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SHORT COMMUNICATION

The snake head-shape signal: a reply to Valkonen & Mappes

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It has already been suggested that snake head triangulation might be related to mimicry of the head shape of vipers (Greene & McDiarmid 2005, and references therein). Until very recently, this hypothesis has never been experimentally tested. We first tested the hypothesis of snakes' head shape as a dangerous signal to predators by use of plasticine models (Guimarães & Sawaya 2011). We suggested in that study that shape of the head does not confer advantage itself but may work in synergy with a set of traits including colour and behavioural displays that warn and discourage predator attacks.

Shortly after our publication, Valkonen *et al.* (2011) published an article in which they suggest triangular head shape was a warning signal to predators, also based on experiments using plasticine snakes. Valkonen & Mappes (2012) argue: 'In contrast to the findings of Guimarães & Sawaya (2011), our results demonstrate that the triangular head shape typical of vipers can act as a warning signal to predators.'

We consider the debate on the evolutionary significance of head shape and its possible associated mimetic behaviour very productive. In order to further advance that discussion, we need to clarify some points discussed by Valkonen & Mappes (2012). The combination of colour pattern and head shape used by Valkonen *et al.* (2011) may have played an important role in repelling predators. We think a more conservative interpretation would be one very similar to ours: head shape associated with colour pattern can act as a warning signal to predators. Thus, we do not agree that their findings are in contrast with ours, but in the same direction.

However, an interesting point discussed by Valkonen & Mappes (2012) is that attacks by mammalian and avian predators must not be pooled together. It would be better indeed to consider only avian predators in order to ascertain that only visual signals are involved. In our experiment (Guimarães & Sawaya 2011) we pooled attacks by mammalian and avian predators. We recorded 17 and 11 attacks to oval and triangular-shaped heads, respectively, pooling avian and mammalian predators, which was not significantly different. Considering separately the two types of predators in our experiments (omitted from our publication), we recorded for avian predators 11 and seven attacks to oval and triangular-shaped heads, respectively; and for mammalian predators six and four attacks, respectively. Those results would not change our conclusions, even when considering only avian predators ($\chi^2 = 0.89$, df = 1, $P = 0.35$).

More studies are necessary to better understand the evolutionary role of head shape of snakes as visual cues to predators and its possible related mimetic complexes (see Greene & McDiarmid 2005 for a review, complementary questions and future prospects in snake mimicry). However, we believe head triangulation must be considered a complementary warning signal to predators, acting within a set of traits in the defensive behaviour of snakes.

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