

Neurobiological Foundation for Psychological Motivation Theories

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AUTHOR BIO

I'm Tatiana Lermusiaux, and I am a 17 year old high school student. I am interested in science, in particular the fields of neuroscience and psychology. I plan to major in one of those fields or another science field. I like learning new things and learning about new discoveries.

ABSTRACT

Psychological theories of motivation to date are rudimentary in that they assign the underlying explanatory component of motivation to either a single set of needs or to more cognitive influences like expectations or fairness. A review of the neurological processes taking place in motivated behaviors shows a much more complex and personalized situation. New distinctions are needed, for instance between wanting and liking, as it has been shown that wanting is a separate neural process from liking. Furthermore, neural patterns of learned dislike can be overridden by physiological imbalance that motivate new behaviors. In this review we propose that there is no grand theory of motivation that can address all individuals equally. We can, however, single out generic underlying theories, like incentive salience theory, that underlie the biological dopamine process for cue-based personal incentives. When applied to situations that require changes in motivation, such as interventions to stop a particular behavior, the current use of oversimplified theories of motivation hinder success. Therefore, this review highlights that attempting to alter a person's behavior and motivation, especially through an intervention requires unique, personalized strategies that go beyond broad-stroke psychological theories.

INTRODUCTION

Psychological motivation theories are useful for categorizing, understanding, and influencing behaviors. Those theories are often based on observational studies or questionnaire-based inquiries. Consequently, they are seen by neuroscientists as categories with no real connection to the true underlying biology or physiology. In this review, we aim to draw connections between categorizations and neurobiology (Figure 1.). This is part of a larger movement within the National Institute of Mental Health (NIMH) called Research Domain Criteria (RDoC), which has stated an explicit goal of integrating many levels of information, including genomics, circuits, physiology, and behavior, to better understand the basic dimensions of functioning underlying the full range of human behavior. (Pacheco, 2022) Our review aims to revisit the categorizations of psychological theories and promote the ones that are the closest to their neurobiological foundation. Several levels of connections have been suggested years ago (Insel, 2010), ranging from the self-reports to observed behaviors, neural circuitry, molecular mechanisms, and finally to genetics. In this paper, we will only make the jump to the psychological theories of motivation which are historically based on self-reports and behaviors, and go to the circuits level.

The overarching purpose of this review is to promote theories that better tie motivational theories to their neurobiological foundation such that more effective behavioral interventions can be developed. This work relates to other fields, such as the diagnostics of ADHD, autism or childhood irritability, in that they also have sub-types and require complex, individualized treatments (Pacheco, 2022).

DEFINING MOTIVATION

To be understood, motivation implies a goal. A goal is sought to gain a desired state (Bong, 2023) (see Figure 2). We're always motivated to achieve something. There is no motivation created without a desired goal. However, the biology behind motivation is more difficult to define. The neurobiology of motivation requires a neuroscientist to understand the neural processes stimulating selective behaviors that drive someone toward a larger goal. In other terms, motivation is the precursor of behaviors toward what people want and what they decide to do.

But where do goals come from? At the origin, any goal is rooted in needs.(Bong, 2023) Those can be physiological needs (thirst, hunger) or psychological needs (relatedness, competence, predictability). As those needs ask to be fulfilled, they trigger a state that motivates a goal as a way to reach the state. The mental processes that combine goal selection and triggered action is what we call motivation.

In its basic form, we may want to walk to a fountain (action) to get water (goal) and not to be thirsty (state). We want to walk to a pub (action) to meet some friends (goal) to not be alone all evening (state avoidance). As you can judge from these two examples, distinct goals can intertwine, i.e. while drinking in the pub you also did not become thirsty. Very quickly through life's multiple dimensions, goals become more complex and move beyond a directly connected goal to an original single need. Moreover, the contextual learning process of each goal fulfillment creates a diversity of ways to satisfy our needs. For instance, we may decide to drink water, lemonade, or beer. They all will help to reduce thirst and will add as we will see other complexities to the motivational pathways. Similarly, beliefs, perceptions, and

emotions influence the motivation process, adding many more layers to the complexity of motivated behaviors. For instance, if you believe sugar or alcohol is not good for your health, you may not eat candy or drink alcohol even when you are hungry or thirsty. The complexity of human culture and belief systems therefore influences the power of motivation. Another layer of complexity is that many of the motivational influences are not all conscious. In fact, the majority of the influences on our behaviors are non-conscious (Bong, 2023). This especially highlights the need for neurobiological analysis in understanding motivation, as a questionnaire-based approach would not be able to track unconscious decision making. Moreover, as individual strategies to fulfill certain needs are learned, patterns are formed and can be referred to as traits or personality. It is important to understand individualistic behavior patterns, or personality traits, when considering motivation and attempts to change behaviors. In summary, motivation is the combination of the selection of a goal and the action attached to it. The goal foundations can be considered as psychological needs. Identifying key neurobiological underpinnings of motivation and how it relates to these psychological needs will unlock the key to more easily changing people's behaviors.

