Platypus Surfing *

In Search of the Perfect Wave

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ABSTRACT

In this project we design a self-activated wave enrichment system for a solo male Platypus, 'Sam', at XXXX zoo. We focus on providing a device that Sam can learn to activate at will to produce a wave sequence, providing both choice (to activate a wave pattern) and control (whether to activate) over his environment. We predict that the use of this item will promote natural exploration and play behaviours and reduce abnormal repetitive behaviour. The project involves multiple stakeholders—the city and state zoos with Animal Welfare Specialists, keepers and operational systems' teams; researchers from different universities and states; multiple funding applications and ethical clearance processes. We have experienced a series of stop-starts before and beyond COVID-19 complications. With the project 'still under construction', we detail the initial testing which indicated the overall potential success of the interactive system and specify the next steps for implementation, observation, analysis and beyond.

CCS CONCEPTS

•Human-centered computing

KEYWORDS

Platypus, Animal Enrichment, Animal Welfare, Interactive, Play, Animal Computer Interaction, Animal centered computing

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1 Introduction

Sam is a 15-year old male platypus, Species360 Zoological Information Management System (ZIMS) local ID: XXXX, who has lived at XXXXXX Zoo (XZ) for the last 14 years. XXXXXX Zoo implements an annual welfare risk assessment (Sherwen et al., 2018). Sam's welfare assessment in 2017 resulted in the development and implementation of countermeasures to reduce potential risks to welfare. These countermeasures included feeding at varied and unpredictable intervals during the day, providing choice for Sam to access his on-display swimming area and back-of-house dens at all times, and the introduction of new outdoor swimming channels to the back-of-house area. The most recent welfare survey (2019) indicated that overall there is no observable risk to Sam's welfare, specific questions regarding his behavioural opportunities and performance of any abnormal repetitive behaviours, (e.g. swimming in tight circles) were identified as moderate risks by assessment standards (Sherwen et al., 2018). Therefore, XZ works to offer further opportunities for positive behavioural and welfare outcomes in his environment.



Figure 1. Sam comes out of the channels behind where he sleeps when fast flowing water is added to the enclosure.

Sam's keepers reported that Sam regularly engages in a "surfing-like" play behaviour in fast flowing water. He is seen doing this when the display tank is cleaned and/or backwashed. As a result, the primary keeper applied for sponsorship funding to add some additional opportunities for water play activities to Sam's environment. Fellow researchers were introduced to the keepers, the Animal Welfare Specialist, Sam, the specifics of the design and interactive technology problem, as well as the situated environment and requirements of XXXXXX Zoo, Zoos XXXX. The larger problem and solution—to make the interaction up to Sam's choice—is of foremost importance for the project. The element of choice is central to modern animal welfare (Wolfensohn et al., 2018) and is becoming increasingly important to Zoos XXXX's main goals.

1 Background Literature

Zoos XXXX (ZX) are continuously working to provide environmental enrichment for animals in order to promote the performance of natural behaviour, increase positive experiences such as pleasure, comfort, and joy, and reduce undesirable behaviours such as abnormal repetitive behaviours. As part of this work, Zoos XXXX runs a philanthropically sponsored program called "XXX XXX", where staff pitch unique ideas for enrichment items to provide their chosen species with positive experiences. Keepers for the XZ XXXXX Bush team, successfully applied for a small grant to build a wave machine for Sam.

Twice a week, Sam's tank is cleaned or backwashed which creates a heavy flow of water into the tank. In the generated wave flows, Sam displays various types of play behaviour, indicating this is a positive experience. Watching this play inspired the wave machine design (see Figure 1). While at XZ, certain undesirable behaviours have become part of Sam's routine. As he moves around his tank, Sam swims in repetitive circles. The welfare outcome of this specific repetitive behaviour in this individual is unknown, but the performance of this behaviour is undesirable as it indicates a potential risk to welfare (Mason & Rushen, 2006; Rose et al., 2017). Environmental enrichment that increases natural behaviours can be effective in also reducing abnormal repetitive behaviours (Mason et al., 2007).

