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Context-dependent decisions among options varying in a single dimension

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ABSTRACT

Contrary to theories of rational choice, adding alternatives to a choice set can change the choices made by both humans and animals. This is usually done by adding an inferior decoy to a choice set of two favoured options that are characterized on two distinct dimensions. We presented wild, free-living rufous hummingbirds (*Selasphorus rufus*) with choices between two or three options that varied in a single dimension only. The options varied in concentration, in volume or in corolla length. When the options varied in concentration, the addition of a medium option to a choice set of a low and a high concentration caused birds to increase their preference for the high option. However, they decreased their preference for the high concentration option when a low option was added to a choice set of high and medium concentrations. When the options varied only in volume, the addition of a high volume option to a choice set of low and medium options decreased the birds' preference for the medium option. We saw no effects of adding a third option when the options varied in corolla length alone. Hummingbirds, then, make context-dependent decisions even when the options vary in only a single dimension although which effect occurs seems to depend on the dimension being manipulated. None of the current theories alone adequately explain these results.

During its lifetime an animal has to make decisions in a range of situations, such as foraging, nesting building, mate choice and social interactions and the choices made can have dramatic effects on the fitness of that animal. Understanding decision making in animals, and how and whether context affects particular decisions, enables us to understand how animals respond to changing environments as well as helping us to examine the cognitive processes involved in the processing of information.

It has long been assumed that animal decision making is rational such that animals assign an unchanging value to each item encountered and then consistently choose the item with the highest value (Pyke et al., 1977; Schoener, 1971). A consequence of this assumption is that in any situation the animal is expected to choose consistently the option with the highest value but also to choose this option at the same frequency regardless of other, inferior options available. Each option is, therefore, independent of the other options available, both in number and type of options available. Additionally, the relative preferences between two items should not be altered by the inclusion of an inferior option (Tversky and Simonson, 1993).

For humans, however, it has been accepted for some time that choices are often based on relative judgements (Huber et al., 1982; Tversky, 1977; Tversky and Kahneman, 1974; Zellner et al., 2003) and it is beginning to appear that using absolute currencies may also not describe all decisions that other animals make. Decisions that are not consistent with the use of absolute currencies have been recorded in mammals (Scarpi, 2011), birds (Bateson, 2002; Bateson et al., 2002, 2003; Schuck-Paim et al., 2004), eusocial insects (Edwards and Pratt, 2009; Shafir et al., 2002) and eukaryotic slime moulds (Latty and Beekman, 2011). In these experiments, organisms appear to have used relative currencies such that the decision to be made was changed by the context in which it was placed, in particular the number or kind of alternative options in the choice set.

In such context-dependent experiments, the human or animal is typically asked to choose between two favourable options, which are presented alongside one or more additional options (decoys, i.e. options that are not expected to be chosen). The effect of such a decoy may depend on its relationship to the two options of interest. For example, the inclusion of an asymmetrically dominated decoy to a choice set tends to increase the preference for the

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option by which it is dominated. Rufous hummingbirds have been presented with such a task in which the sucrose options presented to the birds varied in two dimensions, volume and concentration (Bateson et al., 2003). One option (Volume Target) had a large volume (40 μl) coupled with a low concentration (20%) while the other option (Concentration Target) had a small volume (20 μl) with a high concentration (40%). It was assumed that birds would see these two options as being essentially equivalent and that neither would be preferred over the other. The decoy options added to this pair of targets, in two separate treatments (i.e. the birds faced a choice between only three options, the target, competitor and a decoy but were presented with both sets of trinary choices) were both inferior to the two target options. The Volume Decoy (30 μl, 10%) had more sucrose than the Concentration Target but was less concentrated than was the Volume Target. This decoy was, then, dominated by the Volume Target. The Concentration Decoy (10 μl, 30%), on the other hand, was more concentrated than the Volume Target but contained less sucrose than did the Concentration Target. This decoy was, then, dominated by the Concentration Target. The addition of each of these decoys to the binary pairing of the two target options led to an increase in the number of choices the birds made to the Target by which it was dominated: addition of the Volume Decoy caused birds to increase their preference of the Volume Target, relative to the binary condition whereas the addition of the Concentration Decoy increased the birds preference for the Concentration Target, relative to the binary condition. The impacts of decoys appear to be very robust and have been observed in a range of human decision making such as in choices of management or game strategies, for products such as tapes, batteries, juice, cars, beer, films, TV's, computers and microwaves as well as for restaurants or tradespeople (Bateman et al., 2008; Colman et al., 2007; Doyle et al., 1999; Huber et al., 1982; Pettibone and Wedell, 2007).