PSYCHOLOGICAL THEORIES

Historically, motivation has been a concept used mainly in psychology and is rich in theories (Dean Mobbs, 2013). Maslow with its pyramid of needs is probably the most well known, but many other theories emerged over the years. Maslow created a pyramid of needs, he observed and learned from the people around him and created this pyramid based on what he thought was most important. The bottom of his pyramid starts with physiological needs (food, water, warmth, rest), then moves up to safety

needs (security, safety), then belongingness and love needs (intimate relationships, friends), then esteem needs (prestige and feeling of accomplishment), and lastly self-actualization/self-fulfillment needs (achieving one's full potential, including creative activities.) At the bottom of the pyramid, he is stating things we need to survive, and as we go up the pyramid it's more mental and psychological things we need. McLelland had a concept about needs where he thought that everyone has driving motivators; achievement, power and affiliation, and implicit influence. Alderfer had a theory of need as well called ERG where he believed there were three leaves of needs: existence, relatedness, and growth. Skinner had a concept of reinforcement where he believed that the environment would create reinforcement and motivation actions. There's also the theory of Equity where the core concept is fairness or reinforcement. This theory says that the fairness of rewards will impact the role in which motivation happens. The theory of Expectancy has the concept of expectations. This concept says that motivation will depend on if there is a positive outcome. Lastly, the theory of self-determination is a concept of needs. This concept has three parts; competence, achievement, and autonomy. (see Table 1.)

Table 1. Psychological Core Concepts.

This table summarizes the core concepts of each psychology theory.

Theory Name	Year	Core concept	Explanation
Maslow	1954	Needs	Five core needs (physiological, safety, social, esteem, and self-actualization) push us to act to fulfill them

McLelland	1961	Needs	Achievement, power, and affiliation and their implicit influence.
ERG	1969	Needs	Three needs levels: existence, relatedness, and growth
Skinner	1954	Reinforcement	The environment creates reinforcement and motivates action
Equity	2001	Fairness or reinforcement	In the social environment, the fairness of rewards plays a major role in motivation
Expectancy	1964	Expectation	Motivation is dependent on the likelihood of a positive outcome.
Self-determination	1980	Needs	Three cores: Competence, achievement, and autonomy

We can categorize the motivation-independent variables into the following categories. (1) Need-based, linked to an internal innate requirement (similar to homeostasis). (2) Environment-based, linked to external reward and reinforcement, can be social. (3) Belief-based, linked to the internal creation of goals or expectation modulation.

We can summarize the third column showing there are only three independent variables influencing motivation. If we think of motivation as a function we can write it as we have done below and state that motivation is dependent on (1) the internal needs or unconscious motives of the individual. (2) The external rewards, and (3) the beliefs that have

been learned. Hence we can summarize that any motivation theories we have reviewed are a function of those.

Motivation = f (needs, external reward, belief)

SIMPLIFIED BEHAVIORAL NEUROSCIENCE OVERVIEW OF MOTIVATION

Motivation as we have defined it is the energizing of behavior in pursuit of a goal. Existing behavioral neuroscience analysis converges with our categorization of the three independent variables of needs, external reward, and belief. Those three factors influence motivation of an organism's internal physiological states, the current environmental conditions, as well as the organism's history and experiences. Shown in Figure 3 adapted from Simpson and Balsam (2015), where the three factors enter into a cost/benefit calculation to compute motivation. While the cost/benefit analogy is shared by many (Bong, 2023), others suggest that the winning goals depend greatly on the strength of the mental representation influenced by internal and external stimuli. While Simpson and Balsam (2015) admit the limitation of our current understanding of the cost-benefit computation, having clarity of the input components driving motivation - even if the decision is made in a black box - can still help to impact its outcomes. A similar metaphor as the cost-benefit computation to understand the mind is the hedonic sharpener (Knutson & Srirangarajan, 2019) which is not precise but tries quickly to optimize pleasant feelings. However, we understand the complexity of the concept of motivation as it involves the processes of learning, perception, and physiological states. In summary, a simplified view of the motivational influences of any action can be represented by a prediction computation of cost and benefit coming from our internal physiology, the feedback of our environment via

our sensors, and our beliefs. It is now time to see the underlying processes uncovered so far by neurobiology that influence those three inputs.