Research indicates that providing zoo animals with choice and control over their environment promotes and facilitates positive affective states in these animals and improves welfare (Whitham & Wielebnowski, 2013). Therefore, XZ keepers set about enabling Sam's capacity to control the flow of waves, giving him choice how and when he interacts with the water flow. Keepers aim to reduce abnormal repetitive behaviours and increase the performance of positive natural behaviours including exploration and play.

As a species, platypus forage and feed underwater, but rather than using their eyes to seek out prey, they use small electrical fields that are emitted underwater by fleeing prey. Captive platypus have been shown to respond to small artificially generated electromagnetic fields which can be used to influence foraging behaviour (Manger & Pettigrew, 1995). The goal of this project is to use a small underwater sensor that emits electromagnetic fields to attract Sam to the sensor which will then activate a wave sequence.

Research on the electroreception capabilities of the platypus includes research on feeding behaviour (Manger & Pettigrew, 1995). However, successful demonstration of direction tuning in response to the imitating electrical pulses holds potential for scalability to other activities (Fjällbrant, Manger, & Pettigrew, 1998; Manger, Calford & Pettigrew, 1996; Manger, Collins, & Pettigrew, 1998; Ruxton, 2009). In particular, for this project our aim is to attract Sam to seek out and engage with enriching activities placed in the environment (Pettigrew, Manger, & Fine, 1998), by emulating the imitating electrical pulses (Manger & Pettigrew, 1995) to an immersed electrode pulse in the range identified (50 μ V cm-1) to attract Sam (Scheich, Langner, Tidemann, Coles, & Guppy, 1986).

The sensor used for this project would loosely emulate the electromagnetic fields range emitted naturally by platypus prey species (yabbies, bloodworms etc.) (Manger & Pettigrew, 1995). Sam is fed live yabbies and bloodworms on a daily basis. However, it is important to note that while we cannot exactly replicate the prey signals, neither do we want to. We are replicating the signals as used by earlier investigations (Pettigrew, Manger, & Fine, 1998) to ensure the signals are not directly linked to prey signals to avoid confusion, frustration and disappointment.

2 The Study Design

Testing of the enrichment device will take place at XXXXX Zoo in the display tank for Sam.

2.1 Ethical Considerations:

This study has been approved by the Zoos XXXX, Research and Animal Ethics Committee (ZXXXX) and all additional equipment placed in the animal enclosure is approved by a senior veterinarian at XXXXXX Zoo. The study is designed to be non-invasive and therefore is not expected to have negative impacts on animal welfare. No change to husbandry routines and no noticeable housing structures in the tank will occur. No direct manipulation on the animals has been adopted for this project. The position of the extra flexible pipe in the tank will be selected to ensure the safety of the animals and to minimise potential interference with the animals but to maximise water patterns and flow for Sam. Physiological measurements have not been included in this project.

2. 2 Wave Treatments:

In consultation with the keepers at XZ, three specific wave forms have been designed for this project. However, we will consult and decide on using **only one** type of wave treatment with a single signal to reduce complexity of the design in the first implementation of the project and then use the choice between signal types and waves treatments as a second part of the project.

The three wave treatments choices are:

1) Lagoonal Random mode where low-energy, gentle currents simulate a lagoon environment. The pump speed changes slowly. Emits wavelengths of 250 Hz.
2) Tank-fill Random mode: simulates a higher energy wave as experienced in a tank fill. The pump changes speed frequently to simulate rolling waves and surges similar to tides. Emits wavelengths of 450-600 Hz.
3) Gyre mode creates a flow pattern of uniform clockwise and counter-clockwise flow levels pulsing at selected intervals. Emits wavelengths of 350 Hz.

If triggered by the Platypus, each wave sequence will last between 60 and 300 seconds.

