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Behavioral plasticity of a spring-driven ultrafast smashing by mantis shrimp

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Behavioral plasticity permits animals to behave adaptively. This study asks if a spring-driven ultrafast behavior by mantis shrimp has the property. The animals evolved a specific mechanism to perform the movements (Fig. 1). The muscle contraction occurs before the movement to store elastic potential energy, which is subsequently released through catch mechanisms. The mantis shrimp called 'smashers' have the mechanism in their raptorial appendages. Additionally, they have bulbous 'biological hammer' in the appendages to break open hard shells of prey items. Although the dactyl heel of the appendage is damage-tolerant to the formidable impacts of smashing strikes [1], we often observe worn heels over the repeated use during the inter molt period. Thus, decreasing the damage can be a critical problem for their survival.

The behavioral plasticity of the ultrafast movement might allow them to reduce damage on the heels, if they tactically decrease the speeds of smashing. Our recent study demonstrated that the mantis shrimp have the ability of changing speed of the smashing [2]. Therefore, I tested the damage cost hypothesis that they use the controllability to reduce the future cost of loosing food because of failure to break the shells. Operant conditioning was adopted to approach the problem. One prediction based on the hypothesis is that if the animals would be required to perform a slow strike to get food, they would decrease the speeds of strikes. Another prediction is that if they would be required to perform stronger strike to get food, they would increase the speeds.

After the shaping the operant behavior, I measured the peak strike forces during five days from nine individuals (six of *Neogonodactylus bredini*, three of *Gonodactylus chiragra*) using a piezoelectric force sensor attached to the feeder. The feeder pushes out scallop smoothie when the animals strike on it, and what is more, it outperforms the threshold values. One session of fifteen minutes was performed for one day. For the first week, the values were kept low just to detect the strikes. After the deprivation of the food for two days, the two types of procedures were performed to test the variability of speeds for the second week. The two threshold values were set for the two groups of animals: (1) the values were increased to the third quartile of the distribution of the first week for the second week, (2) the values were kept the same with the first week condition.

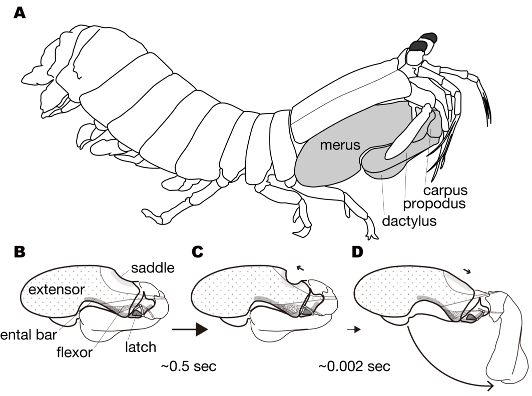

Figure 1: Smashing behavior of mantis shrimp is performed through a spring-driven system. The raptorial appendage (A) has 5 key components (B) to compress exoskeletal spring to store elastic energy (C) and releasing the energy results in rapid smashing movement (D).

The distribution of strike speeds over all sessions has several peaks. The larger peak might be caused by the strikes with cavitation and the smaller one might be the strikes without it, suggesting that the animals might control the cavitation to reduce the damage. For the results from the first week, most of animals decreased the speeds in the end of the fifth session when the speeds were compared with the first session in the first week. For the second week sessions, the distribution drastically changed when it is compared with that of the first distribution depending on the condition of the threshold. Also, most of animals did not increase the strike speeds. Although this is contrary to the prediction, the result can be interpreted that the change of distribution is affected by the balance of cost and benefit relationship internally calculated. Further investigation from the viewpoint of energetics [3] and differential reinforcement procedure would be needed to test the damage hypothesis and alternatives including energetic hypothesis.

References

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