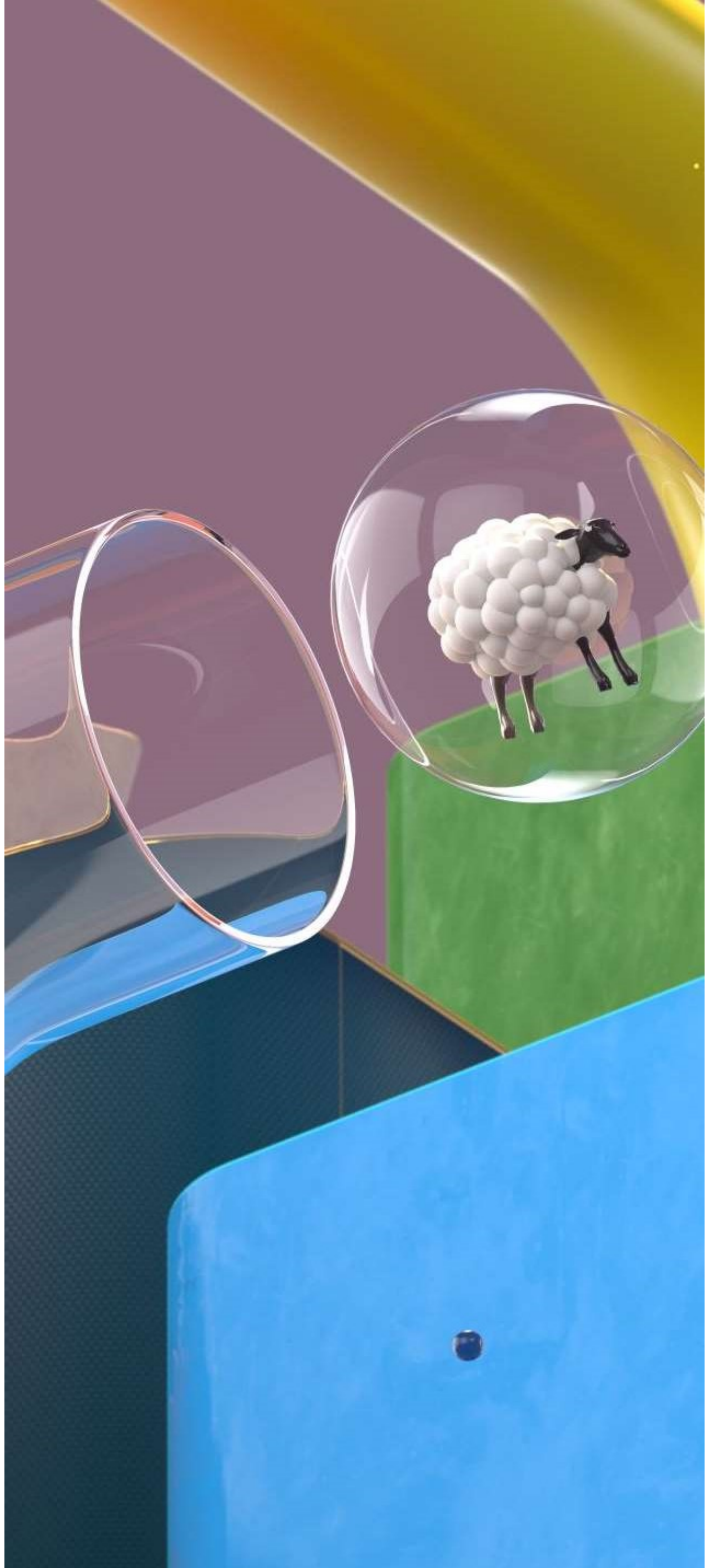
Improving the Lives of Zoo Animals with Technology:
A Historical and Empirical Perspective

Eduardo J Fernandez, PhD

School of Animal and Veterinary Sciences

University of Adelaide

THE UNIVERSITY OF ADELAIDE AUSTRALIA



Talk Syllabus:

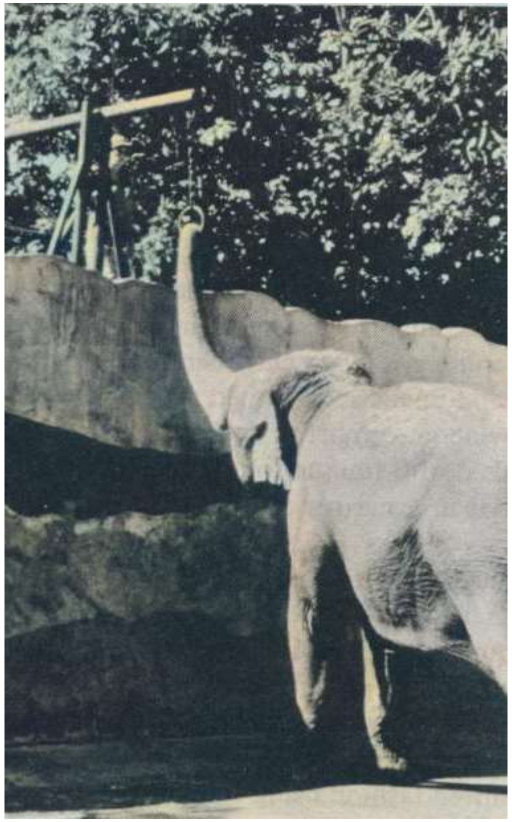
- We will focus on improving the lives of zoo animals with technology in 3 parts:

1. Technological enrichment, including both interactive and non-interactive forms.
2. Improving exhibit design, including by Temporary Exhibit Design (TED).
3. The ability to monitor welfare, including with software.

- The goal is to be empirical and technological in how we improve welfare.

History of enrichment

(see Fernandez & Martin, 2021).



The concept started as a behavioral engineering endeavor in the 1970's & 1980's (Markowitz, 1978; 1982; Markowitz & LaForse, 1987)

In other words, it was devised as a technological operant conditioning procedure!

Markowitz saw animals in an environment (antecedent stimuli) that he wanted doing specific responses (behaviors), so he rewarded the actions (consequence):

Antecedent – **B**ehavior - **C**onsequence

ABC three-term contingency

For example: Pacing polar bears and chasing servals

Polar bears paced all day.

Markowitz created a voice-activated mechanical device.

- Device attached to conveyer belt with fish.
- Polar bears vocalized into microphone; fish launched into exhibit.

OR – servals presented with artificial prey.

- Serval chased prey; got food reward.

History of enrichment (cont.): Criticisms and advancements

Critics argued that behavioral engineering was contrived.

Animals needed complexity: naturalistic complexity (Hancocks, 1980; Hutchins et al., 1984).

Markowitz (1982) responded to some of these criticisms by noting that, “the best interests of captive animals may not be served by making their state as ‘wild’ as possible.” (p. 12).

Nonetheless, Markowitz did start incorporating ‘natural’ designs (see Markowitz et al., 1995).

Today, enrichment involves both engineered and natural arrangements (Forthman-Quick, 1984).

Technological Enrichment: Interactive and Non-interactive

(Hryhorenko, McWhorter, Whittaker, & Fernandez, 2025)

We conducted a systematic scoping review on the use of technological enrichment:

Technological Enrichment: Devices or events with automated internal mechanics that are at least partially self-controlled.

Interactive: Manipulation of the device or event that results in a direct consequence as a result of the interaction.

A total of 22 published studies were included in the review.

Figure 2. Distribution of species used in technological enrichment studies, grouped by taxonomic order. The sunburst chart illustrates the number of studies associated with each species (e.g. orangutan [*Pongo* spp], chimpanzee [*Pan troglodytes*], sun bear [*Helarctos malayanus*]) and higher taxonomic grouping (e.g. primates, carnivores). Larger segments represent species more frequently studied.

