

# Reward, Reinforcement and the Dopamine System: Making Conceptual Transitions Across Multiple Levels of Organization

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## Introduction

Recent experimentation on the midbrain dopamine system and the brain areas it enervates, including the nucleus accumbens (NAc), striatum and prefrontal cortex, has led to a revival of the theoretical framework of classical animal learning theory. Data obtained in this research area has served as the basis for numerous claims about the reward-related functions of the midbrain dopamine system.

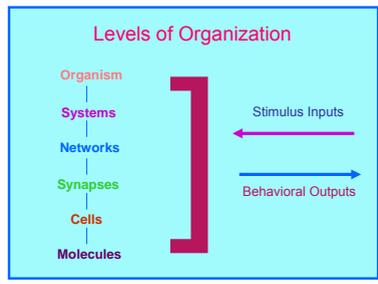
One widespread belief is that a primary function of the mid-brain dopamine system is the prediction of future reward, where the notion of reward, conceived at the level of behavior, is assumed to clearly and directly relate to how reward is conceived at the levels of 'behaving' populations of or single dopamine neurons.

The aim of this poster is to make the case that we should be skeptical of this interpretation of the data for at least several reasons:

- (1) No consensus in the literature as to how to operationally define *reward* at the level of the behaving organism.
- (2) No agreement with respect to whether a "rewarding" stimulus causes observable behaviors at the level of the behaving organism through *single* or *multiple* psychological processes.
- (3) The input-output relations with respect to reward at the level of the behaving organism are assumed to be *symmetrical* with observed input-output relations at the level of behaving dopamine neurons. However, such symmetry in no way establishes causal relationships between electrical activity in dopamine neurons and overt organism-level behaviors.

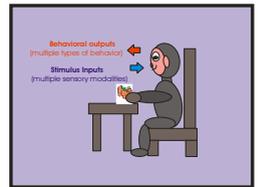
Once these features of contemporary research on the dopamine system are established, the primary concern, then, appears to be that if a rigorous operational grip on the notion of *reward* at the level of the behaving organism and an account of the intervening psychological processing are lacking, and it is unclear how operationalizations of reward at the level of behaving neurons relate to operationalizations of reward at the level of overt behaviors, then it would seem that the goal of locating a plausible mechanism that will enable us to establish how activation of dopamine neurons causally relates to behavior cannot be realized. I will end by considering some of the specific ramifications of this for research aimed at providing such causal explanations and consider whether any solutions to these problems are forthcoming.

## Ontological Framework for Experimentation



This framework captures a set of assumptions that serves as a foundation for *experimentation* on motivation and reward.

## (1) Multiple concepts of reward at level of behaving organism



## Multiple definitions/functions of reward

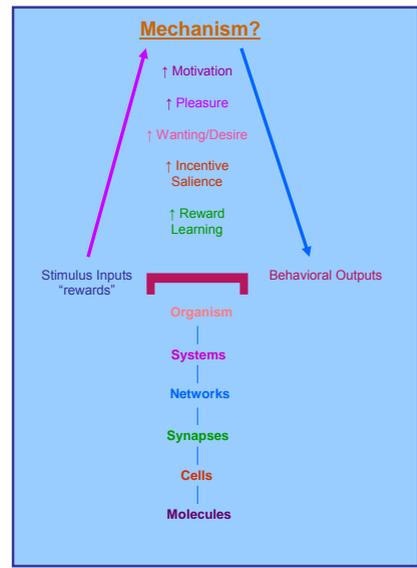
x is a reward if x satisfies at least one of the following conditions:

- (1) x induces learning in subject, making subject return for more
- (2) x induces approach and consummatory behavior in subject
- (3) x induces positive emotions in subject
- (4) x induces "wanting" behavior in subject
- (5) x is the goal of subject's behavior
- (6) x induces "seeking" behavior in subject

(Schultz 2004; Berridge & Robinson 1998; Dayan & Balleine 2002; Ikemoto & Panksepp 1999)

The concept of *reward* fails to attach to a discrete behavioral phenomenon in so far as many things can fulfill one or more of these functions.

## (2) Reward may operate through single or multiple psychological processes



It is unclear how *reward* behaves causally. For example, it can act as a *motivational mechanism*, motivating a subject to seek a stimulus. The rewarding features of a stimulus may increase the *incentive salience* of the stimulus for a subject. The multiple mechanisms through which reward can act may be inextricably tied together making it difficult to determine which aspect of reward the dopamine system is actually mediating.

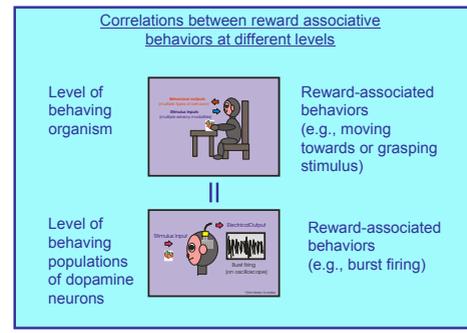
## Conclusions/Potential Solutions

Scientists working in the research area of reward are aware of the problems with isolating the function of the dopamine system and providing mechanistic explanations for reward-related phenomena. However, solutions to these problems are not forthcoming due to specific disagreements in the field about how to understand (1) the concept of reward, (2) the variables that intervene between rewarding stimuli and behavioral responses (at different levels of organization) and (3) the relationships between levels and how correlations between levels may inform the discovery of mechanistic explanations.

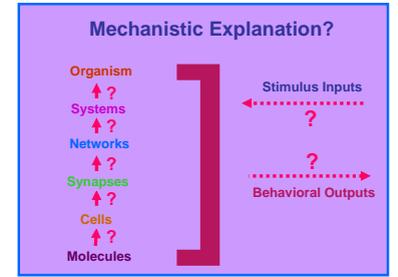
Some authors have proposed that these conceptual issues may be teased out in the context of experimentation (Berridge and Robinson 1998). Another viable approach may be to look towards computational approaches that attempt to capture reward, reinforcement and dopamine system function in network models. In such models, specific assumptions about how to cash out reward and reinforcement learning conceptually are to some extent laid bare. In turn, this approach may shed light on how to make specific concepts more rigorous in cognitive neuroscience and neurobiology. However, it is possible that computational approaches will run into similar kinds of problems in so far as they often have to buy into the distinctions made by researchers who are generating the data they are attempting to model. They might also fail, from the standpoint of neurobiology, because the algorithms that implement learning in neural networks (e.g., Temporal-Difference) are not thought to be biologically plausible with respect to how learning actually occurs in the brain.

Thanks to Peter Machamer for his helpful comments on this poster. This work was supported by NSF-IGERT.

## (3) Isomorphism does not guarantee causal relationships



Behaviors associated with reward at the level of the organism are assumed to correlate directly with behaviors associated with reward at "lower" levels. Such isomorphism or symmetry between levels does not establish causal relations—it is not clear what one type of behavior has to do with the other.



If the aforementioned claims are correct, then it appears that problems will arise when researchers attempt to "tease out" mechanistic explanations for phenomena associated with reward and dopamine function.