviours coded based on sub-ethogram in Table 9. (Sec Evaluation6.2.1)

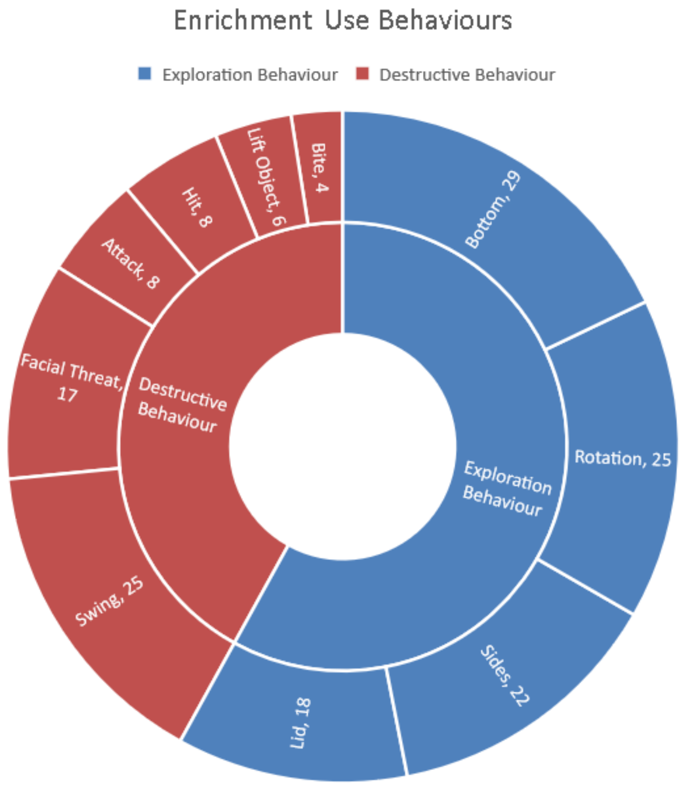


Figure 84: Enrichment Use Behaviours

The animals interacted with the device in a variety of ways. Exploratory behaviours (90) outnumbered destructive ones (40). (68). The insect sounds from the device made the animals more alert, and they demonstrated numerous aggressive behaviours, such as displaying a facial threat towards the device (17), hitting or kicking the device (8), attacking it by jumping towards it (8), and swinging it back and forth (8). (25). One animal hoisted the device via the rope twice before tossing it to the ground. The individual then raised the entire device, placed it on a railing, and hurled it with strength.

They also demonstrated several exploratory behaviours over the duration of the observational study. They rotated the device (25) to examine its interior from the sides. They responded to the lights and sounds and attempted to touch them. Once the animals had removed the branches, they focused on trying to see inside the device through the holes of the branch clamps, LEDs, and speakers.

10.3 Baseline Condition vs Condition 2

A comparison between baseline condition (no-enrichment) and condition -2(with enrichment) is shown in Figure 85. It compares the time budgets for behaviour between the two conditions. In condition-2, positive *behaviours* such as enrichment use, and social behaviour have increased significantly by 151% and 6%, respectively compared to condition -1 while there is an 80% decrease in food-related behaviour, 67% decrease in resting activity and 47% decrease in active movement compared to condition -1. In the negative behaviours, there is 62% increase in aggression ,13% rise in alertness and roughly 10% increase pacing and scratching in condition -2 compared to condition 1.

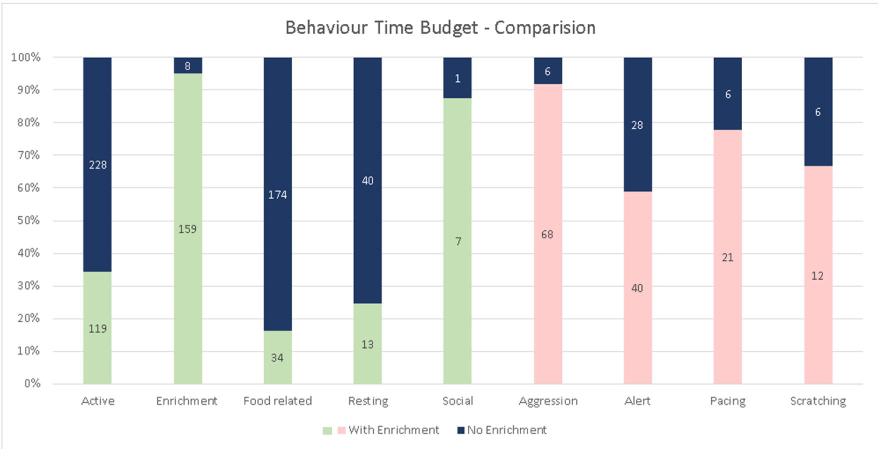


Figure 85: Behaviour Time budgets Comparison

10.4 Post- Implementation Feedback

A post-implementation feedback interview was conducted with the animal welfare expert and the caretakers to gain a deeper understanding of the results, animal interactions with the experiential prototype, achievement of objectives, aggression or frustration of the animals, and future implementation as quoted by animal welfare expert. The detailed interview can be found in Appendix B.