As described above, the impact of decoys on decision making in animals has been investigated experimentally by presenting animals with options that varied in two dimensions simultaneously. However, although an impact of decoy on preferences was seen in all these tests, the interpretation of the effect was not readily interpreted (e.g. Bateson et al., 2002, 2003). One possibility was that because the options the birds had to choose between varied in two dimensions they did not perceive the options as intended. The choice of parameters for the two-dimensional (volume and concentration) options was made on the assumption that changes in concentration and in volume are perceived along an approximately similar, arithmetic scale. However, this may not be the case as although volumes may be most discriminable when they are small, changes in concentration for these hummingbirds may peak around 25% (Blem et al., 2000). As both dimensions changed with each option it is possible that the way the birds perceived the options differed from the original assumptions i.e. that the placement of decoys relative to the target and competitor was not how the birds perceived them. An alternative explanation is that the birds made their choices based on their energetic state. The clearest prediction in this case is that the inclusion of poorer options would lower the bird's energetic state, so it should increase its preference for any option that offers a better caloric return (Schuck-Paim et al., 2004). This explanation could not be entirely excluded with the data produced by those earlier experiments.

As manipulations with two dimensions resulted in a more complex outcome than expected, we attempted in this experiment to present birds with options that would allow us to determine more readily how their preferences were related to the options we provided. To do this as simply as possible, we presented rufous hummingbirds with options that varied in a single dimension only (Wedell et al., 2005; Wedell and Pettibone, 1999; Choplin and Hummel, 2005).

To manipulate choice in a single dimension we presented birds with binary and trinary comparisons in which volume, concentration or corolla length alone were varied. For each experimental treatment (volume, concentration or corolla length), birds faced three binary conditions and a single trinary condition. In this trinary condition, each option was effectively a decoy for the other two options. If the birds choose options based on energetic value, in all conditions, the birds should choose the option that provides the greatest energetic return. The inclusion of a third, poorer option may dilute the preference for the best option but should not alter that preference relative to the second-best option. This was what we expected the birds to do but with the additional effect that we would observe whether our linearly related options would be matched by linearly related preferences.

If the birds make decisions based on the absolute energetic value on the available options, we predicted that they would prefer the option that affords them the greatest energetic return, which may mean the lowest energetic expenditure, as in the case of the corolla treatment. If, however, the birds employ other comparison mechanisms to decide among options, there were a number of possible outcomes, depending on the relationship among the options.

1. The inclusion of the smallest option (longest for the Corolla Treatment) may lead the bird to increase its preference for the middle option at the expense of the largest option if the bird perceives that middle option to be better than it appeared in comparison with the largest option. This possibility is predicted by Helson's (1964) Adaptation Level Theory, in which options are judged to be good or bad relative to the average of the options in the context in which they are presented. For example, a middle option paired with a higher option will be below the average of the two options and therefore should not be often chosen often when in the presence of the higher option. If, however, a low option is added to the choice set then the middle option becomes the average and so might be chosen more frequently than it was in the binary context.
2. The inclusion of the middle option may lead the bird to increase its preference for the largest option over the smallest option because the two extreme options now appear to be more different. This outcome is suggested by Krumhansl's (1978) Distance Density Model in which it is considered to be easier to make more sensitive distinctions when the available options are more similar to one another.
3. The inclusion of the largest option might lead the bird to decrease its relative preference for the middle option. This is also suggested by Helson's (1964) Adaptation Level Theory as the middle option would go from being above average in a low/middle binary choice set to being the average option in a low/middle/high trinary choice set. As in our Volume (Ratio) Treatment the middle option would be much poorer than average in the trinary condition than it is in the low-middle binary condition, the decrease in preference for the middle option should be more pronounced than in the other Treatments.

The experiment was conducted using wild male rufous hummingbirds foraging in the field from artificial flowers. The sucrose contents of artificial flowers from which the hummingbirds were feeding were manipulated along three dimensions: volume, concentration or corolla length. These dimensions were chosen because they all affect choices made by foraging hummingbirds: they prefer shorter corollas, larger volumes and higher concentrations (Montgomerie, 1984).