Learning and information-use in the Bluestreak Cleaner-Wrasse (*Labroides dimidiatus*)

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Study Goals & Impact

My research is focused on the learning process of behavioral sequences, where the order in which tasks are performed may affect their outcome. Such sequences are widespread in both animal and human behavior, and I am trying to understand the learning process required to construct them. To do so, I study the behavior of Bluestreak Cleaner-Wrasses (*Labroides dimidiatus*) – tropical marine fish who feed on the ectoparasites of other fish species. These fish have been shown to prioritize clients with access to multiple cleaning stations, as such clients tend to depart if not treated quickly. However, this preference is uncommon both in juveniles and cleaners from patchy reefs, where such clients are less abundant. If cleaners can learn the "correct" service order from their experience, they are expected to learn novel tasks which require similar cognitive abilities. I presented cleaners with two such tasks, each composed of two consecutive decisions, where the rewards depended not only on each separate choice, but on the order in which they were made. To analyze the learning process, I developed a reinforcement learning model which accounts for rewards from separate decisions as well as overall sequence rewards. My model describes the learning process from a cognitive perspective, as often applied in human psychological research. My research will not only shed a new light on sequence learning processes, but may also narrow the gap between human and animal cognition studies, as well as provide an evolutionary perspective to our common cognitive abilities.

Experimental Setup & Protocol

My setup consists of an aquarium with two feeding holes – one on each side, which can be covered or exposed using motor-powered barriers. Food supply and barrier operation are controlled by a computer program in a semi-automatic manner, responding to the operator's input on the decisions made by the fish. Experimental sessions consisted of several decision-pairs separated by two-minute intervals, where each pair consisted of two consecutive choices, separated by a 5-second interval. The fish were presented with two learning tasks, which differed in their reward probabilities and the most beneficial choice order. The same individuals participated in both tasks, starting the second task after successfully learning the first.

Task 1 – Sequence learning and "future-based" decisions.

In the first task presented to the fish, the first decision was always rewarded, regardless of choice, but rewards from the second decision depended on both the first and second choices. This required the fish to not only learn which side provided a certain reward on the second step, but also which side should be chosen first to ensure that reward. In other words – fish were required to choose both immediate and future steps in a single decision. All nine individuals faced with this task successfully learned the most beneficial sequence. However, there were considerable differences in both learning time and initial choice patterns (Figure 1). Cognitive model analysis revealed two parallel learning processes - one for estimating individual choice values and the other for estimating overall sequence values. Cleaners initially utilized both processes, but gradually learned to base their decisions almost exclusively on overall sequence values (Figure 2). The merger of these parallel processes towards a single decision has been supported in humans and other primates but, as far as I know, has not yet been studied in other species.

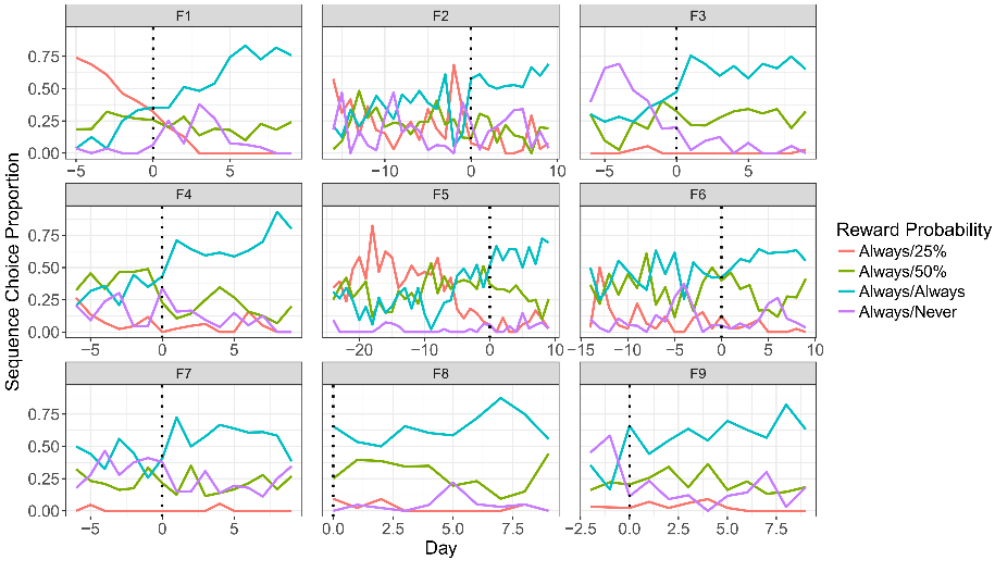

Figure 1: Daily choice proportions of four two-choice sequences for nine Bluestreak Cleaner-Wrasses in the first task (see text). Colored curves depict sequences with different reward probabilities on the second choice. Day values were centered around the "switch-day" – the first day in which the eventually adopted sequence was the most common one.