On the whole there was a positive response from both caretakers and animal welfare expert about the final prototype. They see potential in the prototype for future implementations with both capuchin species as well as other species(maybe) with some modifications. Currently, the device is problematic for over-night use. The animals can eventually destroy the device if they have more time. Since there was nothing coming out of the device, they say, it can frustrate the animals in the long run.

10.4.1 Foraging Behaviour

The device triggered foraging behaviour since the animals explored and swung the enrichment device, used other methods of destruction. This is something that the animals do while foraging.

10.4.1.1 Frustration Observed

Some animals showed some scratching, and one individual threatened the device but less fearful responses from animals was seen. The frustration can be due to multiple reasons: (1) Unable to escape the sounds (2) Nothing comes out the device for too long (3) fight preceding to testing.

The animals were confronted in their territory with a thing that makes noises, and they had to move to outer enclosure escape from it. The sounds were loud, or it sounded loud since the camera amplified certain frequencies more. Though not to the extent that it was intolerable for the monkeys since the device is meant to be used during winter, when the monkeys prefer staying in inner enclosure. This might have caused some frustration and short-term acute stress in the animals. Furthermore, there was nothing coming out of the device for the entirety of the testing unlike the husbandry routine that the animals are used in which, there is always a reward. This might have frustrated the animals. There was a small fight preceding to the observation period which may/may not be related to the device owing to multiple other factors.

Short-term acute stress is not necessarily bad. The animals showed behaviours that are usually displayed during a fight like using threat behaviours at the device. This is a natural behaviour for primates which helps them test out boundaries also save energy compared to physical aggression. However, we did not see any incredibly negative behaviours. The animals had the option to run away from it at all times.

10.4.2 Interest

The device is something new for the animals and they were interested. The animals (some individuals at least) kept coming back and showed signs of curiosity and interest in the sounds. There was interest in sounds.

10.4.3 Meeting Objectives

The device itself is something new for the animals and they approached it multiple times. It is solid, sturdy and monkey-proof and held up to the destructive efforts from the WFCs. But that also depends on the placement of the device. Replacing the chain with snap hook has made it less harmful for the animals, but the device may break eventually if kept in the enclosure for longer durations without supervision. Since the other enclosures were out of view and we couldn't see how the animals reacted after interacting with the device, it is difficult to conclude if there were any fights. However, there were no incidents of chase behaviours observed and also the caretakers did not feel the need to stop the session at any point of the observation period. We can say that social structures were not disrupted but we don’t know how the animals responded after interacting with the device and left the observation zone. This can easily be solved by having multiple devices in the enclosure. However, food can elicit too much monopolization. The animals are super smart and can cooperate. However, it is unsure if its conscious corporation – intentionally or not.

10.4.4 Future Implementation

To avoid/minimise frustration in the animals, combining the current prototype with shorter duration of sounds, food rewards and having multiple devices would be benefiacial for the animals. If something comes out of the device, they will be less frustrated and therefore less motivated to destroy the device.

Replacing natural leaves every time : The WFCs found the device interesting even without the leaves around it. And YBCs who are more gentle may not tear down the leaves.

10.4.5 Conclusion

Due to the short nature of the test, it is difficult to draw conclusions.

11 DISCUSSION

The animals approached the device repeatedly 56 times in the entirety of the observation period. Comparing the results (Figure 85) between the two conditions, we see that the animals showed more “active” behaviour in the baseline condition compared to the condition -2 with enrichment, probably because most of the time budget was spent on enrichment-use (34%) in condition -2 compared to the baseline condition (2%) and therefore associated behaviours such as locomotion and social play were less observed. This is further correlated with the observed decrease by 84% in food-related activity and a decrease by 67% in resting behaviour in the presence of enrichment in condition -2. Furthermore, use of enrichment might have led to an increase (6%) in cooperation observed in social behaviour, although it cannot be concluded If it was due to conscious cooperation as stated by animal welfare expert in sec. 10.4.3. Consequently, we can say that use of enrichment has had an impact on the other behaviours of the animals.

