# Platypus Surfing

## In Search of the Perfect Wave

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## ABSTRACT

For this project, we design a self-activated wave enrichment system for a solo male platypus, 'Sam', at Melbourne Zoo. We develop a sensor system that Sam can learn to activate by swimming near the device to trigger a wave sequence, providing both choice (to activate a wave pattern) and control (whether to activate) over his environment. We predict that the triggering will promote natural exploration and play behaviours in response to the wave patterns and reduce noted abnormal repetitive behaviours. The project involves multiple stakeholders with city and state zoos, Animal Welfare Specialists, keepers and operational systems teams, university researchers and multiple funding applications and ethical clearances. With the project 'still in process', we detail the initial testing which indicates the overall potential success of the interactive system for Sam 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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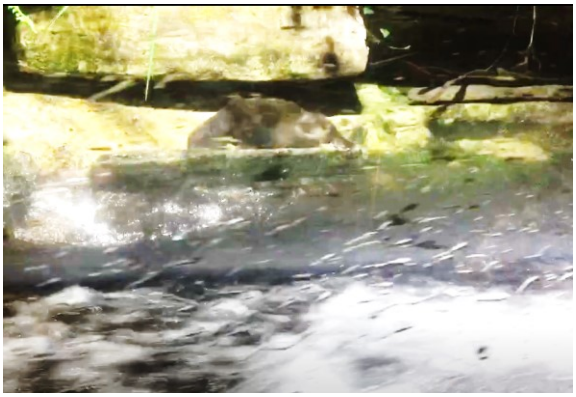


Figure 1. Sam comes out of the channels behind where he sleeps when fast flowing water (and food) is added to the enclosure.

## 1 Introduction

Sam is a 15-year old male platypus, Species360 Zoological Information Management System (ZIMS) local ID: A60442, who has lived at Melbourne Zoo (MZ) for the last 14 years. Melbourne Zoo implements an annual welfare risk assessment [1-4]. A welfare assessment of Sam in 2017 resulted in the design and implementation of countermeasures to reduce potential risks to welfare. These counter-measures 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 (see Figure 1), and the introduction of new outdoor swimming channels to the back-of-house area. The most recent 2019 welfare survey indicated that overall while 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 [3]. Therefore, MZ is working to offer Sam further opportunities for positive behavioural and welfare outcomes in his environment. As a male with venomous poisonous spurs, it is not possible to add a companion to his tank.

Sam's keepers reported that he 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 platypus, the specifics of the design and interactive technology problem, as well as the situated environment and requirements of Melbourne Zoo, Zoos Victoria. 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 for animals in captivity, introduced by among others Jon Coe [5] and continued throughout the decades is central to the forces, focus and impetus that shape modern animal welfare concerns, the Animal Computer Interaction (ACI) community [4,6,14] and has become increasingly the focus of Zoos Victoria's goals.

## 2 Project Background

Zoos Victoria (ZV) are continuously working to provide environmental enrichment for their 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 Victoria runs a philanthropically sponsored program called "Willy Wonka", where staff pitch unique ideas for enrichment items to provide their chosen species with positive experiences. Keepers for the MZ Australian Bush team, successfully applied for a small grant to build Sam a wave machine.

Twice a week, Sam's tank is cleaned or backwashed and this, creates a heavy flow of water into the tank. In the generated wave flows, Sam exhibits various types of play behaviour, indicating this is a positive experience. Watching this play inspired the design of the interactive wave machine design (see
Figure 2). As certain undesirable behaviours, such as swimming in repetitive circles have become part of Sam's routine as he moves around his tank, the welfare outcome can indicate a potential risk to welfare [15,16]. Environmental enrichment that increases natural behaviours can be effective in reducing abnormal repetitive behaviours [4,15,17-19].

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 [6-8,11,13,14,20]. The approach for animal-driven devices is a high area of interest and increasingly important in the ACI field, with agency, choice and control listed as core goals of the ACI manifesto [21]. Work involving choice and co-design is found in studies such as, with companion dogs, [22-27] primates [4,11,28], and includes processes for designing enrichment devices for zoos [10,13,29]. MZ 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, aiming to increase the performance of positive natural behaviours including exploration and play.