Sensor Control System:
In order to trigger a wave event, Sam must swim up to and interact with the underwater sensor. To encourage this, an electromagnetic wavelength, loosely mimicking those discharged by platypus prey species (Pettigrew, Manger, & Fine, 1998), will be emitted by the sensor for a period of 5-10 minutes. Post successful pilot testing, if positive engagement with the sensor has been elicited, we will then add the choice of additional wave patterns. For each wave sequence a different electromagnetic wavelength will be emitted, providing an opportunity for Sam to learn what wavelength emission is associated with which wave sequence and providing a form of cognitive enrichment in the learning phase.

The emission of wavelengths (and the ability for Sam to activate waves) will occur randomly throughout the day (maximum of 6).

3. Pilot, Safety and Treatment Schedule:

1) Prior to assessing the effectiveness of the wave machine as an enrichment device, a short pilot study will be conducted to assess if there are any negative behavioural responses to the device. This pilot study will last for three days and involve:

- Two frequency emissions per day at the maximum duration (10 minutes).
- Two wave events at the maximum duration (5 minutes), regardless as to whether Sam has triggered these events.

During this pilot study, Sam's response to the emissions and waves will be monitored by an observer in the visitor area. Any overt negative response (i.e. rapid retreat, aggression towards sensor, abnormal repetitive behaviours, e.g. swimming in tight circles) to either the emissions or the waves will trigger the observer to immediately cease the emissions or waves. All other behaviours will be recorded continuously while the enrichment device is active. Keepers will also record any changes in feeding behaviour or participation in normal husbandry tasks (e,g. training, other enrichment).

In order to assess the effectiveness of the wave machine as enrichment for Sam, each emission and associated wave function will be considered as a different treatment. All treatments will be delivered Monday – Friday (excluding public or school holidays) to reduce the influence of high visitation days on behaviour. Treatments will consist of 2-day replicates and be repeated twice over a six-week period following an ABACADA design for multiple treatments (see Table 1).

Table 1. Treatment schedule self-activated wave enrichment

Wk	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
1	A	A	B	B	A	X	X
2	A	C	C	A	A	X	X
3	D	D	A	A	A	X	X
4	A	A	A	B	B	X	X
5	A	A	A	C	C	X	X
6	A	D	D	A	A	X	X

Normal husbandry routines will not be influenced by the treatment schedule, however all attempts will be made by the keeping team to maintain stable husbandry routines to eliminate other sources of variation that might influence Sam's behaviour. Tank cleans will be scheduled for non-treatment days, and a control day (A) or weekend day (X) be scheduled either side of the tank clean days. No other wave-based enrichment will be used during this study period (see Table 1).

On each treatment day, the number of electromagnetic emissions, and thus opportunities for Sam to engage with the wave enrichment, will be randomly allocated between 2 and 6. This safeguards the enrichment device becoming 'less stimulating' or even negative. The time at which emissions begin, the duration of each emission and the duration of the waves will also be randomly allocated throughout the study. This is to ensure that Sam is not able to predict when emissions (and thus the opportunity to interact with waves) will occur, which has the likelihood of increasing anticipatory circling behaviour.

During this study period, a single observer will conduct behavioural observations Monday – Friday from 9am to 4:30pm (visitor hours), using a combination of scan sampling and continuous sampling. Scan sampling will occur at 5-minute intervals to record state behaviours and generate an activity budget for Sam, identifying the proportion of time he spends engaged in various behaviours such as swimming, foraging, circling, and engaging with enrichment. Continuous sampling will be conducted on treatment days (B, C, and D) to record the number of times Sam activates the enrichment device, the duration of which he engages directly with device (both sensor and waves) and the time of day in which this occurs. On control (A) days, the number of times Sam interacts with the sensor will be recorded.

3.1 Additional data collection

Video recordings of Sam interacting with each of the wave treatments will be taken by the observer throughout the study, in

order to characterise the interaction style and any changes between treatments or over time.

An SD card linked to the system will collect all data from activity with the waterproofed interactive electrode sensor placed in the water. This logged data can supplement the information obtained from observations and scheduled video recordings.

