Title: Betta fish (*Betta splendens*) spontaneously use the combination of numerosity and surface area during discrimination learning

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Abstract

Like many other species, fish have been found to represent numerical values in visual discrimination tasks. Little is known, however, about whether fish use number even when other stimulus properties are available. Some researchers propose that animals represent number only as a last resort, while others have found that monkeys will base their decision on numerical value if the numerical ratio is easy to discriminate. In this study, betta fish (*betta splendens*) were trained to associate food with one of two visual stimuli that differed in both numerical value and cumulative surface area. Non-differentially reinforced probe trials indicated that betta fish were only able to discriminate between stimuli that contained both kinds of information. They performed at chance in discriminating between stimuli that differed only on numerical value, and between stimuli that differed only on cumulative surface area. These results indicate that fish may attend to a combination of these factors during discrimination training, leaving them unable to solve the discrimination with only one of the jointly-learned cues.