MOTIVATIONAL NEUROLOGICAL PATHWAYS

From Drive Theory to Incentive Salience Theory

Early theories in motivation started with the assumption that we were mostly driven to reduce our unpleasant physiological drives (such as hunger and thirst). Drinking water eliminated our unpleasant thirst drive. However, numerous analyses of the brain motivation circuitry (Berridge, 2018) shows that we are more incentive-driven than drive reduction-driven, even though the drive reduction seems intuitively appealing.

Our brain does not try to reinforce the motivation for us to seek or avoid a state, i.e. fulfill a lack of water, but our circuitry seems to be built to motivate the action of getting water. In other words, we are rewarding progress, not satiation. Many experiments have shown (Berridge, 2018) that thirst or hunger will enhance the incentive to act, but only if there is a way to act.

The theory that seems to better reflect the internal functioning of our brains is called the incentive salience theory of motivation. The incentive motivation is often divided into three types of mechanisms: wanting, liking, and learning (Berridge, 2018). Liking is anatomically located in scattered hedonic hotspots, going from the cortex to the brainstem. Wanting is associated with dopamine processes and is located in the Ventral Tegmental Area and the striatum. The relative robustness of the wanting circuitry compared to the liking circuitry seems to be an explanation for why

high levels of dopamine give us a feeling of energy, engagement, and focus and reinforce the motivation to exert effort (Salamone, 2018), not just to enjoy pleasure. This sense of productivity or progress towards a worthwhile goal is what the mesolimbic dopamine pathway reinforces. Modern neuroscientists are increasingly confident that the main processes for motivated actions are not reinforced by drives but by learned wanting. This leads us to a critical distinction between wanting and liking.

Wanting vs. Liking

In our day-to-day life, we often equate wanting and liking. We assume that we would only want and be motivated to seek what we like. Research has shown that the wanting can vary dramatically while the liking may not have changed much (Berridge, 2016). Many experiments have confirmed that what drives motivation, or the fact of making an action towards a goal, is not the lack of liking, but the lack of wanting it. The question could be asked about the real role of the liking process if what matters for survival and reproduction is wanting. One of the most recognized figures in this field, Kent Berridge (2016), made the conjecture that liking could be there only for the original learning and some reinforcement. Our next question is to better understand motivation and what we came to understand as the core process: wanting.

Incentive salience vs. wanting

What we understand so far is that to understand motivation, wanting is the core of the focus as it is the source of the action. Wanting can have two forms; cognitive wanting is based on cognitive expectations and is goal-oriented, while incentive salience is often written as 'wanting', is a mesolimbic dopamine-related system, and is cue-triggered to obtain a reward

(Berridge, 2018). Typically wanting (cognitive expectation) and ‘wanting’ (incentive salience) are aligned and the ‘wanting’ linked to the dopamine system facilitates action.

‘Wanting’ will look for triggers in the world, they can be physical stimuli or in the imagination. For instance, if someone sees a bottle of cold water, it triggers them to go towards drinking it. Or imagine serving a glass of sparkling water. Both can act as triggers to want water. Even though our brain can learn new triggers, over time with repeated activation of a specific trigger, we can narrow our want to the extreme, and that can lead to addiction. We have seen in this section, that incentive salience or ‘wanting’ is a process linked to the dopamine system and triggering actions linked to cues. Those cues can be physical or imaginary.

Physiological influence on our ‘wants’

The concept of Alliesthesia is the experience that we will enjoy a glass of water more if we are thirsty, food if we are hungry, and so on. The ‘wanting’ can adjust automatically with physiological needs changes. An experiment that models this exposing a rat to high salinity water. The rat initially shows dislike for this salty water, but when induced in a low sodium state it will spontaneously go towards the salty water lever without any new training or learning.

This begs the question of how a learned– dislike can be transformed without new learning to a desire for a particular cue or substance. This is where the incentive salience or ‘wanting’ of the mesolimbic process can complement the cortical cognitive system. We can see that physiology influences our wants. New research (Dohnalová, 2022) on mice also shows that the microbiome can influence the dopamine level in reaction to exercise, hence

promoting athletic activities and performance. If those translate to humans, that would be another level of influence and a mind-body connection. In short, physiology can help trigger the ‘wanting’ but does not seem to reinforce the motivation, while, for instance, the microbiome can influence dopamine levels.

