Operant and Classical Learning at the Flight Simulator: What is the Role of the Context?

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1. Introduction

Classical conditioning is often described as the transfer of the response-eliciting property of a stimulus to a new stimulus without that property. In contrast, the processes underlying operant conditioning may be diverse and are still poorly understood.

Drosophila can be conditioned classically or operantly to avoid certain orientations in the flight simulator. To reach the same performance, more reinforcement (heat) is required during classical than during operant training. We considered the possibility that classically trained animals might use their naive behavioral repertoire to express learning performance while animals that are allowed to control the reinforcer during operant training may refine their behavioral strategies. However, an extensive comparison of flight behavior after operant and classical training did not reveal such a difference.

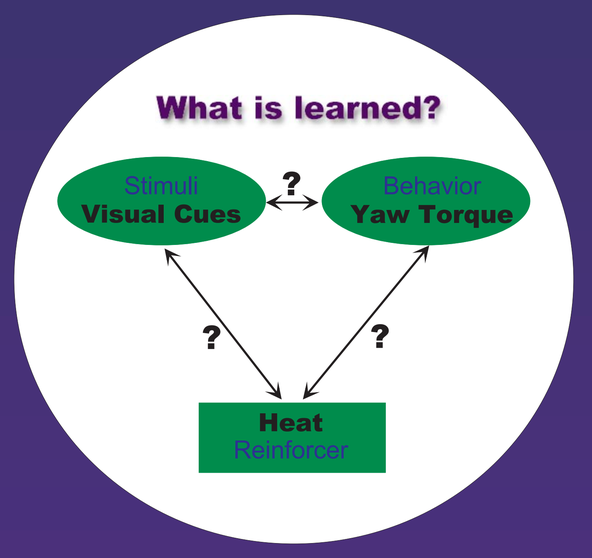
We therefore proposed, that operant behavior facilitates the transfer from the unconditioned to the conditioned stimulus.

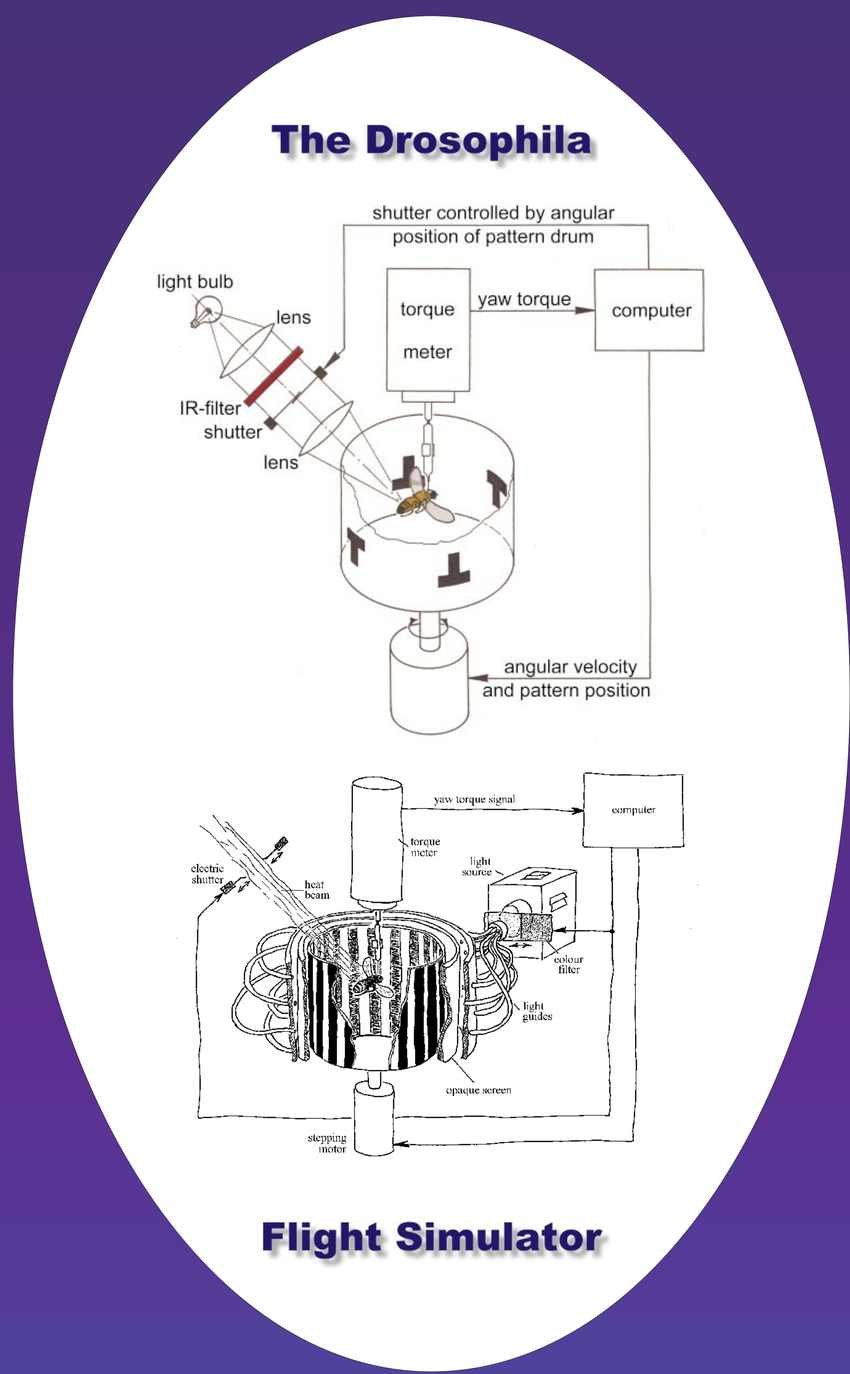
If that were so, the transfer should lead to a valued stimulus that keeps its attractive/repulsive properties irrespective of the behavior used to test/train the animal. We used two different behaviors to test that prediction: (1) The fly uses two visual cues (either patterns or colors) to avoid certain flight directions in the flight simulator (fs-mode). (2) The fly controls the two visual stimuli using the sign of its yaw torque [switching(sw)-mode].