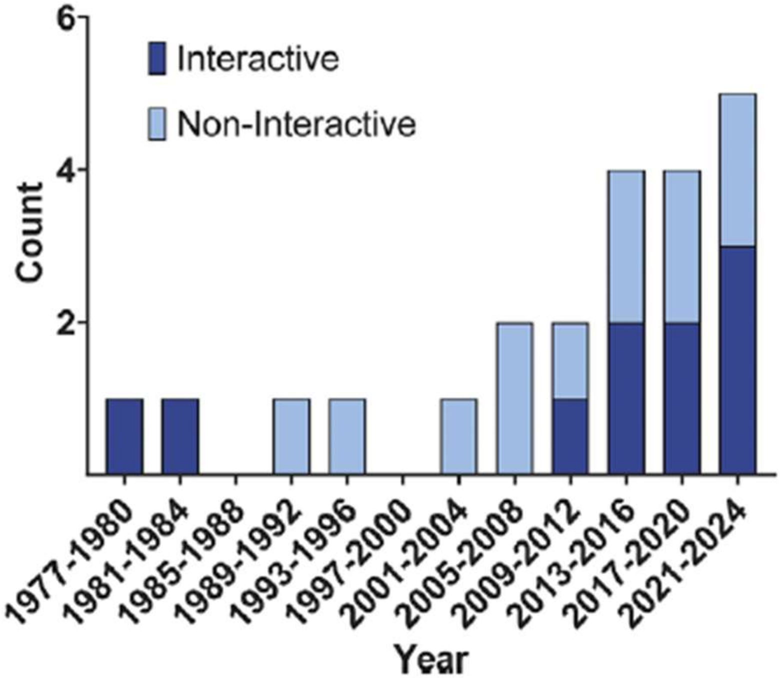


Figure 3. Number of articles published from 1978 to 2024 that assessed technological enrichment in zoos, aquaria, or wildlife parks. The dark blue bar shows the total number of articles by year, while the light blue bar shows the subset of studies involving interactive technologies (e.g. touchscreen devices or motion sensors).

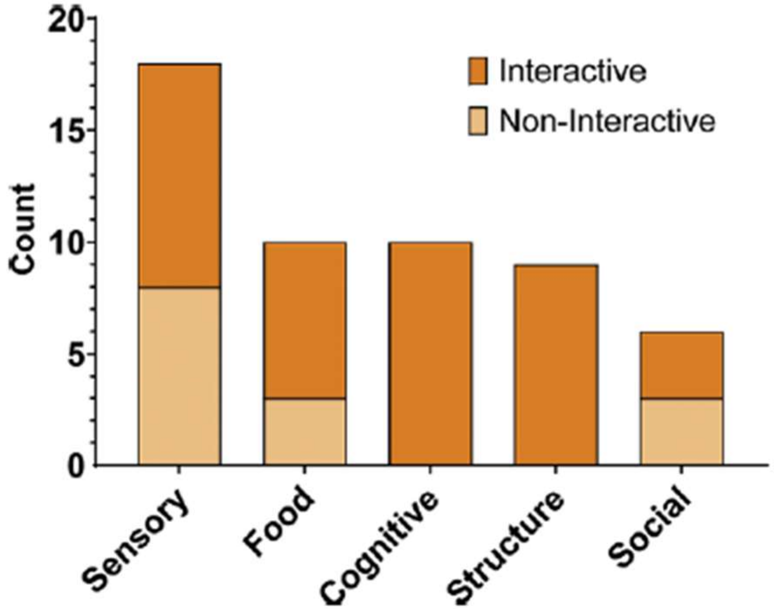


Figure 4. Frequency of each enrichment type (sensory, food, cognitive, structural, social) across the 25 studies reviewed. Bars are divided by interactivity: dark orange = interactive technology (e.g. touchscreens, push-buttons), light orange = non-interactive technology (e.g. speakers, automated feeders).

Table 2. Classification of technological enrichment types used in zoo, aquaria, and wildlife park studies. Technologies are categorised as interactive or non-interactive, with definitions, the number of studies using each technology, and the species (common names) involved. Interactive technologies require animal-initiated input (e.g.computers, push-buttons), whereas non-interactive devices operate automatically (e.g., speakers, response-independent feeders)

Interactive		Definition	Count	Species
	Computer	Electronic devices equipped with screens and capable of running programs, displaying content, or enabling interactive experiences	8	Orangutan, Chimpanzee, Sun Bear, Japanese Macaque
	Motion Sensor	Device that detects the presence or movements of animals and responds accordingly	2	African Leopard, Chimpanzee
	Projector	Device that displays visual content onto surfaces within the animal's enclosure	1	Orangutan
	Push-button	A mechanical or digital button that triggers a pre-programmed response when pressed by the animal	2	Mandrill, Asian Small-Clawed Otter
Non-Interactive				
	Speaker	Device that plays audio content, such as recorded animal calls, music, or environmental sounds	5	Gorilla, Elephant, Lemur, Dolphin
	Video	Moving images or pre-recorded content to stimulate animals visually	4	Dolphin, Orangutan, White-Faced Saki
	Response Independent Feeder	Device that releases food or treats at predetermined intervals	3	Red Fox, Black Bear, Grizzly Bear

Future of Exhibit Design (Fernandez, Brereton, & Coe, 2023)

The science of exhibit design is a two-part process:

1. Assessment (use of typical and newer welfare tools and topics).
2. Intervention (Temporary Exhibit Design; TED).

Also reliant on <u>individualized</u> data (welfare is always a science of $n = 1$).

Assessment of Exhibit Design

Newer measures include:

Behavioral Diversity (Brereton & Fernandez, 2022a; Miller et al., 2020)

Enclosure Use Variability (Brereton & Fernandez, 2022b).