3.2. Implementation

1. The implementation of the wave machine will involve the isolation of Sam into his off-display areas so that the technician can work safely in the area. This process will take approximately 2 hours and is not considered to be more disruptive than normal enclosure maintenance
2. The Pilot study will be run as above (see Section 3).
3. Wave treatments will be implemented in 2-day replicates over a six-week duration. Each treatment will be implemented twice throughout this period, with two - four days in-between each treatment. Thus, the total number of days in which the treatment will be implemented will be 12.
   If Sam activates the waves by swimming over the emitter, the maximum duration of the waves will be random between 60 seconds and 5 minutes
4. Observations will be conducted on each treatment day and for at least 2 control (non-treatment) days per week throughout the study (a minimum of 24 observation days). Further control days may be observed if other variables might impact normal behaviour (e.g. exceptionally high visitation, temperature, other husbandry routines etc.). Observations will be conducted from the visitor area.

If at the end of the study, the wave machine is estimated to have an overall enriching effect on Sam, as indicated by an increase in more natural behaviours (e.g. exploration, play) and a decrease in undesirable behaviours (abnormal repetitive behaviours), then it will be incorporated into the enrichment calendar indefinitely.

4. Data Analysis

For activity budgets: the proportion of sample points in which each behavioural state is observed will be calculated and averaged to calculate the proportion of time spent engaged in each behaviour for each day. The proportion of time engaged in each activity observed will be measured. For continuous data: the average time spent interacting with the device and average frequency of activations of the wave function will be calculated per treatment.

Measurements will be analysed using repeated measures analysis of variance (ANOVA) with each day as the initial unit of analysis to examine the effects of the treatments compared to baseline. As there will be no direct comparisons between treatments in the study design, each treatment will be compared only to the baseline.

5. The System Description

The system provides different types and intensities of wave patterns, enabling more choice to Sam. The design includes a remotely accessed interface so the keepers can easily adjust and control the environment according to Sam's needs (see Figure 2).
The control system includes three components. The sensor ball, the wave controller, and the pump controller. The pump controller is implemented using a programmable logic controller (PLC). PLCs are ruggedised industrial digital computing units widely used in control applications. The wave controller, a custom build microcontroller unit, connects to the PLC and the sensor ball. It has a WIFI interface to connect to the zoo wireless network and an inbuilt web server to generate the user interface.

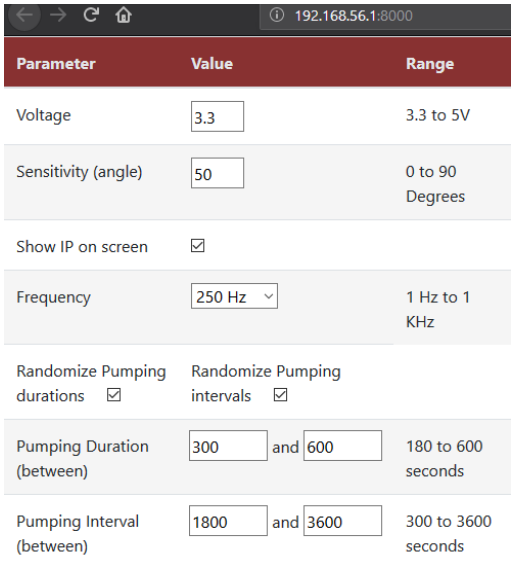


Figure 2. Interface for Remotely Adjusting Wave Settings

The user interface allows the configuration of the wave patterns If the ball sensor is triggered, wave patterns can be generated by controlling the pump flow volume via the PLC. All parameters such as trigger threshold, duration, inactive periods and patterns are configurable. The sensor ball is equipped with an internal inertial measurement unit (IMU) and the signal generator. Both are configured by the wave controller.

The senor cable is enclosed in the food-grade vinyl hose, the senor is enclosed in a PVC (polyvinyl chloride) pressure water pipe and the floating ball is 3d printed from PETG (polyethylene terephthalate glycol). The sensor ball has two stainless steel electrodes on the outside that are used to emit the electrical signal. The sensor is weighted in a way that it floats just below the surface and it is suspended from the ceiling (see Figure 3). It connects to the control unit that is installed outside the enclosure.



Figure 3: Components of the sensor ball – sensor enclosed in pressure water pipe houses an internal inertial measurement unit (IMU), signal generator and whole ball system is weighted so it floats just below the surface of the water.