Similarly, there was an increase by 67% in aggressive behaviour (AgE) in condition-2 compared to baseline condition, although directed at the prototype and not at other members of the group. There was a more than twofold increase in pacing and scratching, which can be attributed to either the frustration of not getting anything out of the device (sec 10.4.1.1) or the difficulty to figure out where the sounds and lights were coming from and what the enrichment device seemed to be. Their reactions could be interpreted as *“What is this? What can I do with this? What does this thing want?” - animal welfare expert (*Appendix *B)*

The instances of alert behaviour had only marginal increase which is less than twofold in the presence of enrichment in condition -2 compared to the baseline condition. This might be attributed to the noise that was heard during the baseline condition (sec 10.1) which might have made the animals show more alert behaviours even without the new element in their environment. This is further supported by timestamps of pacing and open threat face behaviour observed only during the time of the noise originating from outside the observation zone. Furthermore, the camera angle in condition-2 was slightly off (sec 10.2), and some of the ground-level activity near the window was hidden from view which may also account for the decline in food-related and resting activities observed in condition-2.

The animals were curious and kept coming back to interact, and the device was able to endure and respond to the various interactions made by the WFCs. The animals interacted with the device in explorative and destructive ways, some of which was not anticipated and designed for, but the device was sturdy during these interactions as well. As time progressed, they engaged in increasingly violent behaviours, (punching, biting, lifting the device w/o the rope and flinging it). The device was able to tolerate such aggressive behaviours and was operational throughout the duration of observation. Further study is needed to check if the device can survive being in the enclosure overnight, since the current design specifications were not meant for long term usage.

“*We chose, of course a very, very challenging and difficult species to begin with. I think if you provide this device to a different species, which is less destructive or something like that, it could work better, even they will not think of destroying it ever. But this species is. That's also why we gave it as a challenge because they're super inventive and it's difficult. But I think the device held up, it wasn't* *destroyed, it was very sturdy. They didn't manage to break it even though they pulled it up in ways that maybe you didn't anticipate." – animal welfare expert*

The enrichment device invoked more interactions of >20sec (25min 35 s, sec.10.2.1) compared to the lo-fi rattle-way version(4min 29c, sec 6.3.2). The maximum time of continous interaction also increased to 2 min, 46 sec(sec. 10.2.1), in the final device compared to 1min 22 sec in lo-fi testing. Consequently we can say, that there was increased interest in the final prototype.

Multiple individuals of different ranks also interacted with the device according to the caretaker at the test site. Individuals of lower ranks approached the device at later stages of the observation.

"Basio(High rank) interacted with the device multiple times and eventually towards the later half lower ranked individual like Ti sento interacted with the device" – caretaker of WFC

The goal of the project was how to design interactive digital enrichments for captive capuchin monkeys, that fosters their species-natural foraging behavior and maintains their interest. The subsequent sections answer the research question through the secondary questions.

1. *What factors of an enrichment maintain interest among captive capuchin monkeys?*
2. *What constitutes the natural foraging behaviour of capuchin?*
3. *What is an ethical way of designing for the capuchin monkeys?*
4. *How can the design process be animal-centered?*
5. *How can prior work on interactive digital enrichments be applied to capuchin monkeys in captivity at Apenheul?*

11.1 Revisiting Research Questions

11.1.1 What factors of an enrichment maintain interest among captive capuchin monkeys?

Literature findings (sec. 2.2.3) show that to maintain interest of the animals in an enrichment, the enrichment should be novel, increase foraging time, be interesting to look at, invoke multiple senses, challenge their individual competence, and not disrupt social structures. The preliminary findings suggest that there was some type of interest or exploratory opportunity for the capuchin monkeys as there were a variety of interactions with the enrichment observed (Figure 84) in the absence of food reinforcement (sec 10.2.1).

"They (the monkeys) can sort of illicit whether if it makes sounds. Some individuals again and again approached the enrichment, moved it and it produced sounds"– animal welfare expert (Appendix B)

The device was a new element for the animals (10.4.2) that fostered *multisensory* interactions - visual(lights), auditory (sounds), and tactile(leaves). The animals interacted instinctively without prior training and kept coming back. When the leaves were lifted, the sensors of the device triggered random insect/frog sound followed by blinking LED lights. The animals initially triggered the device by looking through the leaves a few times, but eventually began interacting with it in numerous other ways as already mentioned in (sec 10.2.1). Consequently, we believe the device looked interesting for the animals and catered to their individual competences and therefore interested the animals to come back.

The enrichment was also *novel* since the animals did not interact with digital enrichments before (sec 3.3.2.4). Furthermore since it is a digital enrichment, it can be easily modifiable to cater to other sounds depending on individual animal preferences. Also, as already stated in the preceeding section, individuals of different ranks showed interest in the enrichment device.

The observations show that the enrichment device did not visibly disrupt social structures although their reactions to interactions with the enrichment after the animals moved away from the observation area could not be registered. The caretakers, however, did not think it was necessary to redirect the session.

There was curiosity to find out what was inside the device, and after multiple attempts to explore inside, the animals resorted to more aggressive behaviours such as biting, kicking, and swinging with force to break the device. To *increase foraging time*, zoos provide capuchins hard-shelled foods such as coconuts are given, and/or other foods hidden in food baskets[1, 119]. The device elicited similar response from the animals as breaking hard nuts or foraging, and inaccessible places[2] which can have potential downside as with laser dots(laser dots in sec 6.3.1).