Also, considers newer areas of research, including Choice and Control (Brando & Buchanan-Smith, 2018) and (Human-Animal Interactions (HAIs) or Animal-Visitor Interactions (AVIs) (Fernandez & Sherwen, 2024).

Temporary Exhibit Design (TED)

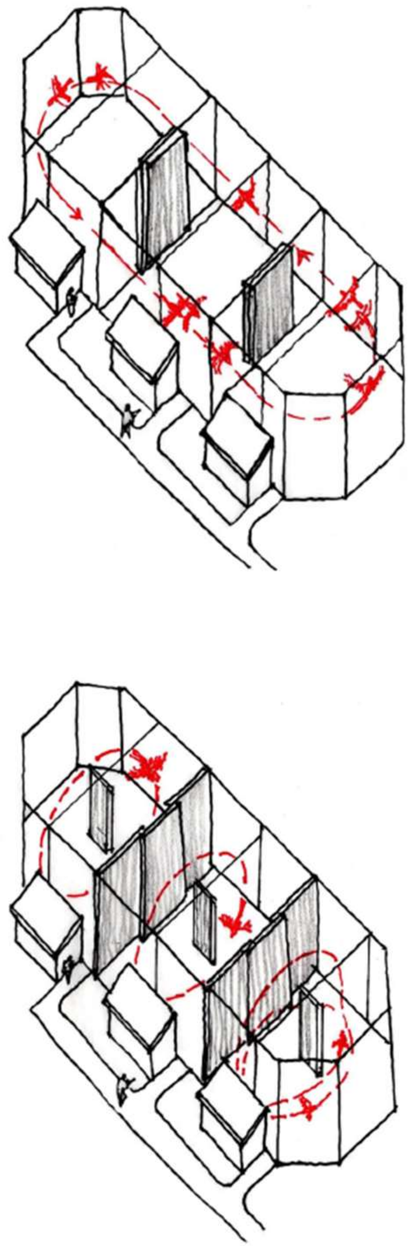
Using DATA to determine INDIVIDUAL exhibit use.

Exhibit Design is usually done by:

- Anecdotal evidence (Individual-based, but no data).
- Natural histories (Data-based, but no individuals).

With TED, we can test potential prototyped structures.

- Produce empirically-based suggestions that themselves can be further tested.



For example:

Animals might be anecdotally observed to be more visible in areas where it is darker/covered.

TED: provide more temporary covering (tarps).

Collect data on tarp vs. non-tarp area use.

The results can be used to guide permanent exhibit designs.

What can we test?

Everything!

You can test not only the TED, but types (parametric) of TED (e.g., different temporary pool depths; course/fine texture of substrate) and visitor/staff responses to TED.

This can also help guide permanent mechanical enrichment structures (see Fernandez & Martin, 2021; 2023).

The Enclosure MonitoR Use (EMU) App (Brereton, Tuke, & Fernandez, 2025):

The ZooMonitor software (Wark et al., 2019) has been critical for collecting behavioral data of zoo animals.

However, limitations exist in terms of making exhibit use comparisons beyond heat maps.

Therefore, we created the EMU app to allow for better exhibit use comparisons.

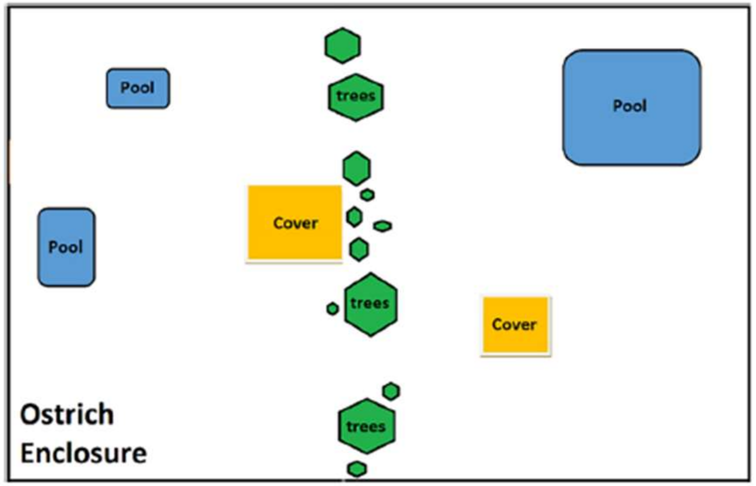


FIGURE 1 | Hypothetical enclosure for one ostrich. [Color figure can be viewed at wileyonlinelibrary.com]