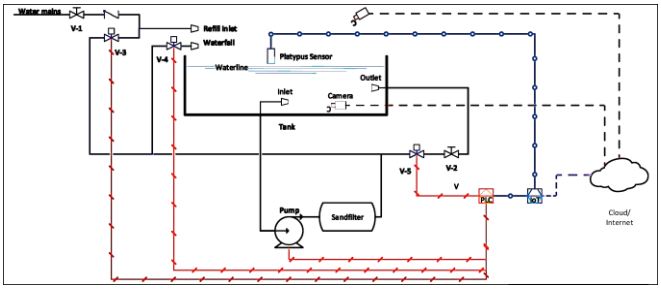



Figure 2. New Pipes, Valves, IoT. Colour Code Lines: Black-Existing pipes and valves; Blue-new piping and valves; Orange-new PLC Control System; Lavender-new IoT System. Valve List: V1-V2; existing manual. V3-V5; new actuated.

As a species, platypus forage and feed underwater, but when they dive underwater folds of skin cover their eyes, and their nostrils seal up to become watertight. They follow small electrical fields that are emitted underwater by fleeing prey. Captive platypus respond to small artificially generated electromagnetic fields which can be used to influence foraging behaviour [30-32]. In this project, we will use an underwater sensor that emits electromagnetic fields to attract Sam to it, in order that he then activates a wave sequence. With repeated instances of successful use, our aim is that Sam develops an understanding that his behaviour produces the wave activations.

Research on the electroreception capabilities of the platypus includes research on feeding behaviour [32]. Successful demonstration of direction tuning in response to electrical pulses demonstrates potential scalability to other activities [31,33-35]. For this project our aim is to attract Sam to choose to engage with enriching activities in his environment [36], by emulating imitations of electrical pulses [32] to an immersed electrode pulse in the range identified (50 μ V cm-1) to attract Sam [37].

The sensor used for this project would *emulate* the electromagnetic fields range emitted naturally by platypus prey species (yabbies, bloodworms etc.) [32]. Sam is fed live yabbies and bloodworms on a daily basis. However, we proximate rather than exactly replicate the prey signals to avoid confusion, frustration or disappointment where there is no prey food to be had. We replicate the identified signals [36] and in this way ensure these signals are not directly linked to prey signals.

## 3 The Senor System Description

An interactive wave system has been designed that is housed within a ball that floats just below the water level in the middle of the right end of the tank and emits an attracting signal to Sam. Sam must swim up to and interact with the underwater sensor to trigger a wave event, The wave pattern is triggered by Sam's proximity and movement next to the sensor.

| Parameter | Value | Range |
|---|---|---|
| Voltage | 3.3 | 3.3 to 5V |
| Sensitivity (angle) | 50 | 0 to 90 Degrees |
| Show IP on screen | ☑ | |
| Frequency | 250 Hz | 1 Hz to 1 KHz |
| Randomize Pumping durations ☑ | Randomize Pumping intervals ☑ | |
| Pumping Duration (between) | 300 and 600 | 180 to 600 seconds |
| Pumping Interval (between) | 1800 and 3600 | 300 to 3600 seconds |

Figure 3. Interface for Remotely Adjusting Wave Settings

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 3).
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-built 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.
The user interface allows the configuration of the wave patterns. If the ball sensor is triggered by Sam's movement swimming up to it, 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 a signal generator. Both are configured by the wave controller. The senor cable is enclosed in a 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 (see Figure 4) 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. It connects to the control unit that is installed outside the enclosure.



Figure 4: The sensor–Pressure water pipe houses an internal IMU & signal generator within a weighted whole ball system.

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 Victoria 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 addition, electrical work to accommodate the sensor was completed by Zoos Victoria electrician.

## 4 Ethical Considerations

This study has been approved by the Zoos Victoria, Research and Animal Ethics Committee (ZV19004) and all additional equipment placed in the animal enclosure is approved by a senior veterinarian at Melbourne Zoo. No elements that are physically accessible to Sam are of safety concern. The study is designed to be non-invasive and therefore is not expected to have negative impacts on animal welfare. No change to major housing structures in the tank will occur. There is no direct manipulation on Sam. The positioning of any additions in the tank will minimise interference, but maximise water patterns and swimming and water flow.

## 5 The Study Design

Testing of the enrichment device will take place at Melbourne Zoo in the display tank for Sam. We will conduct the study in a series of steps, stages and phases to eliminate any potential welfare issues at each stage. As a first step, we conducted an initial early prototype tests (see 5.1) as a proof of concept. In the next stage, we will conduct a short pilot study to assess if there are any negative behavioural responses to the device (see 5.2). We will use **only one** wave treatment to reduce complexity in the pilot study and phase one stages of the safety implementation testing of the project. On success, we will move to the next phase, where we assess the effectiveness of the wave machine as an enrichment device. In phase one (see 5.3), we will run a limited version, again with only one wave treatment to ensure all safety and familarisation and variations are taken into account. With success, we will move into phase two (see 5.4), where we will run a full version of the enrichment device, gradually introducing three wave forms, each with a variation of the electrical pulse so Sam can choose which

one he triggers. The study behaviour recording Observation Procedures (OP) (see 6) will continue throughout all phases.