11.1.2 What constitutes the natural foraging behaviour of capuchin species?

Literature points out that capuchin monkeys engage in multiple explorative and destructive behaviours to get access to food sources like examining tree trunks, evaluating and planning, utilizing tools to break open more substantial foods, exploring the foods, hitting, pounding(sec 2.1.4.1.1, sec 2.1.4.1.2).

The animals engaged in a variety of destructive and exploratory behaviours as already mentioned which are similar to the literature findings (sec 10.2.1) while interacting with the digital enrichment. They investigated the device in search of its contents, attempted to reach the interior, and engaged in destructive foraging behaviours already mentioned above (Figure 84).

Cooperation and sharing food resources (scrounging, sec. 2.1.4.1.2), is also part of capuchin monkeys' repertoire of foraging-related behaviours. The animals demonstrated multiple instances of cooperation (10.2), although unclear it was conscious cooperation (10.4.3), in which more than one individual worked with the enrichment at the same time and/or attacked the enrichment together.

11.1.3 What is an ethical way of designing for the capuchin monkeys?

Throughout the project, the focus was to minimise harm to the animals. This was achieved through iterative testing and at every stage during the test times, the prototypes were checked for potential problems by the stakeholders and there was an animal welfare expert, a caretaker always available throughout the observations to ensure animal safety during the testing. According to ethical guidelines (chap 4), harm can be physical, psychological and threats to social wellbeing.

The design of the enrichment incorporated design decisions(sec 8.1, sec 8.2) to fulfil the outlined objectives (3.4.1), to prevent physical harm to the animals. The exterior of enrichment had no sharp corners, edges, protrusions, or small holes in which the animals' body parts could become entangled. Furthermore, the external materials that the animals would come in contact with were natural, non-toxic, and of high strength with the exception of branches and leaves, to ensure animal safety upon ingestion. All electronics including wiring were enclosed inside the device to minimise undesirable contacts and the setup was reinforced to make it as waterproof as possible after pilot testing (sec 8.3.1). Natural sounding insect and frog sounds that the capuchins usually forage were chosen for use in the enrichment (2.2.1.2). Red and yellowish orange lights which fall within their visual colour spectrum (sec 2.2.1.1) was used.

From the feedback from animals' welfare experts and caretakers, we know that there was probably no social hierarchy disruption on the social wellbeing front (sec 10.4.3).

However, in condition-2 (sec10.2), there was an increase in aggressive behaviours in the form of rough exploration (AgE) with the enrichment and no aggression towards conspecifics (AgI). Although aggression is undesirable(sec 2.1.4.5), small amounts of aggression that is not directed at other group members are acceptable [146] which is also supported by the animal welfare expert(sec. 10.4.1.1). Literature also supports that, acute stress in small amounts is crucial for the survival of the animal in the wild (sec. 2.1.4.5.1). In addition, the animals always had the option to respond or not respond to the device, could leave at will, and were not restrained in any way following ethical guidelines (o chap 4), of this project. Other factors to aggressive behaviour may include *expectation management* by the animals themselves, as stated by animal welfare expert in sec.10.4.1.1, were used to a certain husbandry routine followed at Apenheul in which when something is placed in their enclosure, some tangible reward follows. This is also supported by the concept of ethological needs, which states that "the degree to which the behavioural urges of the animals are frustrated under the particular confinement conditions must be a major factor in determining its acceptability or otherwise" [147].

The digital enrichment indeed elicited aggressive behaviour in the animals. However, this behaviour could not be construed as a detrimental effect since, they were threats put forward by the animals as a group to test the new element that was present in their environment.

"I *didn't see any real aggression at the device itself. they were like, oh! what's this? And what can we do with it? I think that is positive*. *A lot of primates do not engage in physical aggression, but they use the threats to test out the boundaries, test out how far the other is willing to go, because that saves energy. So, it's natural behaviour and I think that's also what they did with the device"- animal welfare expert.*

11.1.4 How can the design process be animal-centered?

One of the ways to Implement co-design for animals is to have the creative collaboration of designers and non-designers in the design creation process[100] (sec. 2.2.2.2). It was used as the design process in this study, with design preferences derived from the animals themselves. It involved iterative design process which included contextual interviews, direct video footage observations of the animals' behaviour in the outside enclosures, focus group sessions with animal welfare experts, HCI expert, and caretakers; followed by the building of low-fidelity prototypes to understand the animals' needs and preferences. In-depth co-design sessions (design workshops, Wizard of Oz prototyping) [14] and animal interactions were ruled out of scope due to time constraints.