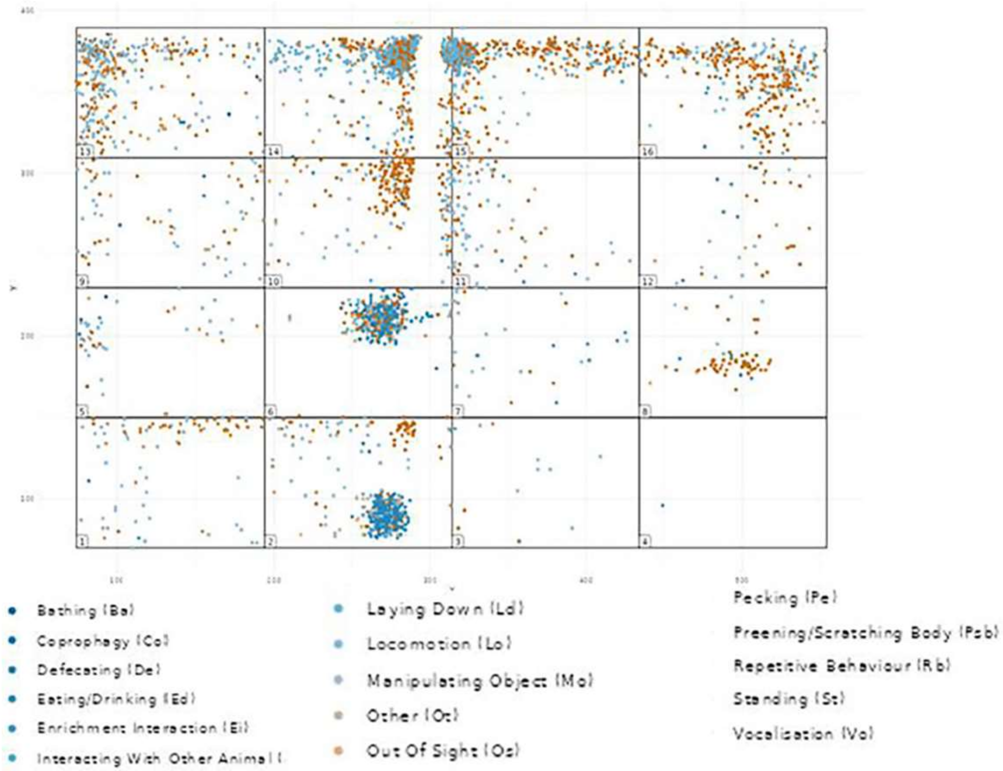


FIGURE 2 | A hypothetical example of ostrich enclosure use, using the output from EMU. Here, different behaviors appear as different colors. This image shows where individual behaviors are most likely to occur. [Color figure can be viewed at wileyonlinelibrary.com]

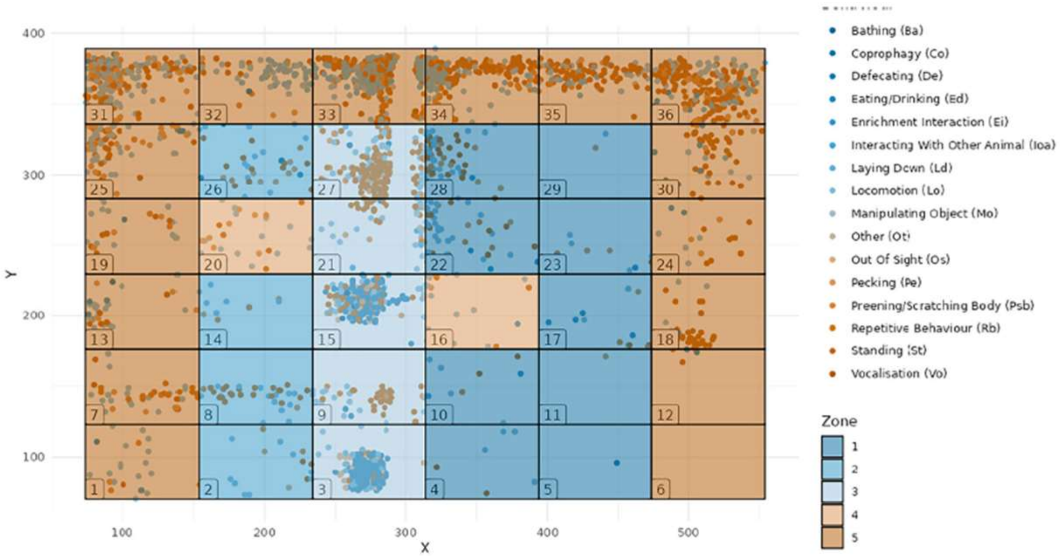


FIGURE 5 | An XY scatterplot, made using space use data collected from the hypothetical ostrich data, with a 6 × 6 grid, and five different "zones" (as shown by the different shaded colors). In this case, the perimeter of the exhibit has been selected as a zone (zone 5) because it is close to visitors. The dividing fence between exhibits is also a zone (zone 3). EMU allows the user to self-select specific zones in an enclosure, up to a maximum of five different zones. These zones feed into all enclosure use analysis, such as Entropy, mSPI, and Electivity Index. [Color figure can be viewed at wileyonlinelibrary.com]

