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Mini Review

Is the Ability of Active Colour Change in Octopus and Cuttlefish a Part of Cognitive Abilities?

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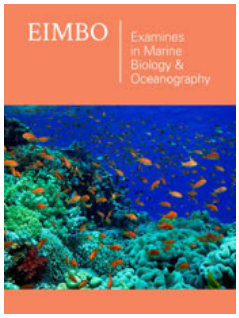

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Abstract

Phenomena like camouflage or crypsis connect animal's traits used by the individual to make itself more difficult to detect via merging with its surroundings. These traits can be especially beneficial in predatory/anti-predatory behaviour, which is why they have been frequently studied from the point of view of evolutionary biology. However, specific behavioural strategies of the animal in contextually different situations are required and higher cognitive abilities may be selected together with the cryptic coloration of the animal. In this review we ask the question whether the ability of active colour change in octopuses and cuttlefish has features of specific contextual behaviour that counts for complex cognitive abilities. The octopuses and cuttlefish are ideal model animals because their abilities of colour change and background matching are contextual and extend the predatory and anti-predatory function of behaviour. Their active colour change also serves other purposes like communication or hunting. Moreover, octopuses and cuttlefish possess not only a variety of highly developed senses, namely visual, chemoreceptive, and mechanoreceptive, but at the same time also cognitive functions, for example manipulation with objects, advanced learning abilities, casual reasoning, and assessment of its own proportions compared to the relative size of an obstacle. Based on the current literature we argue that: first, octopuses and cuttlefish purposefully use their shapeshifting and colour change abilities regardless of the surrounding environment or their predators' cognitive abilities which requires utilization of their complex cognitive abilities, and second, the colour change can serve as an instrument of communication and cognitively demanding tactical deception in territorial fights and mating rituals. Thus, the ability of active colour change and contextual behaviour requiring complex cognitive abilities are mutually connected in octopuses and cuttlefish, probably as a result of coevolution of these traits.

Keywords: Octopus; Cuttlefish; Cephalopod; Coleoid; Cognition; Camouflage; Crypsis; Deception

Introduction

Many animals use camouflage as means to escape predation, when they try to merge with their backgrounds to make themselves more difficult to detect. In octopuses and cuttlefish, this ability has taken a truly unique form. These animals have a colour changing ability so sophisticated, that they can change both their colour and shape in a matter of tenths of a second. Thanks to the complex structure of their skin containing chromatophore organs and skin papillae, they can change their colour, pattern, how the light reflects off the skin, and the shape of their surface [1]. They use these unparalleled abilities for camouflage and communication, and they probably evolved among them because of the enormous selective pressure from the great number of their predators who orient themselves optically, ranging from cartilaginous fishes to mammals. Unlike other molluscs, cephalopods have lost their protective shells, which enabled them to take the role of active predators themselves, but it also exposed their soft bodies, which made them a favourite pray for a vast range of marine carnivores. To survive, they have developed a highly advanced ability of camouflage, and sophisticated cognitive abilities. In laboratory experiments, cephalopods can solve advanced cognitive tests, sometimes even matching the success rate of mammals. They are capable of casual reasoning, prospection, learning complicated tasks, and chiefly an incredible flexibility of their behaviour, which they can use in new situations [2]. By doing a review of scientific literature, we tried to find a link between these two most prominent abilities of cephalopods. Do octopuses and cuttlefish use their advanced cognition when changing colour, and could this connection work in both direction? Do cephalopods use colour-change for other purposes than simply background matching?

Contextual behaviour

Octopuses and cuttlefish are capable of actively matching with their background. Their behaviour is highly contextual-they display patterns and colours, that enable them to hide on the background they are on. They act according to specific visual cues. For example, common cuttlefish can create highly contrasting white square on their backs, which serves as a part of their disruptive pattern, but they use this pattern only when there are objects in their vicinity which correspond to 40% or 120% of the size of their white square. Another important factor is the lighting-they won't use highly contrasting patterns if the object is not sufficiently contrasting compared to the rest of the background. The size of the white square changes with the growth of the individual, but so does the behaviour-the ratio is always correlated to the actual size of the white square [3].

Being hidden while moving

Merging with background might be easy while being still but avoiding detection while moving presents another challenge. Octopuses and cuttlefish generally prefer using mottled patterns while moving, possibly because it would be more beneficial to resemble sand or other small objects, which can move with tide, rather than large contrasting objects like big rocks, which would be highly conspicuous if they moved [4]. Some species of octopuses have developed specific camouflage to disguise themselves while moving. Octopus aculeatus uses two arms for bipedal walking, while using the remaining arms to mask itself as a seaweed. Octopus marginatus also walks on two arms but tries to resemble a rock or a coconut [5]. This strategy of a moving rock was also observed in Octopus cyanea [6]. Anecdotal observations of Octopus cyanea show that these octopuses never move faster than is the speed of the visible movement in the background, created by the dispersal of light by the water [7]. A completely different strategy was observed on Octopus cyanea in the Indo-Pacific-octopuses there were constantly changing their patterns, as often as 2.95 times per second, while switching between cryptic and highly conspicuous patterns [6]. This behaviour was labelled as polyphenism. Its benefits could lay in creating so many phenotypes that a predator would find it hard to keep the octopus in focus, or it could hesitate before attacking, which would give the octopus time to escape.