To facilitate this project, modifications to the pump, electrical and internet facilities of the Platypus House were required. A commercial plumbing company upgraded and modified the pump system. An IT Solutions company and internal Zoos XXXX IT services installed a wireless access point and antennae to enable wireless internet access in the Platypus House to enable remote control of the system. In additions, electrical work to accommodate the sensor was completed by Zoos XXXX electrician.

Additionally, XXXXXX Zoo veterinary staff were consulted to ensure that all aspects of the project that would be physically accessible to Sam (the sensor) were not a safety concern. After submitting specifications of the sensor to the veterinary department and discussing operational aspects, approval was granted for the sensor to be installed in Sam's tank.

6. Initial Prototype Testing

An early sensor prototype was developed and tested in late 2019. Testing was initially performed in an unoccupied water tank to finalise any specifications before being set up in Sam's display tank where he was foraging. Sam was given approximately five minutes to adjust to the presence of the sensor and was monitored for any negative behaviours, such as actively avoiding the sensor or displaying aggressive behaviours. Sam initially moved to the other side of the tank away from the disturbance of the sensor being set up, but soon moved back into the middle to forage. With Sam deemed calm and alert by the keepers, the first test of the sensor emitting electromagnetic signals began. Sam continued to forage in the same area of the tank, seemingly unperturbed by the signals (if he could sense them). The frequency was then gradually increased within pulse the identified range (50 μ V cm-1) (Scheich, Langner, Tidemann, Coles, & Guppy, 1986), while Sam's behaviour was closely monitored. Sam continued to display calm foraging behaviours and eventually began to move towards the sensor and positively interact with enrichment items close to the sensor. With these positive natural and playful behaviours observed, the test was ceased. The overall testing period ran for approximately ten minutes.

7. Anticipated Outcomes

Due to multiple interventions, the process has been delayed. Like many projects that involve multiple stakeholders—Zoos XXXX, XXXXXX Zoo, an Animal Welfare Specialist, Zoo keepers and operational systems teams (research, management, construction, electronics, plumbing etc.), researchers based at three universities, all in a different state to the Zoo, funding applications (successful and not) as well as Zoo and university ethical clearance processes—there have been a series of stop-starts before and beyond COVID-19 complications. In addition, two of the researchers have moved to different institutions—one in a different sate and another in a different country, funding and travel is on hold during COVID and second wave lockdowns etc. meaning the project is 'still under construction'. We are involved in a project that is a genuine work in progress, housing a team of dedicated and passionate researcher/implementers. As such, the final version of the interactive sensor is yet to be tested.

With the deployment of the wave machine we aim to provide an engaging physical and cognitive environmental enrichment that is controlled by Sam. Control is an important element for providing positive welfare outcomes in zoo housed animals, and is difficult to deliver for certain species or enclosures. Often enrichment items or activities are delivered in complete control of the keeping staff, due to restrictions in safety requirements, enclosure structures, or other technically challenging problems. In this case, Sam will be able to recognize when the waves are able to be activated, what type of wave is being signaled, and have complete control as to whether the waves will be activated at that time. This allows Sam to exercise agency in his daily routine in a way that does not rely on keeper routines or involvement.

Furthermore, if we are able to demonstrate that the wave machine is motiving and enriching for Sam by increasing the performance of natural behaviours and reducing abnormal repetitive behaviours, we will have demonstrated a unique enrichment item that can be relatively easily installed in Platypus housing that engages in the unique natural sensory and cognitive capabilities of the Platypus species. Future work could focus on understanding how different individuals within the species respond to this technology and how other factors might influence motivation to engage in this enrichment. This will lead to a greater understanding of the animal-environment interaction for captive Platypus housing and allow animal care staff to set up habitats and enrichment in a way that provides multiple opportunities to express natural behaviour, positive experiences through the implementation of choice and control, and ultimately lead to animals thriving in our care. Once successfully established, similar developments for other species who enjoy water play (e.g. Penguins) can then be investigated.

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