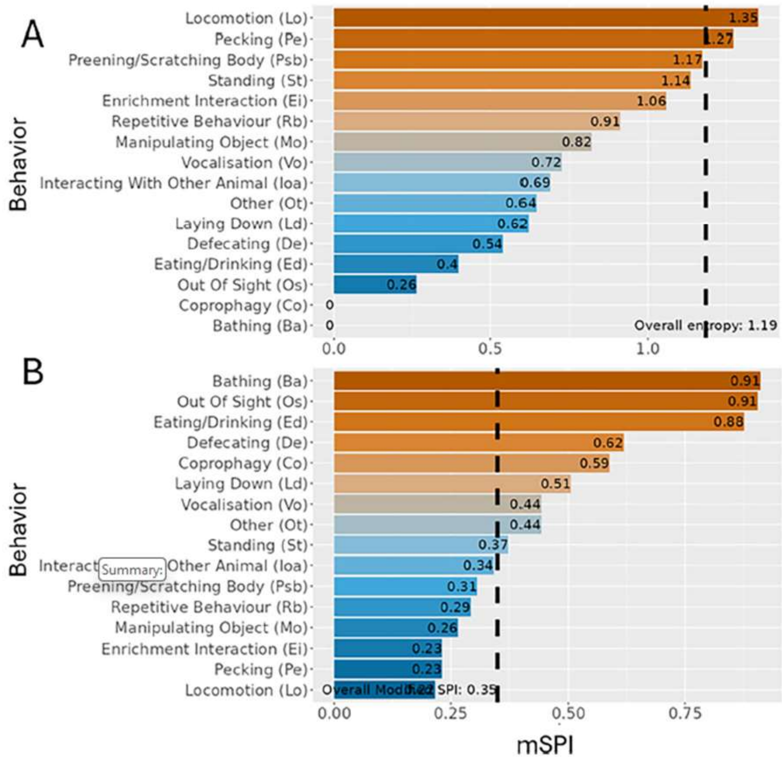
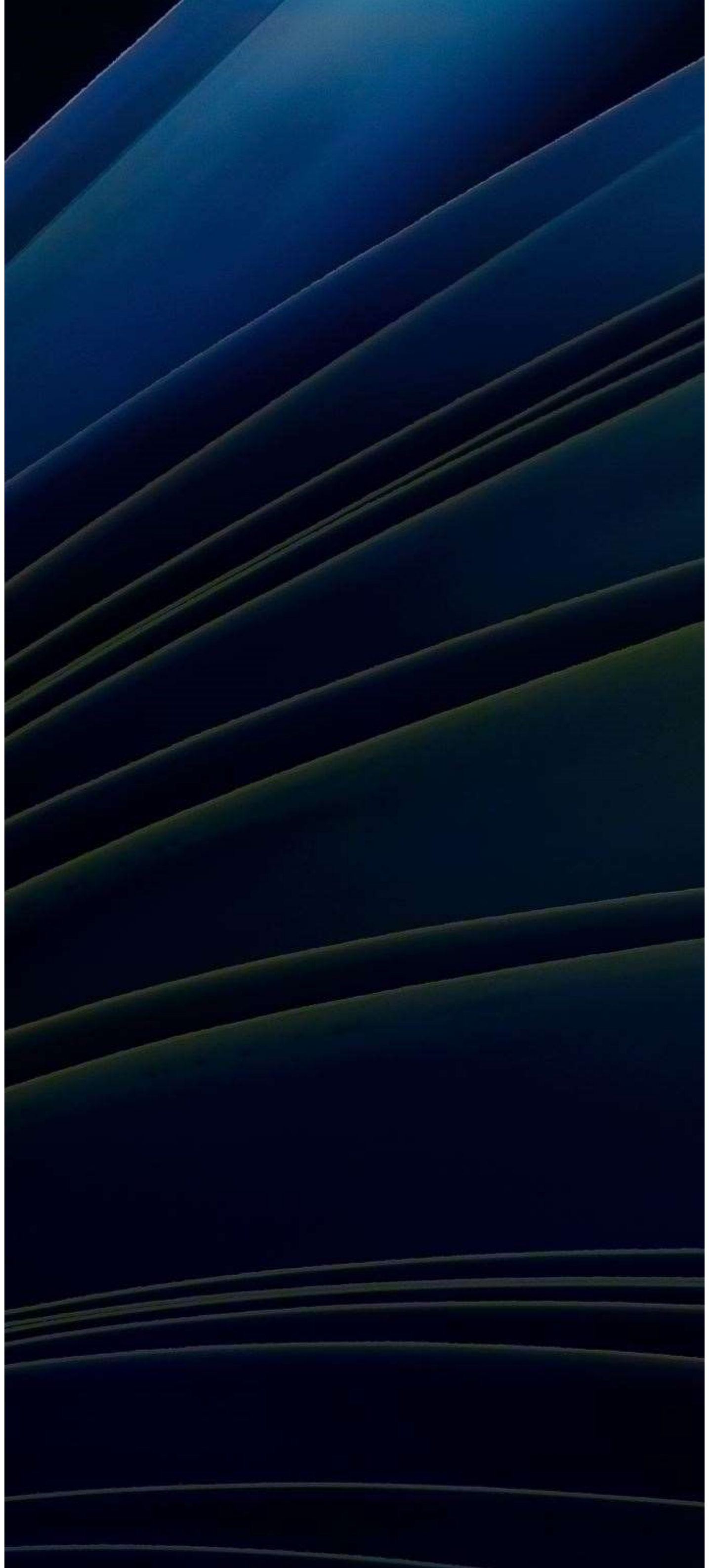