## 5.1 Initial Early Prototype Test Step

We developed and tested an early sensor prototype 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 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. The frequency was gradually increased within the identified pulse range (50 μ V cm-1) [37], 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 ten minutes. The team began final development of the device and system.

## 5.2 Pilot Study Stage

The pilot study stage 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.

## 5.3 Phase One Stage

In the next stage, phase one, 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 pilot and phase one. 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. Wave treatments will be implemented in 2-day replicates over a six-week duration. 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.

## 5.4 Phase Two Stage and Wave Treatments

If at the end of phase one implementation, 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 and play) and a decrease in undesirable repetitive behaviours, then it will be incorporated into the enrichment calendar indefinitely. Once we have established that playing in the water (wave patterns) is what Sam is responding too and that he chooses to spend time playing there, we can then proceed to phase two stage.
The keepers and researchers observed and discussed Sam's play styles and the wave types and backwash velocities he was interacting the most with. Consequently, three specific wave forms that resemble Sam's preferences were selected.

### 5.4.1 Wave Treatments and Triggering

The three identified wave treatments are:
(1) Lagoonal Random mode where low-energy, gentle currents simulate a lagoon environment. The water 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 water 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 counterclockwise flow levels pulsing at selected intervals. Emits wavelengths of 350 Hz.

In order to trigger a wave event, Sam must swim up to and interact with the underwater sensor. The wave pattern is triggered by Sam's proximity and movement next to the sensor. To encourage this, an electromagnetic wavelength, loosely mimicking those discharged by platypus prey species [36], will be emitted by the sensor for a period of 5-10 minutes. Once triggered by the platypus, each wave sequence will last between 60 and 300 seconds.

At this stage, phase two, the device will be open for Sam to trigger at will, so any further adjustments and additions can be co-designed with Sam [14]. 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, adding cognitive enrichment in the learning phase. We can easily make adjustments to his responses according to what we perceive to be most enjoyable to him, beyond addressing welfare needs (see Figure 3). Sam will have agency over the device and the frequency, times of use, types of waves and durations of interaction responses will be up his choices [38]. We can then begin to study Sam's genuine preferences and adapt the environment accordingly.

# 6 Data Collection and Observation Procedures

During all stages of the study Sam's response to the emissions and waves will be monitored by an observer using MZ Observation Procedures (OP) in the visitor area. Any overt negative responses (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).

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 and Sam's response noted.

The keepers will maintain usual 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 or weekend day be scheduled either side of the tank clean days. No other wave-based enrichment will be used during this study period.

Observations from the visitor area will be conducted on each treatment day and for at least 2 control (non-treatment) days each week throughout the study.

A single observer will conduct behavioural observations (OP), Monday – Friday in 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, play, foraging, circling, and engaging with enrichment. Continuous sampling will be conducted on treatment to record the number of times Sam activates the enrichment device, the duration of which he engages directly with the waves triggered by the device and the time of day in which this occurs. On control days, the number of times Sam interacts with the sensor/waves will be recorded. Further control days may be added if variables such as exceptionally high visitation, temperature, other husbandry routines might impact.

## 6.1 Additional data collection

Video recordings of Sam interacting with each of the wave treatments will be taken by the observer throughout all phases of the study to characterise interaction styles, and any changes between responses to treatments or responses over time.

An SD card linked to the system will collect all activity data from the interactive electrode sensor placed in the water. The logged data will supplement observations and video recording information.

## 7 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. Categorised behavioural states include: Swimming circles, in one portion tank (Left or Right or Centre), and does not surface; Out of water stationary or resting; Underwater stationary or resting; Out of water and moving; Swimming length of tank, no circling; Swimming or floating (still for > 3 seconds) on surface of water; Foraging or feeding at bottom of tank; Deliberate interaction with wave machine; Incidental interaction with wave machine; Deliberate play in water flow etc. The proportion of time engaged in each activity observed will be measured. For continuous data: the average time spent interacting with the functions the device elicits 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.