The two behavioral modes are then interchanged between training and test. The resulting test scores should tell us whether the avoidance-eliciting property of the heat was transferred along with the visual cues independently from the behavior with which the stimuli were controlled during training.

A significant learning score would corroborate our hypothesis that operant behavior facilitates "classcial" associations. Those associations are learned independently from the context.

No significant learning score indicates a tighter involvement of the behavior used to control the reinforcer during operant training. Learning is then said to have occurred in a context-dependent manner.





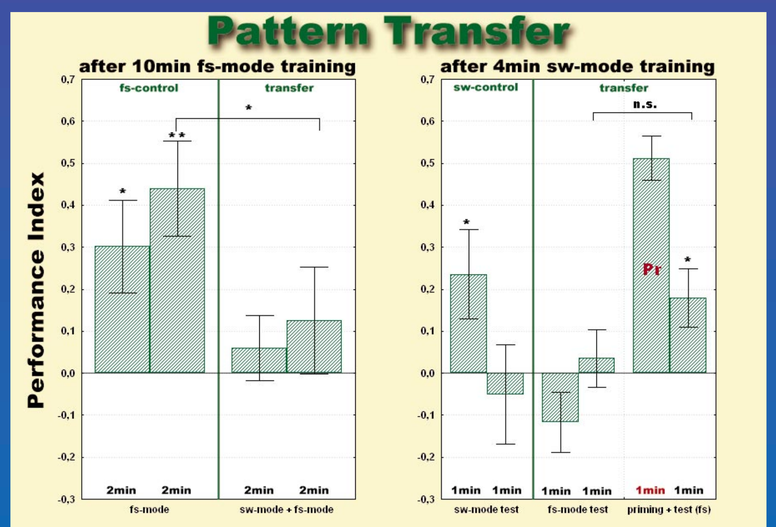
2. Two Visual Stimuli

Patterns:
In the first setup, two pairs of identical patterns are evenly spaced in alternating sequence on the inside wall of a drum (arena; see upper center image). The fly is positioned in the center of the arena. During training, one of the pattern orientations is combined with the reinforcer (heat). During test, the heat is permanently switched off.