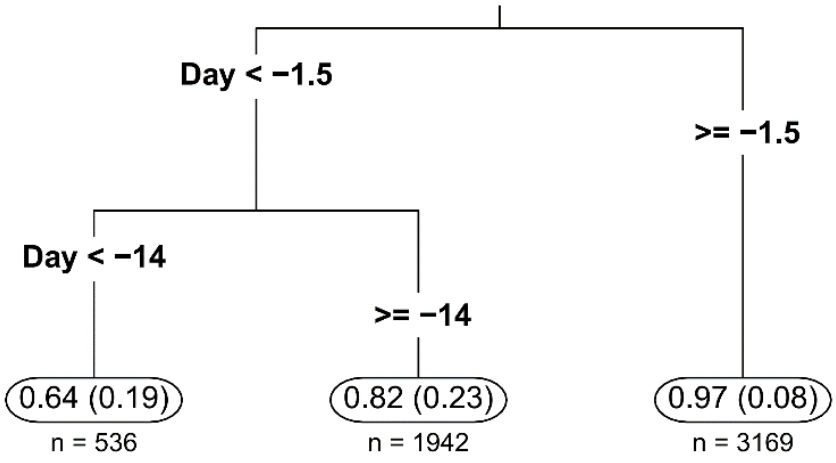

Figure 2: Regression tree results of the proportional weight (mean ± SD) given to full sequence estimates over single choice estimates as a function of experiment day for eight Bluestreak Cleaner-Wrasses (one individual was biased and its behavior could not be fitted to the model). Day values were centered around the "switch-day" of each fish (see Fig. 1 for details).

Task 2 - Conflicting choices: overall value against immediate value

Eight individuals from the first task continued to participate in the second one, where rewards from the first decision were either certain or uncertain, depending on the chosen side. When the uncertain side was chosen first, the opposite side would provide a certain reward on the second choice. This presents a conflict between immediate and overall gain, as fish must actively choose an uncertain immediate reward to receive an overall higher one. Six of the eight fish successfully learned the correct sequence, but again differed in their learning time and patterns (Figure 3). Having participated in the first task, the fish continued to base their decisions on overall sequence values, and I am currently analyzing other cognitive parameters which may explain their differences.

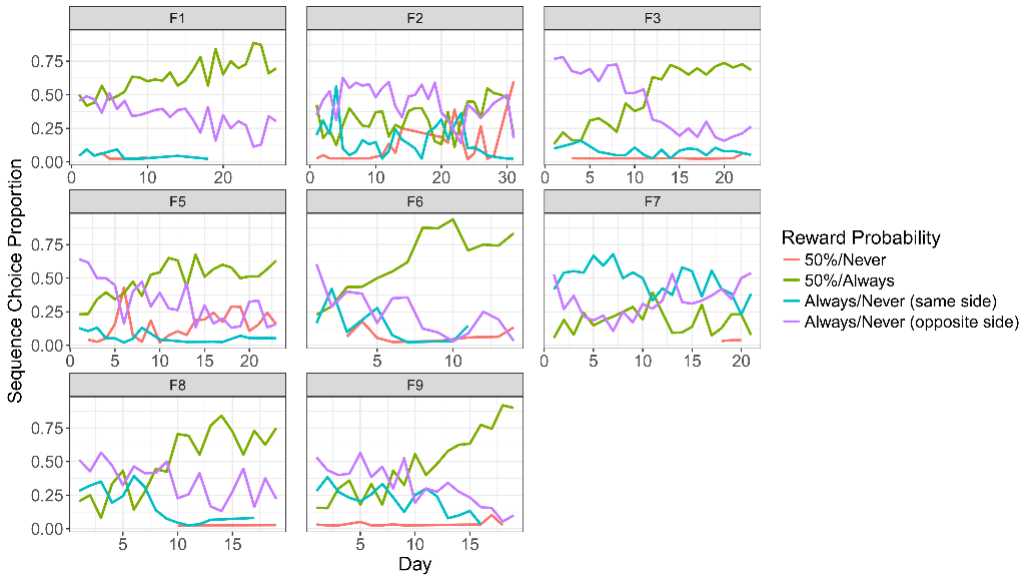

Figure 3: Daily choice proportions of four two-choice sequences for eight Bluestreak Cleaner-Wrasses in the second task (see text). Individual ID numbers are the same as in Figure 1. Individual F4 did not participate in this task.