A case for itself is the behaviour of ,Mimic Octopuses in the Indo-Pacific. Thaumoctopus mimicus lives on the sandy planes, where there are little to no covers behind which the octopus could hide. Since it cannot easily camouflage itself among coral reef or sea weed, this octopus instead camouflages as different species of animals, living in the area. It can pretend to look like a colony of tunicates, a tube of a polychaete worm, a solitary anemone or a sponge. Even while moving, this octopus masks itself as other animals, especially those which are poisonous for its predators-a lion fish, a flatfish or a banded sea snake. It imitates their colour and pattern as well as their movement, making use of Batesian mimicry. Norman et al. [8] mentions that these octopuses can impersonate as many as 13 different animals. Which animal it impersonates depends on context-if the octopus needs to swim in the water column, it swims like a lionfish, whereas when moving on the bottom it resembles a flatfish. The presence of a predator plays also a role-if it would be a predator which would not be intimidated by the poisonous model, the octopus will rather use its colour change to try and merge into the background. Such behaviour was also observed in another octopus, which is so far known only as blandopus white V, as it has not been given a scientific name yet [9]. Imitating a flatfish was found among other species of long armed octopuses, namely Wonderpus photogenicus, which was also seen impersonating lionfish and banded sea snake [10,11]. Huffard et al. [10] also emphasises that all the three species of octopuses are closely related. However, impersonation of flatfish was also observed in a Caribbean species of octopus, Macrotritopus defilippi [12].

In a species of octopus living in West Atlantic, Octopus insularis, Krajewski et al. [13], discovered a behaviour which they called social mimicry. This species of octopus frequently swims in a group with groupers Cephalopholis fulva, resembling their colour, shape and movement, which enables it to blend within the group, lending it the protection of the crowd. Impersonation was also found in cuttlefish, namely the pharaoh cuttlefish (Sepia pharaonis). It seems to try imitating a hermit crab, changing the colour of the body to resemble the crabs shell while moving its arms the same way those crabs do. The cuttlefish were observed using this behaviour when in a new environment, where they might need protection, and while hunting, because it enabled them to closely approach their prey without scaring it away [14]. This could be classified as aggressive mimicry.

Using colour change for other purposes

Hunting: Octopuses and cuttlefish have a spectacular element in their repertoire-they can coordinate the activity of their chromatophores in such a way, that it may seem as if white and black stripes run on their skin. This phenomenon was named a passing cloud. Its full purpose is still debated, but some octopuses and cuttlefish have been seen using this display for hunting. One of the theories suggests that in may serve the purpose of masking the real speed of the predator, enabling it to catch the prey, or that it may serve as a way how to startle the prey into movement, which would enable the predator to focus on it better, while not risking moving itself and losing the prey [15].

Communication: Both octopuses and cuttlefish use their colour-changing abilities for intraspecific communication. Octopuses, being highly territorial, may use colour-change to inform a conspecific invader of their intentions. If there is an invasion, the octopuses first asses the power of their opponent, and if they decide that they could lose the potential fight, they display lighter colour than the opponent, which ceases their aggression and enables them to emerge unscathed [16]. In contrast to octopuses, who are mostly antisocial, cuttlefish are semi-social, forming large groups when mating. Here cuttlefish use colour-change to identify as males or females, males displaying black and white zebra pattern on their bodies. While mating, males guard females they successfully courted under them, while fighting or chasing away other competing males. Small males of the giant cuttlefish (Sepia apama) have come up with a unique tactic-since they would have no chance fighting a

large male over a female, they instead take on the brown pattern of a female, and let the big male court them. When they get under him, where he guards his female, they show her the zebra pattern when the big male is distracted, to signal their true gender and mate with her. The female usually does not resist, which means that this strategy is highly successful (if they avoid being discovered by the guarding male) [17]. Species of the mourning cuttlefish (Sepia plangon) have taken this tactic to another level, because they can show the zebra pattern only on the side of their body facing the female, while simultaneously displaying the female pattern on the side which their competitor can see [18].

Conclusion

Colour-change in octopuses and cuttlefish is a highly complex and flexible behaviour, which is used for far more purposes than simply background matching. Cuttlefish and octopuses use their cognitive abilities to create unique strategies to escape predators or attack their prey. All this behaviour is high in its complexity, and application of so many different strategies demands integration of visual perception, and the ability to predict the reactions of the observer/predator, which points to the use of complex cognitive abilities. Octopuses and cuttlefish also use their colour-change for communication. It enables them to lessen the aggressiveness of their opponent in agonistic interactions and thus significantly lowering the risk of harm. Cuttlefish use their abilities to deceive their rival in mating. This behaviour highly resembles tactical deception occurring in primates [19], and it certainly requires the use of complex cognitive abilities for assessment of situation and the evaluation of perception of the animal, which is being deceived. It is a flexible behaviour, changing with the actual context of the situation, and demanding an ability of prospection, for predicting future behaviour of all individuals involved.

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