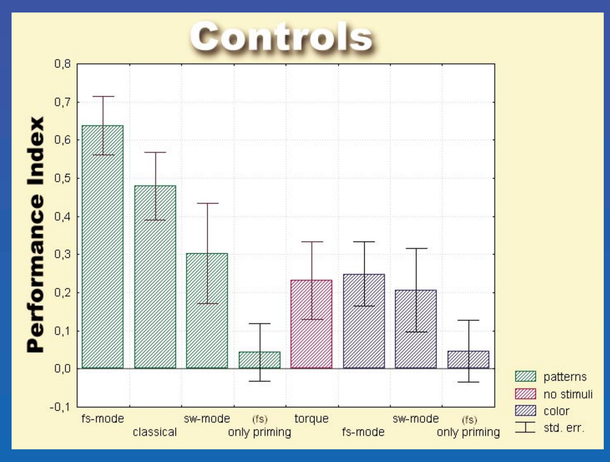
Colors:
In the second setup, the pattern consists of 20 evenly spaced stripes. For blue and green illumination of the arena, the light is passed through monochromatic broad band Kodak Wratten gelatin filters. Filters can be exchanged by a fast magnet within 0.1 sec (see lower center image). During training, one of the colors is combined with the reinforcer. During test, the heat is permanently switched off.

Design:
There are two flight modes: *flight simulator mode* (fs-mode: the fly's yaw torque is continuously transduced into corresponding angular velocity of the drum) and *switching mode* (sw-mode: whenever the fly's yaw torque changes sign, the color of the arena or the pattern orientation is changed). Several experimental designs are employed for probing stimulus transfer:
(1) training in fs-mode is followed by test in sw-mode.
(2) sw-training with subsequent fs-test.
(3) Training in sw-mode is followed by a short priming period in fs-mode and a fs-test.
(4) Training in fs-mode with subsequent sw-priming and a sw-test.

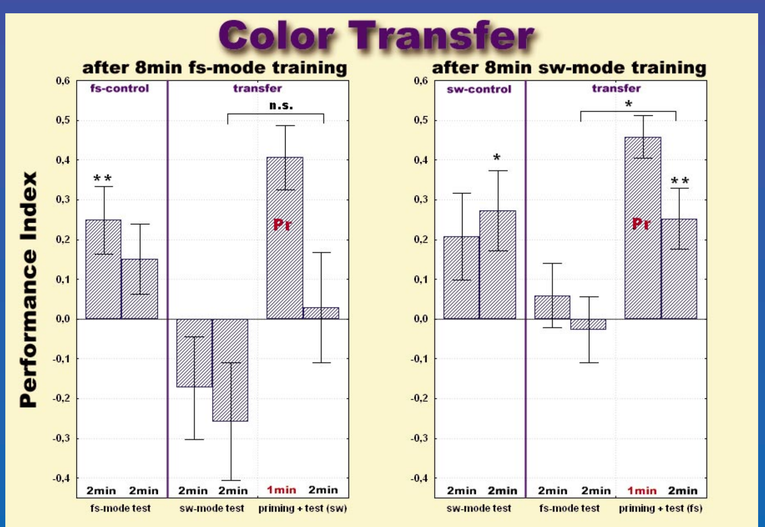
3. Is there context independent learning of visual cues?



Pattern Transfer:
Left: Ten minutes of fs-mode training produce a highly significant learning score in the **fs-control** group. If, however, a 2 minute sw-mode test is inserted, even the fs-mode performance vanishes. There is no **transfer** from fs-mode training to sw-mode test.
Right: Only 4 minutes of sw-mode training are sufficient to produce a significant learning score in the **sw-control** group. As in the color experiment, **transfer** is only observed after sw-training in the fs-mode test after 1 minute of priming (fs-mode training).
The level of fs-performance after **transfer** is somewhat lower than the **sw-controls** and markedly lower than the performance usually seen in **fs-controls**.



Controls:
Performance indices vary with the different experimental designs. The durations of the respective training periods differ as do the durations of the subsequent test periods. It is assumed that the indices displayed in this graph depict a maximum level of performance. There is no learning after a 1 minute fs-mode training period (priming).



Color Transfer:
Left: Eight minutes of fs-mode training are sufficient to obtain a significant learning score in a subsequent fs-mode test period (**fs-control**). This learning is not revealed, when the fly is forced to use a different motor output (sw-mode) to control the color in the test (no **transfer**).
Right: After 8 minutes of switching mode training, however, flies are able to show discrimination between the two colors in fs-mode, if they have been subjected to a 1 minute fs-mode training period (priming) at the onset of the test. Performance after **transfer** and priming is as good as in the **sw-control** and in the **fs-control**.

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