FIGURE 6 | EMU outputs for the hypothetical data ostrich for (A) Entropy at base 10, and (B) mSPI, using the zones assigned in Figure 5. These values demonstrate the evenness of space use for specific behaviors (for Entropy, higher values indicate even space use, whereas for mSPI, values vary between 0 and 1, with values closer to 0 demonstrating more even space use). [Color figure can be viewed at wileyonlinelibrary.com]



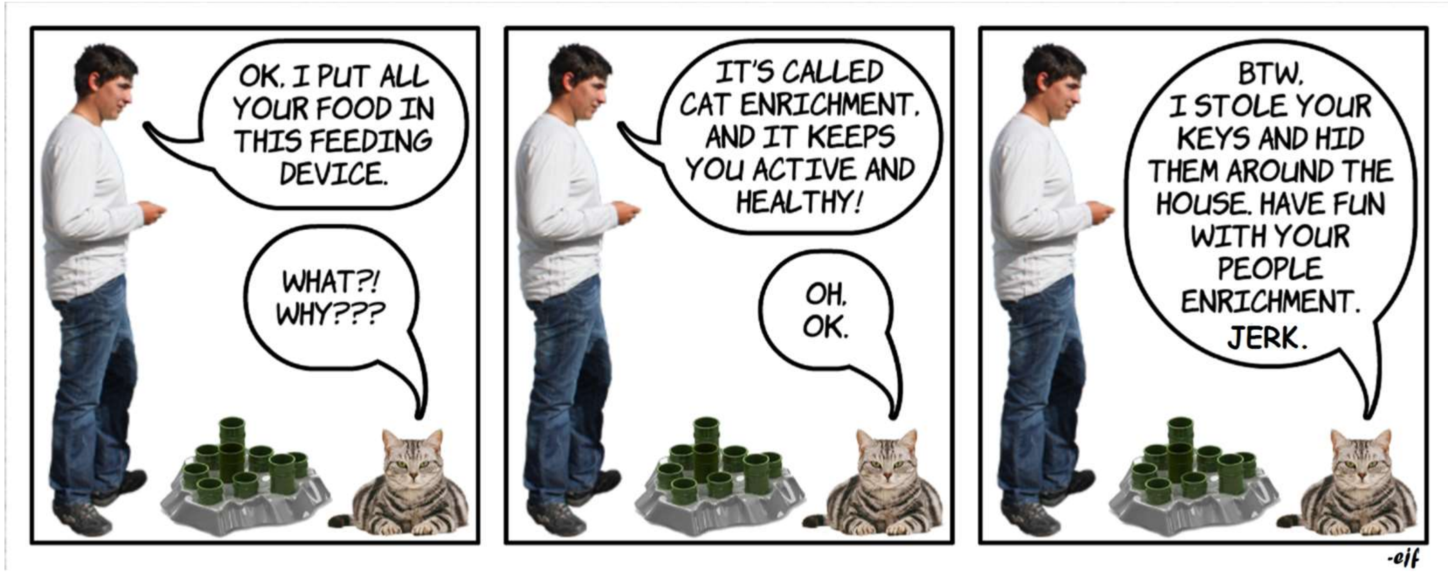
Summary:

Technology plays a critical role in how we provide for animal welfare efforts.

