Computational Neuroecology of Communicated Somatic Markers

Kyle I. Harrington[1], Megan M. Olsen[2] and Hava T. Siegelmann[3]

[1]DEMO Lab, Brandeis University, Waltham, MA 02454
[2]Department of Computer Science, Loyola University Maryland, Baltimore, MD 21210
[3]Department of Computer Science, University of Massachusetts, Amherst, MA 01003
Corresponding author: kyleh@cs.brandeis.edu

Abstract

The somatic marker hypothesis offers a physiological basis for emotion. Somatic markers are thought to stem from basic survival behaviors, and it has been hypothesized that emotional communication can increase the survival rate of a population. We investigate these neuroecological questions in predator-prey simulations by exploring the effect of communicated somatic markers on individuals and their ecology in order to establish an understanding of their evolvability. In particular, we show how fear, happiness, and to a lesser extent surprise, can be favored by natural selection.

Introduction

Certain features of physiology (hunger, hormones, heart rate, etc.) and representations of physiology within the brain are somatic markers that influence behavior and decision making (Damasio et al., 1996; Bechara et al., 2000). Computationally modeling the neural bases of behavior is a goal of computational neuroethology (Beer and Chiel, 2008). Studies in computational neuroethology account for neural mechanisms, biomechanics, and ecological context, but generally focus on an individual.

Neuroecology studies social behaviors and their relationship to neural attributes. For example, the larger hippocampus of the male meadow vole who maintains a larger home range requires additional spatial ability (Sherry, 2006). The distinction between neuroethology and neuroecology arise from neuroecology's study of the linkage between stimulus, neural processes, behavior, and the corresponding effects on population and community (Zimmer and Derby, 2011).

We previously explored the benefits of communicated somatic markers for the species and individual (Harrington et al., 2011), and now examine the effects of somatic markers on individuals and ecologies. Our findings support selective favorability of communicated somatic markers.

Model

Our multi-species agent-based model based upon (Harrington et al., 2011) is a torus inhabited by three species related by predator-prey interactions: rabbits, foxes, and carrots.

Emotion	#	Experience
Happiness	1	1 if ate food, 0 otherwise
	2	1 if reproduced, 0 otherwise
Fear	1	number of neighboring predators
	2	1 if self will starve next turn, 0 otherwise
Anger	1	e^{hunger}
	2	hunger / starvation limit
Disgust	1	1 if ate diseased food, 0 otherwise
	2	fraction of diseased neighboring conspecifics
Sadness	1	time since last reproduction
	2	the decrease in number of surrounding foods, if applicable; 0 otherwise
Surprise[1]	1	$\frac{\Sigma_e E_e(t,x,y) - E_e(t-1,x,y)}{5}$
	2	$\frac{\Sigma_e (tanh(E_e(t,x,y)/E_e(t-1,x,y))+1)/2}{5}$

Table 1: Somatic markers used for emotional response. Rabbits use either #1 or #2, whereas foxes only use #2.

Foxes feed on rabbits, while rabbits feed on carrots. Carrots serve as both an energy input and a vector of disease for the system. All entities breed while non-carrots also move, eat, experience hunger, and suffer from disease. For a detailed description of the model see (Harrington et al., 2011).

Results

We compare the effects of individual somatic markers in rabbits, comparing two definitions[2] of each somatic marker (Tbl. 1) when foxes do and do not use emotions. Figures show trials separated by configuration of rabbit emotion. Error bars represent the standard error centered around the mean as recorded during $t \in [1000, 2500]$ for 25 runs.

Fig. 1(a) and 1(b) show the fox and rabbit average ages. The fox average age increases dramatically when foxes use emotion. However, when only rabbits use emotion the average fox age is equivalent to neither species using emotion. When both rabbits and foxes use emotion the average fox age generally decreases when compared to only foxes using emotion, particularly for fear and anger. Average rabbit age

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[1]Sums are taken over all emotions except surprise.

