**Animal Computer Interaction: Enrichment Indicating Sea Otter Health**

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* Introduction - What you're doing, why it's important
* Previous/Related work - What's already been done and why are you different
  + Need five-10 related works??
* Your Work (Methodology and Results)
* Discussion - What have you learned
  + Compares the original plans with the final achievements. If there is a gap, explain what parts failed and why. If not, share the secrets of success :)
* Future Work - What remains to be done for your project, what are potential next steps for the project
* Conclusions - Take home points/Recap
* References (6+)

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Introduction

* What: creating a toy to monitor otter health
* Why: caring for animals in captivity

*[include part of abstract maybe?]*

This team seeks to explore beneficial applications of animal computer interaction to aid animal health, particularly those in captivity assisted by human handlers. This exploration will be conducted with a focus on Southern Sea Otters by particularly studying how interaction with enrichment items can reveal key information about health factors to proactively inform human handlers as needed. The exploration of enrichment toys indicating health will be explored in the creation of a new otter toy with material and functionality resembling natural behaviors and with ubiquitous computing integrations, such as IMUs.

Our goal is to facilitate a more effective method for human handlers to analyze the health data of sea otters in order to make informed decisions about their well-being

Previous/Related Work

* Point to Josh Terry work
* Different: further pursuing a toy he didn’t

The research that inspires most of the work in this project is from the Animal Computer Interaction Lab (ACI). The vision of this lab is to make strides in the emergent field of Animal Computer Interaction and design interfaces for all species. Due to the more stringent demands of designing for animals, relevant work up to this point mostly revolves around wearable devices or devices involving rudimentary interaction modalities [9,10]. Through this research we find that ACI can be built with the expectation that animals can have a simple understanding of *how* to interact with technologies even if they don’t know *why* [9]. Additional research has been done to look at larger timescale monitoring, including deducing the suitability of dogs for service roles [10]. This has some parallels to our use case of analyzing large timescales of data in order to analyze health information.

This team is part of novel research on marine mammal enrichment and health activity. The most significant source to aid research has been derived from work by fellow Georgia Tech researcher Josh Terry entitled “Marine Mammal Health Informatics” [1]. Terry experimented various otter toy options that engage natural behaviors, narrowed the best toy choice, further optimizes the toy based on realistic material and play behavior factors, and developed an enhanced otter toy with a MicroSD integration among other technology to quantify otter behavior [1]. This optimized toy highly mimics stone-handling behaviors seen in otters to break open invertebrates to retrieve food [6]. This research also highlighted several otter behaviors that will inform how a new toy prototype is developed, such as biting, smashing, spinning, and anxiety, that are unfamiliar to those not involved in the research space. To better understand what these behaviors meant, further research was dedicated to studying these behaviors and their potential causes as further detailed in this paper’s methodology.

Because of the novelty of this research space, this work follows yet differs from Terry’s work in many ways. First, this study is different in exploring the application of an otter toy that engages the sea otters’ behavior and environmental interaction in a similar but different way compared to that of Terry’s toy. This toy is a kelp toy with an entirely different material and build, and it will have different technical integrations given its difficulty to waterproof. Furthermore, this study works solely on the development of this toy and the analysis of its data as opposed to also building an informatics interface to present the data in a user-friendly manner. However, valuable analyses and observations will be noted and communicated despite the different final format.

We take valuable inspiration from work in the ACI lab, Josh Terry’s previous endeavors, and related work in the broader field. Research has been done on gamifying animal play behavior in order to better understand their behavioral patterns [11]. Using all these previous works we intend to create a novel design and pipeline that serves the unique use case of health monitoring, and the unique user demands of sea otters.

Our Work (Methodology & Results)

* Methodology – independent research; meeting to weed ideas out for final product
* Results – plan for final product
  + Otter research
  + Hardware research (SHIMMER)

The development of a novel otter toy required context-building and subsequent discussion on product planning. Given the unfamiliarity of members with this field of research, members were encouraged to take time to understand both animal computer interaction as a subsection of ubiquitous computing and marine mammal research through a technical lens. Then, the team was tasked with independently researching otter enrichment in all settings (natural and captive) and what can be learned from the various behaviors exhibited in these interactions. Thus, most of the work thus far has consisted mostly of information and requirements gathering in addition to initial designing. Significant findings of note in context to this project are shared as follows.

Various sources studied otter behaviors in enrichment settings. One source quantified the presence of similar behaviors among several toys that match some of the data seen in Terry’s work [5].Other sources include otter enrichment videos provided by aquariums that highlighted unique toys and the unique behaviors exhibited after engagement with these toys [2,3,4,7]. The Sacramento Zoo videos food-scarce silicone toys with behaviors of chasing, biting, grabbing, bashing, underwater flipping, and surface-level twisting while Paradise Wildlife Park showcased a rotating contraption involved food promoting behaviors of grabbing and biting [3,4]. Oregon Zoo showed food-scarce plastic toys and ice demonstrating behaviors like that of the Sacramento Zoo’s river otters with an additional behavior of jumping out of the water [2]. Lastly, Audubon Nature Institute highlighted the unexpected love for ice that otters have, in both contexts of infused with food and not, that exhibiting bashing, biting, and grabbing as seen with various other enrichment activities [7]. Thus, the team developed a strong discernment that otters are very rough players and require heavy duty enrichment toys that can deal with the intensity of their play sessions.