To understand the animal context, video observations of the animal behaviour on outside enclosures on regular days was observed(sec 3.3.1). To get deeper insights into their behaviour in indoor enclosures and also over longer periods, focus group discussions (3.3.2) were held. This gave in-depth knowledge into animal behaviours, their environment settings, their husbandry routine, challenges and enrichments that the animals have been introduced to. This learning of animal context is also outlined as one of the prerogatives in ACI framework in sec. 2.2.2.1. Comparisons were drawn from literature about animals in wild settings and in captivity to understand primary foraging behaviours of these animals. This revealed behaviours(3.3.2.2) such as making sounds by striking and pounding objects and food against a hard surface, searching for food underneath the leaves, as well as observations of them gaining access to food by hanging by their tails, constantly active searching for food on the ground, in tree crevices, in food baskets, preference for non-food rewards such as anointing materials with strong smells (on page16-16), which is also supported both by literature(sec 2.1.4.1.1). The animals displayed persistence and spent considerable time to break the objects and tough foods which was also supported by literature about tool use in sec 2.1.4.1.2.

No previous studies on digital enrichments for capuchin monkeys was found and therefore similar studies for other primates (sec 2.2.1) was explored. YouTube videos of enrichments in place in other zoos for capuchins and other primates, documentaries and pet videos were also investigated to understand how these animals interact to draw up the initial concepts (chap 5).

An iterative approach was used in this project. Firstly, elements of the initial concepts were tested out individually (such as sounds, lights, hanging tubes, balls) through lo-fidelity prototypes (sec 6.1). Feedback from the stakeholders was taken at every stage to orient the design process towards the preferences of the animals. For instance, we saw that YBCs did not interact much with prototypes that were placed on the ground while the WFCs did (6.5). So, the ideas for the next iteration were not ground based.

There were multiple instances of contradiction from the previous studies. For instance, chimpanzees were distressed with red lights(sec2.2.1.1) while it had a neutral effect on the capuchins as shown in lo-fi testing (sec 6.3.2). Traffic sounds preferred by Saki monkeys (sec 2.2.1.2) had a negative effect on capuchin monkeys (6.3.1). Wild capuchins fish for clams in water (sec 2.1.4.1.1) while the animals in Apenheul did not like to approach water (sec 6.3.1).

Observations were made jointly by caretakers, an animal welfare expert, and the researcher. Based on the outcomes of the lo-fi prototypes, the final experiential prototype was made which was again tested iteratively in pilot (sec. 8.3), pre-observation (sec. 9.2.2), and final observation (sec. 9.2.2) study. The lo-fidelity prototype testing paved a way into deeper understanding of these animals' preferences and non-preferences as well as their interaction methods. The animals reacted in various ways - such as licking and biting observed in lights, pounding and attacking observed in balls, recurrent exploring observed in Rattleway as explained in sec 6.3.1.

The next step included iterative build of the final prototype. Stakeholders were involved throughout the design process. In ideation, they helped rule out anthropocentric ideas. In the setup process, they helped add safety measures which was a priority throughout the design process. The final prototype was built with safe materials and tested for robustness, endurance and non-harmfulness to animals by HCI expert, HCI technical workshop expert, animal welfare expert and caretakers; and was introduced in the animal enclosures with guided supervision following the ethical considerations as outlined in chap 4. This process was carried out iteratively. Pilot tests revealed the need for reinforcements(sec8.3).

The animals showed interest as already mentioned above. The animals interacted with the final prototype involving their entire bodies. And they were free to engage or walk away from the prototype at any time. Therefore, the animals had some control and freedom over their environment.

Animal-centered evaluation methods as described in sec.2.2.2.4 were used to evaluate the findings.

11.1.5 How can previous work on interactive digital enrichments be transformed to capuchin monkeys at Apenheul?

As previously mentioned, initial lo-fi- prototypes of the study were partially based on findings of the various studies on digital enrichment for primates (pg.20-22). Although the study implemented the co-design approach followed to design interactive projections for orangutans(sec. 2.2.1.3, sec. 2.2.2.2), projections could not be tested effectively due to space and time limitations(sec. 6.3.1). The animals showed brief (2-3 s) interest in the videos projected in the corridor outside their enclosure, but the camera could not capture the reactions of the animals. In contrast, there was more interaction and interest noted for lo-fi prototypes that were accessible to the animals in/within their enclosure such as the lights, Rattleway, and balls. The reason for the increased interaction by the animals might be attributed to more control[12] and agency over their environment with these prototypes (on page22-23).

The study also showed some interesting results that did not conform to the findings with other primates. For instance, traffic sounds that the Saki monkeys found enriching (sec. 2.2.1.2) caused some distress to the capuchins and thus the study was interrupted (sec. 6.3.1). The red light exacerbated hostility in chimpanzees[90] while there were inconclusive results with capuchins both in the lo-fi tests and with the device itself. The capuchins interacted with hexagonal touch sensitive lights while the lights were flashing red. The animals repeated this behaviour with the experiential prototype, which used red and yellowish orange LED lights. The animals showed pacing and scratching behaviours in both the lo-fi and experiential prototype observations, but the exact cause cannot be attributed to the presence of only red colour lights as is the case with frustration (sec. 10.4.1.1) and aggression (sec. 11.1.3).

