**Cognition and emotion in concert in human and non-human animals**
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## Introduction

A major question in our research programme is how in human and non-human animals the balance between positive ("reward") and negative experiences ("punishment", "stress") affects the efficiency of long-term behavior -- defined as choosing strategies with the most profitable cost-benefit outcomes -- in a "complex" (multiple-choice) environment. The balance between positive and negative experiences results from the continuous integration of such experiences. At least in humans it has been shown that failure of such an integration leads to inefficient long-term behavior in a complex (social) environment (Damasio 1996). In order to tackle this question we shall place experiences in a neuro-behavioral model, show how they can be made accessible for experimentation -- especially so in non-human animals -- and briefly discuss a method to study long-term behavioral efficiency.

## Emotion and cognition: motivational systems and neurobiology

### *Motivational systems: emotion and cognition*

The relationship between internal physiological changes on the one hand and behavioral changes on the other in relation to the availability of different commodities in living organisms are captured as motivational systems. Commodities are items in the environment which are potentially essential to the animal's fitness. Motivational states such as hunger, thirst and libido arise because of a difference between actual and reference values in the animal's respective physiological systems, and subsequent behavior -- appetitive and consummatory (Craig 1918) -- is directed at nullifying this difference.

As reviewed elsewhere two features of commodities are relevant for the animal's behavior (Spruijt et al. 2001): knowledge of *when* and *where* a commodity is available (cognition) and assessing the *incentive or rewarding value* of a commodity after and prior to consumption (emotion).

The *when*-component of cognition deals with the animal's capacity to associate stimuli with the arrival of commodities and which mechanisms have been studied in Pavlovian conditioning experiments. The cognitive load increases as the interval between the offset of the cue (conditioned stimulus) and the onset of the arrival of the commodity (unconditioned stimulus) increases from zero (delay-conditioning) to several seconds or minutes (trace-conditioning; Lieberman 2000, pp. 103-107; Clark and Squire 1998; Wallenstein et al. 1998). The trace-conditioning paradigm measures what others have referred to as *beliefs* in the context of intentional action or goal-directed behavior (Heyes and Dickinson 1990). The *where*-component of cognition deals with the animal's capacity to assess the stimuli which indicate where commodities may be found and which mechanisms have been studied in a number of spatial tasks such as the Olton radial maze and the Morris water maze (Kalat 1998, p. 357). The cognitive load increases as the stimuli which indicate the commodity's position are progressively less directly "attached" to the commodity itself (the shift from proximal [direct] to distal [configurations of] stimuli; Wallenstein et al. 1998). Behavior based on these configurations of stimuli may be conceived of as *belief*-based behavior, as mentioned above.

The *incentive value* is dependent on the current internal state (the more the animal has been deprived of the commodity the higher the commodity's incentive value), prior experience with the commodity, and its general properties (for food as a commodity: see Grill and Berridge 1985). Thus, the incentive value may differ between different commodities and over time for the same commodity.

Berridge and colleagues (Berridge 1996; Berridge and Robinson 1998) have