## 8 Anticipated Outcomes

As a work in progress, the interdisciplinary team is yet to test the final version and gauge Sam's responses. While understanding bringing control of their environment as an important element for providing positive welfare outcomes in zoo housed animals, we note this can often be difficult to deliver for certain species or enclosures. With the deployment of the wave machine, we aim to provide an engaging physical and cognitive environmental enrichment that is controlled by Sam. Often enrichment items or activities are maintained in complete control of the keeping staff, due to safety requirement restrictions, enclosure structures, or other technically challenging problems. Once fully implemented, our aim is that 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 he activates the waves at that time. This will allow Sam to exercise agency in his daily routine in a way that does not rely on keeper routines or involvement.

Further, 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 system that can be relatively easily installed in other platypuses housing to engage their unique natural sensory and cognitive capabilities. 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. This would 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 and enjoy 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 also be investigated.

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## REFERENCES

[1] Sherwen, S. L. et al. Effects of visual contact with zoo visitors on black-capped capuchin welfare. Appl. Anim. Behav. Sci. 167, (2015).

[2] Dong, R. et al. Supporting animal welfare with automatic tracking of giraffes with thermal cameras. in Proceedings of the 29th Australian Conference on Computer-Human Interaction - OZCHI '17 (2017). doi:10.1145/3152771.3156142.

[3] Sherwen, S. L. & Hemsworth, P. H. The Visitor Effect on Zoo Animals: Implications and Opportunities for Zoo Animal Welfare. ANIMALS 9, (2019).

[4] Webber, S. et al. Kinecting with Orangutans : Zoo Visitors' Empathetic Responses to Animals' Use of Interactive Technology. in

Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17 (2017). doi:10.1145/3025453.3025729.

[5] Mancini, C. Animal-computer Interaction: A Manifesto. interactions 18, 69–73 (2011).

[6] Whitham, J. C. & Wielebnowski, N. New directions for zoo animal welfare science. Appl. Anim. Behav. Sci. 147, 247–260 (2013).

[7] Hirskyj-Douglas, I., Read, J. C. & Cassidy, B. A dog centred approach to the analysis of dogs' interactions with media on TV screens. Int. J. Hum. Comput. Stud. 98, 208–220 (2017).

[8] Zamansky, A. & Roshier, A. Exploring research methods for ACI (RM4ACI). in Proceedings of the Third International Conference on Animal-Computer Interaction - ACI '16 (2016). doi:10.1145/2995257.3014067.

[9] French, F., Mancini, C. & Sharp, H. Exploring methods for interaction design with animals. in Proceedings of the Third International Conference on Animal-Computer Interaction - ACI '16 (2016). doi:10.1145/2995257.2995394.

[10] Piitulainen, R. & Hirskyj-Douglas, I. Music for monkeys: Building methods to design with white-faced sakis for animal-driven audio enrichment devices. Animals (2020) doi:10.3390/ani10101768.

[11] French, F., Mancini, C. & Sharp, H. Exploring Research through Design in Animal Computer Interaction. in Proceedings of the Fourth International Conference on Animal-Computer Interaction - ACI2017 (2017). doi:10.1145/3152130.3152147.

[12] French, F., Mancini, C. & Sharp, H. More than human aesthetics: Interactive enrichment for elephants. in DIS 2020 - Proceedings of the 2020 ACM Designing Interactive Systems Conference (2020). doi:10.1145/3357236.3395445.

[13] Webber, S., Carter, M., Smith, W. & Vetere, F. Co-designing with orangutans: Enhancing the design of enrichment for animals. in DIS 2020 - Proceedings of the 2020 ACM Designing Interactive Systems Conference (2020). doi:10.1145/3357236.3395559.

[14] Mason, G. & Rushen, J. Stereotypic animal behaviour: Fundamentals and applications to welfare: Second edition. https://eds-a-ebscohost-com.ezproxy.aut.ac.nz/eds/detail/detail?vid=8&sid=0c859ee6-748f-4df9-9a53-05d9e87fbf3e%40sdc-v-sessmgr02&bdata=JnNpdGU9ZWRzLWxpdmU%3D#AN=47935685&db=asx (2006).

[15] Rose, P. E., Brereton, J. E., Rowden, L. J., de Figueiredo, R. L. & Riley, L. M. What's new from the zoo? An analysis of ten years of zoo-themed research output. Palgrave Commun. 5, (2019).

[16] Latham, N. & Mason, G. Frustration and perseveration in stereotypic captive animals: Is a taste of enrichment worse than none at all? Behav. Brain Res. 211, 96–104 (2010).

[17] Mancini, C. et al. Animal-computer interaction SIG. 1233–1236 (2012) doi:10.1145/2212776.2212431.