Furthermore contrary to previous works[27, 91, 97], there was an increase in self-directed behaviours observed(on page81). To understand the underlying cause, factors (sec. 11.1.3) such as intra - species aggression, expectation of reward (instinctively or derived from captive conditions routine) and other factors need to be studied which is beyond the scope of this project.

11.2 Limitations and Lessons

This study was explorative and required a collaboration with the stakeholders at Apenheul and University of Twente, including their resources. Even though the results and findings are promising, there was a small number of limitations that limited the scope of the research, such as time, equipment, animals' safety, regulations, environment, and the device design itself.

The short length of the study limits the possibility of extending the results for long-term. However, the study provides useful insights on the capuchin behaviour that can be used for future applications.

11.2.1 Testing

The first limiting point regarding testing was the given enclosure settings. The white-faced capuchins were housed with other species in the same building and there were instances of loud vocalisations which were out of view and therefore not coded into observations. However, the effect of the external stimuli (loud screams) impacts the animal behaviour in the observation zone. Therefore, it was not possible to completely isolate the behaviour time budgets exclusively for the capuchins. To mitigate this, multiple observations spread across multiple days could be done through randomised balanced trials. The available enclosure space and location of the YBCs limited certain testing choices such as the projection (sec 6.3.1).

Google nest camera was used to videorecord the experiment in the observation zone. This gave only one view of the zone. Many behaviours of the animals after interacting with the enrichment device could not be captured. Furthermore, as mentioned, some of the ground activity and activity at the far end of the room in the “no enrichment” condition could not be captured. In future, installing multiple cameras to get the full view would be very useful for better analysis.

Furthermore, it was not possible to distinguish the vocal repertoire and the identity of individual capuchins from the video footage. This data could be useful to develop enrichments catered to individual preferences. Also, the response to each individual sound was not measured in this study. Future implementations can involve anima behaviour researchers and experts on-site to get more clear and in-depth insights to fill these gaps, to gain a deeper understanding about individual vs group/ species – particular differences in preferences. Additionally, computer-vision based, or RFID based recognition can be used to recognise individuals and log their behaviours.

Some of the sounds were perceived as loud when watched in the camera by the animal expert. Although the animals immediately moved away from the device in such instances, the sounds can have a negative impact on the animals in the long run since the animals cannot really escape from loud sounds and it can lead to more frustration. To mitigate this adverse effect, shorter and low volume sound durations can be used in the future iterations.

And finally, test with projections was inconclusive due to space and time constraints. The projections can be tested again in the future, with the capuchins by introducing the projection in the enclosure area of the animals. This would however, require a safe and secure box to enclosure the Kinect sensor and the projector such a way that the animals cannot reach the electronics housed inside.

11.2.2 Design

The enrichment design was in accordance to foraging behaviour of looking beneath the leaves. The study was unable to find suitable alternate robust material for the use of leaves. Further research is recommended for the future implementations. Furthermore, alternative technologies of sensing such as weight-based/ spring-based triggers that support greater force can also be implemented for species that are more destructive. The system is triggered when the difference in the present and the previous state crosses a particular threshold value. Other methods of state-detection can be explored for detecting more accurate triggers.

Although the project took into account to keep all the parts modular and replaceable, the final prototype setup is fixed now. Due to the small size of the external shell, all internal components cannot be replaced.

11.2.1 Future Scope

As mentioned already in the Fruiting tree concept in sec 7.1.3, multiple devices with same/other concepts, with some dispensing food/anointing rewards, can be implemented in a sequential process. The animals get complex cues as described. The feeding system distributes and scatters food/ anointing material throughout the area. And test the response of the capuchins' behaviour to the device to determine if negative behaviours are diminished. If successful, the integrated fruiting tree concept can maintain interest amongst the animals for longer durations and maybe support multiple other behaviours.

11.3 SUMMARY

Summarising briefly the objectives outlined for the project as stated in sec 3.4.1 and the result of the study

#	OBJECTIVE	RESULT
1.	Promote natural foraging behaviour	Yes
2.	Enjoy interacting	Inconclusive, the animals kept coming back.
3.	Easily changeable	Yes, due to digital nature of enrichment
4.	Cater to competency of animals	Yes, no prior training required
5.	Monkey proof and natural look	Yes, the device was sturdy during the observation period
6.	Non-harmful to animals	Inconclusive, since it can be frustrating to animals without any tangible rewards
7.	No disruptions to social hierarchy	Inconclusive, did not observe any but cannot rule out the possibility without long term testing
8.	Easy installation	Yes
9.	Low-cost and modular	Yes

Table 11: Revisiting Objectives

This project aimed to develop digital enrichments that fosters natural foraging behaviour in captive capuchin monkeys while maintaining their interest. The results show promise but are inconclusive due to the short-term test.

