Learning can mediate both badges of status and individual recognition

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August 18, 2020

Abstract

Learning rules.

Introduction

For social animals the outcome of interactions with con-specifics is an important determinant of fitness. Irrespective of whether such interactions are of cooperative or competitive nature, individual’s actions and their partners will partly determine their success in the reproductive arena. However, the best action for an individual might vary depending on it’s own conditions, and with whom they interact. Thus, an individual making their action dependent on information about interacting partners is typically adaptive (Quiñones et al. 2016). The source of this information however is far from trivial. In some cases interacting partners (signalers) might be ‘willing’ to provide accurate information, but in others it might be in their own interest to conceal information (Johnstone 1997), or to provide erroneous information (Johnstone and Norris 1993). Typically, in a given context, some proportion of individuals will be interested in broadcasting accurate information, and some others in hiding it. Take for instance an interaction between two individuals where one can help the other. Given some conditions of cost and benefits, the donor will be interested in helping a related individual. So for a relative of the donor, broadcasting kinship is advantageous; while for an unrelated individual, concealing the lack of kinship will be better. This same pattern applies to many aspects of social life such as finding mates, feeding offspring, dominance relationships and aggressive interactions. In dominance and aggressive interactions an important information to make actions dependent on is interacting partners fighting ability, which is sometimes referred to as Resource Holding Potential (RHP) (Parker 1974), or as we will here simply quality. This responsiveness to the quality of the partner is achieved in communication systems such as badges of status (BS), where an arbitrary signal conveys quality. BS can be evolutionarily stable whenever the signal imposes a fitness cost which decreases with the quality of an individual (Botero et al. 2010; Johnstone and Norris 1993). So, low quality individuals can’t afford the cost of the signal, and it’s no longer in their interest to fake quality. The cost of the honest signal is a more general principle of communications systems, usually referred to as the handicap principle (Grafen 1990; Zahavi 1975). An alternative system of communication is one where individuals gather and store information about each individual they interact with. This information, directly collected by each individual, should reliably allow them to react adaptively to the quality difference with their opponent. This type of assessment strategy is often referred to as individual recognition (IR, Whitfield 1986). Evidently, IR is restricted to certain interaction structures, individuals are limited by cognitive abilities in how many individuals they can recognize and track. Thus, IR and BS have been assumed to be alternative communication systems fulfilling the same function, but expected to evolve in populations under different conditions (Dale, Lank, and Reeve 2001; Sheehan and Bergman 2016). There is no clear cut reason, however, why both systems could not work together, in fact there is some evidence that they can (Chaine et al. 2018).

A somewhat ignored aspect of communication systems, in the context of aggressive interactions, is the cognitive aspects of the receiver module. BS are often assume to be cognitively less demanding than IR (Sheehan and Bergman 2016). The idea is that using IR, individuals need to store identity and associated information about each individual they interact with. All this information requires more memory and therefore is more demanding. In contrast, the response using BS have been thought as an innate response (Botero et al. 2010; Johnstone and Norris 1993), where individuals use their own quality and the opponent’s badge to determine whether to aggressively contest a resource. An alternative view of BS is that individuals learn to react to the signal based on their experiences (Guilford and Dawkins 1991). In line with that view, both communication systems would require the receivers to learn an association between the signal and the fighting ability of the bearer. In BS, this association would be a a simple monotonic increase of fighting ability with the size of the badge, and would be reinforced by every interaction, so in principle it would be quicker to learn. While in IR, the association would be different for every individual, depending on the interacting partners. Learning could be a unifying cognitive mechanism behind both types of communication systems. This idea of learning being a general response mechanism has not been thoroughly explored, nor in the empirical or theoretical literature.

Associative learning is a key cognitive mechanism that allows individuals to associate rewards with environmental stimuli and appropriate behavior (Staddon 2016). Since it was originally described, associative learning has been found in all major vertebrate taxon, and many invertebrates (Heyes 2012; Macphail 1982; Staddon 2016; Behrens et al. 2008). Using these associations to respond to environmental changes is particularly adaptive in complex environments (Dridi and Lehmann 2016). Besides its wide taxonomic and ecological relevance, associative learning has shown to be a flexible cognitive mechanism that can be tuned to different roles depending on the ecological situation (Enquist, Lind, and Ghirlanda 2016; Quiñones et al. 2019). Despite all this, associative learning is not often included in evolutionary explanations (Fawcett, Hamblin, and Giraldeau 2013; Kamil 1983; McAuliffe and Thornton 2015). Computational models of evolution can play an important role to overcome the lack of integration between learning and evolution. Reinforcement learning theory encompases a series of computational methods inspired on the psychological and neurological mechanisms of associative learning (Sutton and Barto 2018). These set of algorithms allow the implementation of biologically realistic problems, capturing the essence of learning processes (Frankenhuis, Panchanathan, and Barto 2018; Quiñones et al. 2019). Furthermore, these algorithms can be embebed in evolutionary simulations in order to have theoretical predictions of the effect that learning can have in behavioral (Leimar and McNamara 2019) and morphological evolution.

In here we present an evolutionary model where individuals use associative learning to develop a tendency to behave aggressively (or peacefully), in the context of competition over resoureces, depending on the quantitative morphological trait they perceive in their opponent (badge). Over evolutionary time individuals evolve the size of their badge, and whether it depends on their quality. Under this simple set up, individuals can use the badge both as a signal of quality (BS) or as a trait for IR. We use the model to asses under what conditions of interaction structure we expect different communication signals evolve.

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