[18] Rault, J.-L., Webber, S. & Carter, M. Cross-disciplinary perspectives on animal welfare science and animal-computer interaction. in Proceedings (eds. Cheok, A. D., Sunar, M. S., Neo, K. & Chisik, Y.) 1–5 (Association for Computing Machinery, 2015). doi:\url{10.1145/2832932.2837014}.

[19] Wolfensohn, S. et al. Assessment of welfare in zoo animals: Towards optimum quality of life. Animals 8, (2018).

[20] Mancini, C. Animal-computer interaction: A manifesto. Interactions (2011) doi:10.1145/1978822.1978836.

[21] Hirskyj-Douglas, I. & Read, J. C. Using behavioural information to help owners gather requirements from their dogs' responses to media technology. in Proceedings of the 30th International BCS Human Computer Interaction Conference, HCI 2016 vols 2016-July (BCS Learning and Development Ltd., 2016).

[22] Hirskyj-Douglas, I., Read, J. C. & Horton, M. Animal personas: Representing dog stakeholders in interaction design. in HCI 2017: Digital Make Believe - Proceedings of the 31st International BCS Human Computer Interaction Conference, HCI 2017 vols 2017-July (2017).

[23] Robinson, C. L., Mancini, C., van der Linden, J., Guest, C. & Harris, R. Canine-centered interface design. in Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14 3757–3766 (ACM Press, 2014). doi:10.1145/2556288.2557396.

[24] Hirskyj-Douglas, I. & Read, J. C. Animal Behavior and Cognition DoggyVision: Examining how Dogs (Canis familiaris) Interact with Media using a Dog-Driven Proximity Tracker Device. ABC 2018, 388–405.

[25] Robinson, C. et al. Designing an emergency communication system for human and assistance dog partnerships. in Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '15 (2015). doi:10.1145/2750858.2805849.

[26] Hirskyj-Douglas, I., Read, J. C. & Cassidy, B. A dog centred approach to the analysis of dogs' interactions with media on TV screens. Int. J. Hum. Comput. Stud. 98, 208–220 (2017).

[27] Webber, S., Carter, M., Smith, W. & Vetere, F. Interactive technology and human–animal encounters at the zoo. Int. J. Hum. Comput. Stud. 98, 150–168 (2017).

[28] French, F. et al. Don't cut to the chase: Hunting experiences for zoo animals and visitors. in ACM International Conference Proceeding Series vols 15-17-November-2016 (2016).

[29] Proske, U., Gregory, J. E. & Iggo, A. Sensory receptors in monotremes. Philos. Trans. R. Soc. London. Ser. B Biol. Sci. 353, 1187–1198 (1998).

[30] Manger, P. R., Collins, R. & Pettigrew, J. D. The development of the electroreceptors of the platypus ( Ornithorhynchus anatinus ). Philos. Trans. R. Soc. London. Ser. B Biol. Sci. 353, 1171–1186 (1998).

[31] Manger, P. R. & Pettigrew, J. D. Electroreception and the feeding behaviour of platypus (Ornithorhynchus anatinus: Monotremata: Mammalia). Philos. Trans. R. Soc. B Biol. Sci. 347, 359–381 (1995).

[32] Fjällbrant, T. T., Manger, P. R. & Pettigrew, J. D. Some related aspects of platypus electroreception: Temporal integration behaviour, electroreceptive thresholds and directionality of the bill acting as an antenna. Philos. Trans. R. Soc. B Biol. Sci. 353, 1211–1219 (1998).

[33] Manger, P. R., Calford, M. B. & Pettigrew, J. D. Properties of electrosensory neurons in the cortex of the platypus (Ornithorhynchus anatinus): Implications for processing of electrosensory stimuli. Proc. R. Soc. B Biol. Sci. 263, 611–617 (1996).

[34] Ruxton, G. D. Non-visual crypsis: A review of the empirical evidence for camouflage to senses other than vision. Philos. Trans. R. Soc. B Biol. Sci. 364, 549–557 (2009).

[35] Pettigrew, J. D., Manger, P. R. & Fine, S. L. B. The sensory world of the platypus. Philos. Trans. R. Soc. London. Ser. B Biol. Sci. 353, 1199–1210 (1998).

[36] Scheich, H., Langner, G., Tidemann, C., Coles, R. B. & Guppy, A. Electroreception and electrolocation in platypus. Nature 319, 401–402 (1986).

[37] Hirskyj-Douglas, I., Read, J. C., & Cassidy, B. A dog centred approach to the analysis of dogs' interactions with media on TV screens. Int. J. Hum. Comput. Stud. (2017) doi:10.1016/j.ijhcs.2016.05.007.