Other sources highlighted other enrichment behaviors outside of play sessions that were valuable in the design of the new toy prototype. One such paper looked at stone-handling among otter populations as a tool for breaking down food [6]. This motivated discussion on the introduction of a new material and function not previously explored for enrichment. Moreover, another source looked at how prey-hunting was favored by otters despite not being a major part of their diets [8].

Discussion –

* What we have learned comparing original plan with final achievements.
* If there is a gap, explain what parts failed and why.
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* Slow to getting through research and weeding ideas out
* Working on hardware learning curve
* Lots of considerations when working with animals, probably moreso than humans, especially given diverse environments (water) and inability to voice thoughts (preservation of free will)

Through our research and prior literature, the team made the design decision to go forward with a kelp-like toy for development. Prior to this decision another contender was an ice-based toy, however this option presented complications. The ice-based solution was an original option because the ice itself could be bashed, gnawed, etc. And afterwards through photo analysis we could create inferential data points. However, the team postulated that it might be difficult in a supervised setting for the researchers to retrieve the ice chunk from the otters. Additionally, there was a fear that technical pieces embedded within the ice were accessible by the otter and may present a health hazard. A kelp-toy had the added benefit of being a strictly supervised solution (it would be held on one end by the researcher). Moreover, through preliminary discussions a kelp toy would have more sensing capabilities that could categorize and quantify various otter actions: pull, twirl, paw, bite, etc.

Various components of this project make the translation from research and ideation to prototype difficult. First, the design constraints are extensive need to accommodate for the context and users make thinking through the design critical. This device needs to operate in a heavily used aquatic environment. Additionally, lots of research needed to be done to ensure the kelp-toy would accommodate for all possible affordances that an otter needs to play. The research needs of this project are unlike others revolving around HCI. We can’t rely on research methods such as interviews or surveys but instead we depend on primary sources such as videos or research papers. The hardware learning curve has been an additional pain point, but we have relied on members of the Animal-Computer Interaction Lab as subject matter experts and left most of the hardware acquisition needs to them.

Future Work

* What remains to be done
* Next steps
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* Creation of kelp toy with IMUs inside

The team plans to start full-force development on the kelp toy by prototyping and experimentation with a more familiar mammalian species, dogs. Given the immense involvement of dogs in modern animal computer interaction work, their involvement in prototype development allows for easier accessibility to test specific materials, construction, and technical integration without having to undergo difficult planning and negotiation to work with the otters at the aquarium. In the opportunity that the team can work with our target species, there will be a much better product that can test realistic application as opposed to working out simple starting kinks and problems.

The physical development of the toy prototype will involve addressing a variety of factors and fabrication/testing of the system. The plan is to create an enclosure made of a tough material, likely ballistic nylon, that is durable to the roughness of otters and dogs. The enclosure should have an opening and pockets where sensors, microcontrollers, battery, and communication devices can be slipped into. There will be two shimmer IMU devices located on either end of the kelp toy such that the motion of the otter can be gathered, and the handler position relative to the kelp can be determined. Processing the data from the sensors will be accomplished with a Tiny Pico V2 microcontroller while Wi-Fi communication will be handled by an ESP development board. All devices must be powered by a lithium-ion battery, so it is important to research electrical safety and fire hazard guidelines to ensure our equipment does not pose a risk of igniting or electrocuting any subjects. Once the device is made our focus will shift to data processing, the device must first be able to determine which side the handler is holding, likely seen by a decrease in magnitude of various IMU data. Once this is determined, the opposite end can be determined to be associated with the otter/dog and data on that end will be processed to yield information such as speed of various movements the animal performs. This process will likely end up being iterative as the best points patterns in the data are determined to yield the most comprehensive overview of the animals' health.

Throughout this process we intend to start an iterative feedback cycle with the Georgia Aquarium running design decisions by them, getting feedback about feasibility and health concerns, and then revisiting the design until we reach an agreeable design for all.

Conclusions

Animals are often overlooked when thinking about who can benefit from the use of technology. However, through measures like health, behavior, and performance tracking, animals can also become a user that benefits from wearable technology or instrumented toys. As a team, we aim to explore ways to capture health information on sea otters in captivity through their interactions with instrumented enrichment toys, which will in turn inform the handlers of the otters’ health statuses. After conducting research on the play behaviors of otters in the wild and in captivity, we have discovered that otters exhibit biting, smashing, and chasing behaviors with the toys and other objects in their environment [3, 4]. Looking at past studies on animal computer interaction involving otters and dogs, we examined methods in which sensors were incorporated into the animals’ toys to record certain behaviors [1, 9, 10]. Focusing on Josh Terry’s previous work with otters, we will similarly create a toy that will allow the otter to display natural behaviors while interacting with it. Our toy differs in that it will resemble kelp, which is commonly found in the otters’ habitat in the wild. Our toy will also require more involvement from the handler than Terry’s previous toys did. Our next steps involve obtaining the materials required to create the physical prototype, creating the prototype, and then testing the prototype with dogs first.

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