We can effectively use technology to create better enrichment, exhibits, and monitoring systems.

It is the combination of technological environments (enrichment & exhibits) and empiricism (monitoring) that should allow us to best improve the lives of zoo animals. 🐧 🐘 🐙 🦍 🐢

THANK YOU!



QUESTIONS?

Follow or friend me @:

Instragram:
DrEddieFern

Facebook:
ejfernandez

YouTube & LinkedIn:
EduardoJFernandez

https://www.researchgate.net/profile/Eduardo-Fernandez-27

Email: edjfern@gmail.com
or:
eduardo.fernandez@adelaide.edu.au

References

Brando, S., & Buchanan-Smith, H. M. (2018). The 24/7 approach to promoting optimal welfare for captive wild animals. *Behavioural Processes*, *156*, 83-95.

Brereton, J. E., Coe, J. C., & Fernandez, E. J. (2025). Future aviary design: The science of circular flight aviaries for avian welfare. *Zoo Biology*.

Brereton, J. E., & Fernandez, E. J. (2022). Investigating unused tools for the animal behavioral diversity toolkit. *Animals*, *12*(21), 2984.

Brereton, J. E., & Fernandez, E. J. (2022). Which index should I use? A comparison of indices for enclosure use studies. *Animal Behavior and Cognition*, *9*(1), 119-132.

Brereton, J. E., Tuke, J., & Fernandez, E. J. (2025). Incorporating the Enclosure MonitoR Use (EMU) App to ZooMonitor Observations Technical Report. *Zoo biology*.

Fernandez, E. J., Brereton, J. E., & Coe, J. (2023). How do we plan for the zoo exhibit of the future?. *Applied Animal Behaviour Science*, *268*, 106085.

Fernandez, E. J., & Martin, A. L. (2021). Animal training, environmental enrichment, and animal welfare: A history of behavior analysis in zoos. *Journal of Zoological and Botanical Gardens*, *2*(4), 531-543.

Fernandez, E. J., & Martin, A. L. (2023). Applied behavior analysis and the zoo: Forthman and Ogden (1992) thirty years later. *Journal of Applied Behavior Analysis*, *56*(1), 29-54.

Fernandez, E. J., & Sherwen, S. L. (Eds.). (2024). *Human-Animal Interactions in Zoos: Integrating Science and Practice*. CABI.

Forthman-Quick, D. L. (1984). An integrative approach to environmental engineering in zoos. *Zoo Biology*, *3*(1), 65-77.

Hancocks, D. (1980). Bringing nature into the zoo: inexpensive solutions for zoo environments. *International Journal for the Study of Animal Behavior Problems 1,* 170–177.

Hryhorenko, L., McWhorter, T., Whittaker, A., & Fernandez, E. J. (2025). The use of technology as environmental enrichment in zoos: A scoping review. *Animal Welfare*, *34*, e73.

Hutchins, M., Hancocks, D., & Crockett, C. (1984). Natural solutions to the behavioral problems of captive animals. *Zoologische Garten, 54*, 28-42.

Markowitz, H. (1978). Engineering environments for behavioral opportunities in the zoo. *The Behavior Analyst*, *1*(1), 34.

Markowitz, H. (1982). *Behavioral enrichment in the zoo*. Van Nostrand Reinhold.

Markowitz, H., Aday, C., & Gavazzi, A. (1995). Effectiveness of acoustic “prey”: Environmental enrichment for a captive African leopard (Panthera pardus). *Zoo Biology*, *14*(4), 371-379.

Markowitz, H., & LaForse, S. (1987). Artificial prey as behavioral enrichment devices for felines. *Applied Animal Behaviour Science*, *18*(1), 31-43.

Miller, L. J., Vicino, G. A., Sheftel, J., & Lauderdale, L. K. (2020). Behavioral diversity as a potential indicator of positive animal welfare. *Animals*, *10*(7), 1211.

Wark, J. D., Cronin, K. A., Niemann, T., Shender, M. A., Horrigan, A., Kao, A., & Ross, M. R. (2019). Monitoring the behavior and habitat use of animals to enhance welfare using the ZooMonitor app. *Anim. Behav. Cogn*, *6*(3), 158-167.