



Student Challenge Using Differential Equations Modeling

SCUDEM VIII 2023

Problem A: Kangaroo Care

A review of infant mortality for kangaroos indicates that there is a wide range of mortality rates for infant kangaroos, and to better understand the variance in mortality a number of different studies have been conducted. A meta-analysis [1] of some of the different studies indicates that direct care of an infant by a kangaroo mother plays an important role in the infant's first 28 days of life. The quality of care may have limited impact on a number of factors such as neurodevelopmental outcomes, but there may be an impact on other factors such as infections and mortality. The authors of the report recommend that all kangaroo infants, as well as human infants, receive care from their mothers within twenty-four hours of their birth and receive at least eight hours of contact each day.

One issue is that this can require a more intense use of resources. Interacting with kangaroos and their infants may require more time and personnel in order to ensure that both the mother and the infant are properly protected and cared for. To help better understand the situation develop a model of the interactions between an infant kangaroo and its mother or human baby and its mother under Kangaroo Mother Care (KMC) treatment. What are the most important factors, how do they impact the infants, and how are they represented and perform in your model? Does your model indicate if it is possible to skip care for a day at regular intervals? If so, how does this impact the outcomes with respect to mortality and other health measures? What other insights and limitations does your model indicate that animal or human care practitioners should be aware of?

Update Note: Several teams inquired about whether this model is to address kangaroo or human infant care. We offer the possibility of teams taking their pick.

Bibliography

[1] Sivanandan S, MJ Sankar MJ. 2023. Kangaroo mother care for preterm or low birth weight infants: a systematic review and meta-analysis, *BMJ Global Health*. 8:e010728.
<https://gh.bmj.com/content/8/6/e010728> Last accessed 4 August 2023.



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Problem B: Punishing Infants

Researchers recently sought to examine the origins of the tendency to punish anti-social behaviors [1]. They found that infants as young as 19 months old have the capacity to want to punish others for how they interact with a third-party. The researchers claim that some infants have a propensity to try to discipline those who they believe are hurting others, and evidence is provided that this can occur even before language skills develop.

If we assume this is true, what does this imply about interactions in the broader society? Suppose that some proportion of people have an innate desire to react to third party transgressions by punishing those they perceive as acting out against others. What does that imply about interactions between people and what are the long-term dynamics for different proportions of people who desire different levels of punishment?

To examine this question, develop a model that includes different populations with different propensities to act out against those who interact aggressively towards others. How do the relative populations within the groups change over time? What factors impact the long-term stability of a society? Also, if other groups arise that have differing propensities to offer different kinds of corrective actions, what factors are important and how do they compare to situations where punishment is the dominant reaction? Incorporate various behaviours, especially options other than retribution, in your model and discuss the results in changes in these behaviours. If other options result in more favourable outcomes, provide a discussion on how your model may be adapted to demonstrate the efficacy of societal change and attitudes toward punishment.

Bibliography

[1] Kanakogi, Y., Miyazaki, M., Takahashi, H. *et al.* 2022. Third-party punishment by preverbal infants. *Nat Hum Behav* 6, 1234–1242. <https://doi.org/10.1038/s41562-022-01354-2> Last accessed 4 August 2023.



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Problem C: Dog Cannot Catch

A popular video [1] features a dog, Fritz, who has difficulties catching food that is thrown to him. The video features multiple scenes in which someone throws a food item to the dog, and the dog struggles to catch the item in his mouth. Some dogs are quite adept at catching items, but this particular pet struggles to learn the trick. How difficult is this task?

Fritz must use the changes in the path of the object to predict where the item will be and how to respond. How precisely does the dog's brain have to estimate the orientation of his head and eyes in order to best predict the location of the item, and how much time will the dog have to orient its mouth to the correct position? Are certain foods more difficult to catch due to different effects of air friction? Does the height at which the object is thrown matter? What are the most important aspects of the dog's perceptions and behaviors for the dog's success?

Use your analysis of the situation to decide if Fritz is just clumsy or if his owner is being mean to the dog on the Internet. If Fritz needs help, then provide advice to help him out. If the owner is exploiting the pet to make money, then provide advice on how to make the poor animal look even worse so that more videos can be produced.

Bibliography

[1]"Fritz Learns to Catch Compilation #1," <https://www.youtube.com/watch?v=6w2UxDdhZPk> Last accessed 6 September 2023.