12 CONCLUSION

The project aimed to design interactive digital enrichment for captive capuchin monkeys that fosters their species-natural foraging behaviour and maintains their interest to have a dialogue. Capuchin monkeys are known for their wit, intelligence, and tool use capabilities to seek hard to access complex foods. They develop many mental, social, and physical skills in the wild in due process. However, animals in captivity have limited opportunities to develop the same aforementioned skills and therefore zoos and animal conservation facilities like Apenheul provide animals with “enrichments” that stimulate them. Most modern zoos today provide animals with both indoor and larger outdoor enclosures. The outdoor enclosures largely replicate the habitat of the animal, are complex and visitors can view them. Animals spend most of their time foraging for food which is scattered or hidden in their enclosures. However, in winters zoos like Apenheul are closed for visitors. During this time, when the temperatures are below freezing, animals are mostly confined to their indoor enclosures with less complex environment and lesser distractions(visitors). This can result in boredom, anxiety, and self-directed behaviours such as scratching and aggression in some animals[21, 22]. Species that are intelligent such as the capuchin monkeys are more easily bored with the provided enrichment faster, since they are smart and easily figure out the solution and once, they do, they do not engage in it further. Therefore, there is a need for enrichments that can change over time and maintain interest amongst these animals. Furthermore, there is a need for enrichments that are not entirely food reward based. Digital technology is more flexible and can easily be changed to cater to individual animal/species preferences. Therefore, this project delves into the process and design of interactive digital enrichments for the capuchin monkeys at Apenheul (white-faced capuchins and yellow-breasted capuchins) that fosters their species-natural foraging behaviour through five sub-research questions.

This project expanded on the previous works of animal-centered methods that gave animals control over their environments through digital enrichment. Based on the literature review involved in this research, it was found that there is no prior work done on digital enrichments designed for capuchin monkeys in captivity. Therefore, the literature study was expanded to understand the behaviour of the capuchin monkey both in wild and in captive settings.

The project explored into species natural- foraging aspects of the capuchin monkeys and found out their preferences in a greater detail through iterative animal-centered process that involved direct observations, focus group discussions with stakeholders, lo-fidelity prototype testing and final prototype testing inspired from the work of Webber.et.al [27]. Co-design methodology was applied whereby throughout the process, the animals were included in the design process as an expert of their own behaviour using caregivers as proxies. Their needs and preferences were further investigated by focus group discussions. Furthermore, safety was one of the key aspects of this project. Ethical guidelines were followed throughout the design and testing phases to ensure there was no harm caused to the animals directly/indirectly due to the enrichment. Safety measures and backup options were incorporated at every step before introducing to the animals. However, it was also quite a challenge, since the prototype had to be safe for the animals to use while also being “monkey-proof” meaning, it needed to endure all kinds of interactions from the animals without breaking apart during the entirety of the testing.

Initial concepts were formulated through insights from the literature, direct field observations, and focus-groups discussions with the stakeholders (animal care-takers, animal welfare expert and human-centered interaction expert) at Apenheul. The first iteration involved testing of six lo-fi prototypes with the animals. These were based on the initial concepts and included individual elements like balls, lights, sounds, hanging tubes, projections, trampoline and shallow pool. We understood what the animals liked and also what they did not. Feedback sessions with the stakeholders helped eliminate anthropocentric ideas, and; chose between the concepts and formulate future direction. The Lo-fidelity testing revealed that the capuchins showed interest in exploring inside hanging tubes and were curious about lights. But it also showed the difference in preferences of capuchin monkeys compared to other new-world monkeys and apes studied in this project, towards sounds and videos. For instance, sounds that were enriching for Saki monkeys invoked signs of distress among capuchins. And red lights aggravated hostility amongst chimpanzees while had no had no effect on capuchin monkeys.

Furthermore, the lo-fi testing also revealed some crucial differences between the two capuchin monkey species (white-faced capuchins and yellow breasted capuchins) in their approach towards the enrichments, and this helped refine the concepts for the next step such that the enrichment can be catered to both the species. The final prototype followed the direction outlined by these findings.

The final concept was inspired from one of the foraging behaviours of the capuchins – "looking under leaves" for foraging small insects and bugs. The final prototype built and tested was a hanging device covered with leaves which when lifted up, produced random insect sounds that these animals' prey on, along with blinking lights for short 10-12 sec duration. It was pilot tested and reinforced to further ensure it would endure the stronger interactions from the animals such as biting, lifting and throwing, pulling the device and many more.

