Learning Paradigms Exemplified by Virtual Experiments with Honey Bees

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Abstract. Learning is based on rules that can be elucidated by behavioural experiments. This article focuses on virtual experiments, in which non-associative learning (habituation, sensitization) and principles of associative learning (contiguity, inhibitory learning, generalization, overshadowing, positive and negative patterning) can be examined using 'virtual' honey bees in PER (Proboscis Reaction Extension) conditioning experiments. Users can develop experimental designs, simulate and document the experiments and find explanations and suggestions for the analysis of the learning experiments. The virtual experiments are based on video sequences and data from actual learning experiments. The bees' responses are determined by probability-based learning profiles.

Keywords: Behavioural neuroscience, non-associative learning, associative learning, PER conditioning, honey bee, virtual experiments

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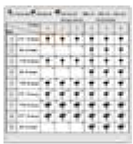
Supplementary Material

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Topical Context

Learning is the ability to modify behaviour with respect to individually experienced interactions with the environment. Non-associative forms of learning are simple forms of experience-dependent changes in behaviour. In contrast to associative learning, no novel stimulus-response relationships are established, but existing stimulus-response relationships are modulated and the animal's response level is normally altered rapidly and reversibly. In associative learning, experience means the impact of simultaneously or successively occurring events. The events become associated to each other in the animal's learning processes and are categorized as a cause-and-effect relationship. Learning is based on rules that can be elucidated by behavioural experiments and expressed mathematically in formalized learning models. During learning, new associations are built in the nervous system, thereby storing the learned information ('memory'). Changes of the synaptic connections in the nervous system caused by associative learning are the prevalent research issue for neural correlates of learning and are already quite well understood (for an introduction into behavioural neuroscience see e.g. Carew 2000).

Application Context

The virtual experiments at issue focus on learning at the behavioural level. Each unit is about a different principle of non-associative or associative learning: habituation, sensitization, contiguity, inhibitory learning, generalization, overshadowing, positive and negative patterning. Thus, the virtual experiments answer the question "What is learned?" Not within the scope of the virtual experiments are formalized learning models (for introduction to formalized learning models, see e.g. Schmajuk 1996) and the neural correlates of learning (for introductions in physiology of learning see e.g. Kandel, Schwartz, and Jessel 2000; Dudel, Menzel, Schmidt (Hrsg.) 2001).

The target group of the virtual experiments are novices in the field of behavioural, neural and cognitive science and the interested interdisciplinary audience. Users gain an overall view of paradigms of non-associative and associative learning and get an idea of experimental work in the field including data analysis. Prior knowledge recommended is a basic knowledge of concepts in behavioural science, particularly classical conditioning and associative learning (for introductions see e.g. Pavlov 1927; McFarland 1999).

In educational contexts, the virtual experiments are suitable for higher education up to university first or even second cycle. In educational settings like lectures and seminars, the virtual experiments can be used for demonstrations or self-learning. In practical training, they can be used to prepare students for developing their own learning experiments with animals. The simulations have proven applicability in university courses at the "Freie Universität Berlin", special trainings for teachers and courses at the NatLab (Freie Universität Berlin), where pupils together with their teachers could practice experiments in Chemistry and Biology.

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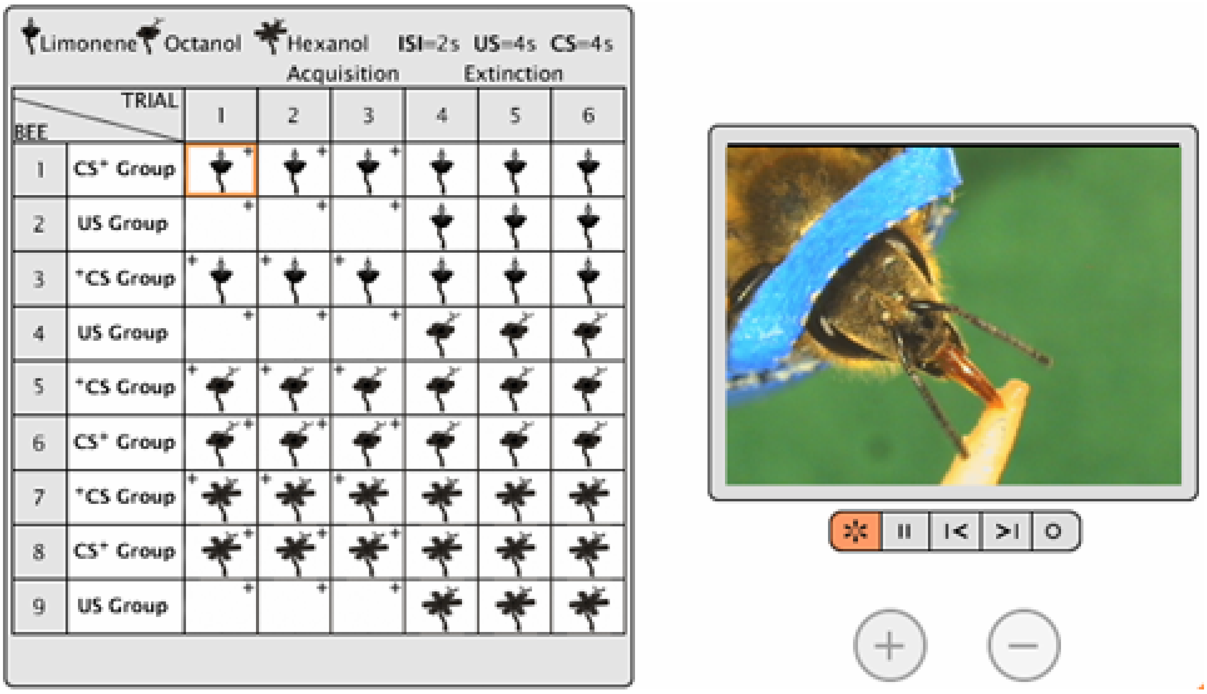

Figure 1: Screenshot of a virtual experiment. In this situation, you perform a contiguity experiment. Three groups of bees are trained (CS+, US, +CS). Three odours are used to the same extent in all groups (odor balancing). You can observe the bee's responses.

The virtual experiments do not only aim at mediating theoretical knowledge but also at introducing into practical experimental work. Users can develop experimental designs for the different learning experiments. For example, users are shown how to use control groups or how to think about adequate test situations. After an experimental design is prepared, the experiment can be performed virtually (see figure 1). In the experiment each bee has an individual learning profile based on statistics of experimentally collected data. Since for each experimental trial one of several learning profiles per bee will be choosen by change by means of the underlying probabilistic algorithm, users can observe different response behaviours in different experimental trials. This effect holds also for a group of users (e.g. in the classroom). Hence, this special feature of the introduced virtual experiments gives an impression of realistic experimental situations in the laboratory. The bee's reactions can be documented in protocol sheets. The collected data from a group (e.g. in the classroom) can be used for data analysis. The interface design and spatio-temporal visualizations of the simulations allow an easy manipulation of parameters (i.e. ordors) required for designing and carrying out the experiment. The virtual experiments are complemented by integrated topical texts, instructions, glossary, bibliographic references and tasks guiding users how to develop, simulate and document the experiment and analyse the experimental data.

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Requirements

The virtual experiments are provided as an installation-software for download. The tutorial, a glossary, bibliographic references and instructions are embedded in the application. The program can be installed on Windows PCs (follow instructions). The required JAVA Resource Environment and JAVA Media Framework is included (separately obtainable at http://java.sun.com/). Recommended hardware requirement is a personal computer with 1 GHz processor, 256MB RAM and 150MB of free disk space or comparable configuration.

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