PRELIMINARY RESULTS FROM A COMPUTATIONAL MULTI AGENT MODELLING APPROACH TO STUDY HUMPBACK WHALE SONG CULTURAL TRANSMISSION

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Humpback whale (*Megaptera novaeangliae*) songs are a striking example of cultural transmission in non-humans (Garland et al., 2011). During the migration and mating season of this species, males produce complex, stereotyped sound sequences defined as '*songs*'(Payne & McVay, 1971). Within a population, males conform to a common yet slowly evolving song. Change can also occur more rapidly when a completely new song is adopted by the entire population in a relatively short time (termed '*revolution*') (Noad, Cato, Bryden, Jenner, & Jenner, 2000). These phenomena can only occur if the whales are learning song from each other. While it is possible to record the shared song within a population and how this evolves in time, the individual mechanisms and learning strategies behind the cultural transmission of song remain unknown. Furthermore, it is not clear how populations maintain conformity in songs that change over variable timescales (evolution vs. revolution). This paper presents a spatially explicit multi-agent model designed to investigate humpback whale song learning and transmission. Models with an emphasis on cultural evolution have previously been used to describe the emergence of genetic diversity in whales, and these models have been adapted to demonstrate how cultural dynamics can have the same impact on genetic diversity in humans (Whitehead,

Richerson, & Boyd, 2002). In these studies however, the exact nature of the cultural evolution is deliberately left vague. Our model seeks to extend and explore that developed in (Kirke, Miranda, Rendell & Ingram, 2015) to specifically study humpback whales songs cultural transmission and may prove to be a valuable reference point for future studies for the early evolution of human language. In detail, the model simulates both the movement and acoustic behavior of humpback whales. The migratory movement of whales between feeding and breeding grounds is enabled using flocking algorithms and movement rules that also govern the interactions among agents. Agents in the model are also equipped with a first order Markov model to generate songs (list of symbols). The transition matrix, or 'grammar', can be updated by 'learning' from other singing agents; the influence of a song on a listener agents' grammar is determined by the distance between the listener and the singer (Kirke, Miranda, Rendell, & Ingram 2015). Each agent is initialized with a randomly generated grammar. This modelling architecture enables us to study how songs are transmitted within and between populations and to record the population convergence on one or multiple song grammars. Modelling results are compared qualitatively to known song evolution patterns and specifically validated against real song data recorded in the South Pacific during the last 11 years. The model was run with varying values of spatial parameters. Namely, the size of the feeding ground, the minimum distance between agents, the size of the acoustic active space, and the size of the breeding ground(s). In total, 56 runs were implemented to explore this parameter space. Four main scenarios emerged. Firstly, in 34% of the experiments the majority of agents converged on one or multiple song grammars, depending primarily on the formation of discrete, spatially segregated groups. This result echoes what is commonly observed in the wild, where spatially segregated populations generally sing different song grammars at any given time. In the second scenario (12%), the agents' convergence was more variable compared to scenario 1 due to a combination of widely spaced breeding grounds and weak attraction between agents. Thirdly, 20% of the runs showed the highest variability in final song grammar due to strong convergence on grammars characterized by lower transition matrix probabilities. Finally, 34% of the runs showed no sign of song learning, as grammars did not converge. Across scenarios song grammars tended to decrease in size/length along each run, resulting in short and simple songs. Future work will include equipping agents with different learning strategies, a more realistic representation of humpback whale song structure and the ability to innovate song.

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References

Garland, E. C., Goldizen, A. W., Rekdahl, M. L., Constantine, R., Garrigue, C., Hauser, N. D., Poole, M. M., Robbins, J., Noad, M. J. (2011). Dynamic horizontal cultural transmission of humpback whale song at the ocean basin scale. *Curr Biol, 21*(8), 687-691. doi: 10.1016/j.cub.2011.03.019

Noad, M. J., Cato, D. H., Bryden, M. M., Jenner, M. N., & Jenner, K. C. S. (2000). Cultural revolution in whale songs. *Nature, 408*(6812), 537-537. doi: 10.1038/35046199

Payne, R. S., & McVay, S. (1971). Songs of Humpback Whales. *Science, 173*(3997), 585-597. doi: 10.1126/science.173.3997.585

Kirke, A., Miranda, E., Rendell, L., Ingram, S. (2015). Towards Modelling Humpback Whale Song Evolution using Multi-agent Systems, *Proceedings of Transdisciplinary Approaches to Cognitive Innovation (Off the Lip 2015),* 7-11 September, Plymouth (UK)

Whitehead, H., Richerson, P. J., & Boyd, R. (2002). Cultural Selection and Genetic Diversity in Humans, *Selection, 3(1)*, 115–125.