The final enrichment device satisfied the design -objectives of the project to a large extent. It was food-based, easy to install in both inside and outside enclosures, was made with low-cost parts, natural materials, with electronics enclosed inside such that there was minimal contact with the animals, required no prior training for the animals to interact with, and was sturdy and operational during the observation periods of the study.

The animals showed considerable interest in the device and interacted with it in numerous ways similar to the foraging behaviours identified in literature and direct observations. The results show that the device invoked exploratory and destructive behaviour of the capuchin monkeys which is normally also a part of their natural foraging repertoire. The animals used their entire bodies to interact with the device, some of which was not anticipated in the design. Additionally, the device being a new multisensory element for the animals also invoked their curiosity with no visible social disruptions within the animal-group, and also promoted rough exploration towards the enrichment. The animals returned to interact with the device multiple times in different ways to figure out the where the sounds were coming from and to see what was inside the device.

There were also signs of scratching and pacing observed in the animals while testing, since there was nothing coming out of it even after multiple interactions which was contrary to general husbandry routine of the animals. This largely differs from the findings of other primate studies where there was a reduced sign of distress due to the presence of the enrichment. Animal -Centered- Interaction evaluation methods were used to determine the effectiveness of the digital enrichment on the capuchins.

The final prototype following an animal-centered approach was non-food based, stimulated natural foraging behaviours in captive capuchin monkeys by producing lights and sounds of prey when interacted with, while maintaining the animals' interest to return and have a dialogue. And therefore, it is plausible that digital interactive enrichments can be a potential form of engagement for the animals if the negative effects can be mitigated through combining small tangible rewards (low-priority foods or anointing materials) . However,, these preliminary findings are inconclusive and even contrary to certain extent to those found in literature including other primates as mentioned above. This can be attributed to the short nature of the study due to time, design and testing limitations. This is also supported by Webber's work [26], where no positive or negative effects of such digital enrichment strategies were found. Despite the shortcomings, this study is a significant step for a broader evaluation of digital enrichments for these capuchin monkeys, a small step towards understanding the capabilities and preferences of capuchin monkeys and a proof of concept for designing interactive digital enrichments in the future.

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APPENDIX

B ETHICAL AGREEMENT RESEARCH AT APENHEUL PRIMATE PARK

To ensure scientific validity, due ethical consideration, good animal welfare and compliance with relevant Dutch and EU legal requirements, Apenheul Primate Park is committed to maintaining the highest ethical standards in the conduct of research.

Regarding the research project as detailed in the attached research proposal, the undersigned researcher and any associated students agree to work within the terms and conditions of this Ethical Agreement, and confirm their research adheres to the ethical standards for zoos and aquariums as formulated in the 'EAZA Code of Ethics' (EAZA, 2015) and the 'Ethical Guidelines for the Conduct of Research on Animals by Zoos and Aquariums' (WAZA, 2005). The researcher took note of these documents and agrees the proposed study does not conflict with any of these guidelines. In particular, the study animals in this research will:

- Never be forced to take part in the study or tests and will always have options available to retreat or avoid test objects and/or researcher(s) in their enclosure;
- Never be separated from their social group for this study (unless for husbandry or veterinary reasons, and only after consent by the head of caretaking, veterinarian or zoological manager);
- Only be positively reinforced, and only after discussion and consent by the head of caretaking, veterinarian, animal welfare coordinator, training expert and zoological manager;
- Never be deprived of food or water at any stage;
- Never be handled or manipulated in any way shape or form.

When behavioural experiments are required for the study, these will always be discussed with the entire Zoology department of Apenheul Primate Park, involving the Zoological Manager, Head(s) of Caretaking, Veterinarian, Nutritionist, Animal welfare coordinator and Curator of Apenheul, and can only proceed with consent by all indicated Zoology staff members. Behavioural experiments can be part of the enrichment program of Apenheul Primate Park, but will always be fully integrated into the daily caretaking/husbandry routine and will require no manipulation of individuals.

Careful monitoring of the behaviour and welfare of all animals is required at all times during the study, and any (self-)harming-, stereotypic or abnormal behaviour, (severe) aggression or wounding will be reported by the researcher to the (head of) caretaking and research supervisor immediately; either by phone or verbally. The research will be constantly evaluated and can be stopped at all times, when Apenheul staff members deem this appropriate.

Therefore, this research is in compliance with all relevant Dutch laws and are in agreement with international and scientific standards and guidelines. Furthermore, because of the strictly non-invasive character of the studies and absence of any potential discomfort of distress, the proposed study does not meet the definition of an animal experiment as mentioned in Article 1 of the Dutch

“Experiments on Animals Act”. Consequently, we hereby confirm that the Zoological Manager, Curator, Head of Caretaking, Veterinarian and Research & Animal Welfare coordinator of Apenheul Primate Park waived the need for approval by the Dutch Central Commission on Animal Experiments (“Centrale Commissie Dierproeven”).