[2]When evaluating surprise definitions all emotions are activated and two tests are performed: (a) all emotions other than surprise are definition 1, and (b) all emotions other than surprise are definition 2. In both cases, surprise is tested with each of its own markers.
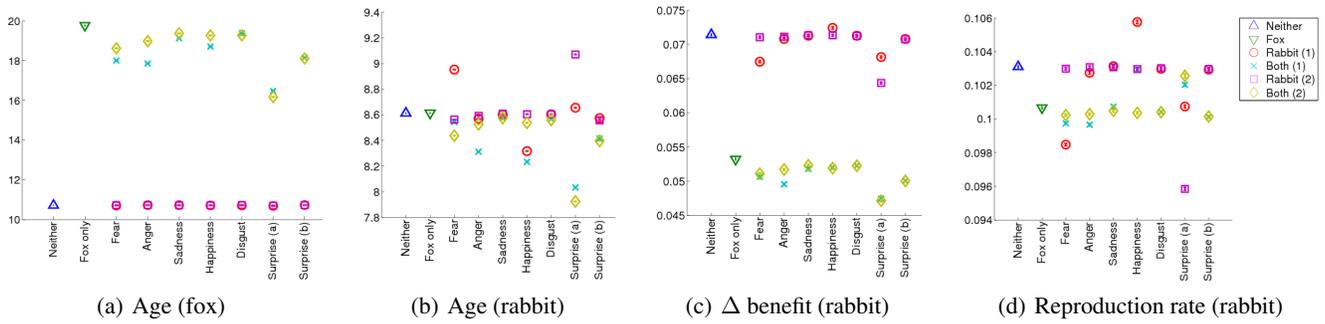
Figure 1: Rabbit and fox averages. X-axis shows the emotion being studied; in the case of surprise, all emotions are activated. The legend shows which somatic markers are in use for each series; for surprise, the number only corresponds to the somatic marker for surprise.

only decreases with both species using anger, happiness, or surprise(a), as well as with rabbits using $happiness_1$.

Both fox and rabbit populations (not shown) fall into two categories: high and low. There are more foxes when neither species uses emotion, or when only rabbits use emotion. Rabbit population sizes follow the opposite trend. The decrease in fox population when both use emotion is most likely because their improved knowledge allows them to be more effective hunters. This seems counter-intuitive given that it also correlates with a larger population of rabbits; however, the results of average age further support this idea.

The change in benefit of surroundings for a rabbit is

$$\Delta \text{ benefit} = \Delta \text{ neighboring carrots} - \Delta \text{ neighboring foxes}.$$

Fox emotion correlates with a decrease in benefit (Fig. 1(c)). When only rabbits use emotion the benefit is generally near the baseline. However, $fear_1$ correlates with a decrease in the average benefit of rabbits. Given that this definition of fear correlates with an increase in the average rabbit age one would suspect that $fear_1$ causes rabbits to leave areas that are more abundant in food in favor of escaping predation.

Fig. 1(d) shows the reproduction rate ($R(t)$) change as a function of emotional configuration. When only rabbits use one emotion $R(t)$ is around baseline except in the case of $fear_1$ (significant decrease) and $happiness_1$ (significant increase). The decrease due to fear is due to high levels of fear halting reproduction. The increase due to $happiness_1$ correlates with decreases in average rabbit age described above.

Surprise(a) trials show a decrease in average benefit of surroundings (Fig. 1(c)), and an inversion of the effect of emotionally intelligent foxes on average rabbit reproduction rates (Fig. 1(d)). As in the other discussed cases, the use of either somatic marker definition for surprise only affects surprise(a) (when all other emotions only use somatic marker definition 1) and not surprise(b). This leads to the consideration that the synergistic effect of definition 1 somatic markers is not as simple as a linear combination of all active somatic markers. We recommend a more extensive study of the effect of secondary emotions such as surprise, employing many combinations of somatic markers to further our

understanding of the nature of this non-linear combination.

Conclusion

We have shown that communicated somatic markers can correspond to individual benefits, whether those benefits are direct or secondary targets of natural selection. These findings suggest the selective favorability of communicated somatic markers. The communicated somatic marker utility in an ecology is a complex question. However, the relationship between the use of certain communicated somatic markers and objectives of natural selection, such as longevity and reproduction, suggests that understanding the origin of somatic markers is achievable by means of computational neuroecology as examined in this paper.

Acknowledgments

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