Learning and rewards

Some experiments have shown an increase or a decrease of dopamine based on expectations being fulfilled or not, which is referred to as the reward prediction error. This is because the mesolimbic dopamine pathway is involved in the anticipation of reward, rather than the experience of reward itself. When we are working towards a goal, the mesolimbic dopamine pathway is activated as we anticipate the reward that we will receive when we achieve the goal. However, the reward prediction error theory seems to be in some conflict with the incentive salience theory, which also claims a critical role for dopamine. However, experiments that distinguish between rapid changes in dopamine (phasic) versus slower changes in base level (tonic) reconcile the dopamine role in both learning and motivation (Wang, 2021). Beliefs influence greatly as well and modify the dopamine level, but mostly linked to learning when there is a quick change in dopamine levels.

Cognitive control and motivation

It is well accepted that self-discipline can exert some control over our motivation. Those processes are typically linked to conscious cognitive control. For cognitive control, many regions of the prefrontal cortex are active (Kim, 2016). The amygdala is responsible for the evaluation and the signal back to the dopamine neurons, but the amygdala also receives signals from the prefrontal cortex.

Hence, we see that motivation happens to someone due to external influences, but also from internal prefrontal cortex influx. It is reasonable to expect that the prefrontal cortex influences what we perceive as our rational choices.

However, there are several observed influences in the decision-making process that are worth noting and linking backward from the rational to the dopamine process. (1) The dopamine hypothesis; the presence of a mild positive feeling will influence the cognitive process. The positive feeling increases dopamine, which in turn facilitates cognition. However, this only works as long as there is not an awareness of the positive influence. (2) Priming; the exposure to a stimulus outside the conscious awareness. A known example is the fact that it has been shown that the odor of cleaning products motivates cleaning actions. (3) The somatic marker hypothesis; the consolidation of how someone feels (interoception) with the actual task and social context.

In comparison, dopamine influences of the mesolimbic system on the prefrontal cortex exist and are typically called bottom-up influences. Other more top-down influences on cues are the cortical circuits acting as inhibitors and creating even more variations in those processes. We have seen here that the prefrontal cortex is also deeply involved in motivation.

Individual variation in motivational cues

One of the consequences of looking at the incentive salience theory as a foundation of motivational theory is the importance of cues. Cues, seen in the Pavlovian learning approach as conditional stimuli, can generate a conditional response, for example salivating in the well-known Pavlov experiment. However,

conditional stimuli can become an incentive stimulus when connected to emotional and motivational states. We have seen that incentive stimuli are at the base of 'wanting' and the source of motivation. However, research has shown (Flagel & Robinson, 2017) considerable individual variation in how conditional stimuli act as an incentive stimulus. In other words, the cues that motivate someone for an action can be very different from what motivates someone else for the same action.

Consequently, we looped back to our original question of looking for neurobiological foundations for psychological theories. We are meant to believe that to have effective psychological theories for interventions, we will need to take into account the individual variation. The connection of incentive salience theory, or 'wanting,' introduces a level of individual variability. This shows the limit of the reliance on physiological processes to offer a foundation for psychological categories.

CONCLUSION

Finding a connection between motivational psychological theories and neurological and biological processes is very complex. There is still a lot of research being done to see if there could be a connection. Our findings highlighted that motivation processes rely on mesolimbic dopamine-dependent actions. Those actions are not reinforced by drive or liking but by cues triggered by 'wanting'. While physiological needs can act as a trigger for action, relying only on them to create psychological motivation theories is not enough. The individuality of the cues created, and the influence of the cognitive control regions of the brain make us believe that any complete psychological motivational explanation cannot be restricted to simple categories. Further research will have to be done

to continue to confirm the incentive salience theory as the best way to depict the internal processes of our motivated actions.

ANNEX

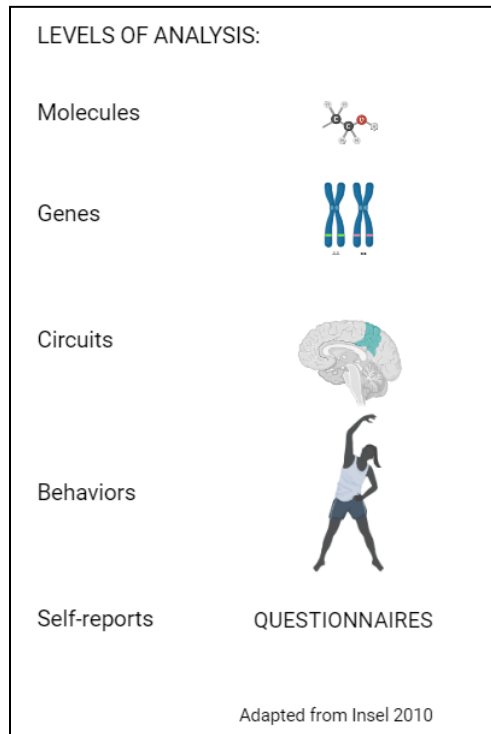


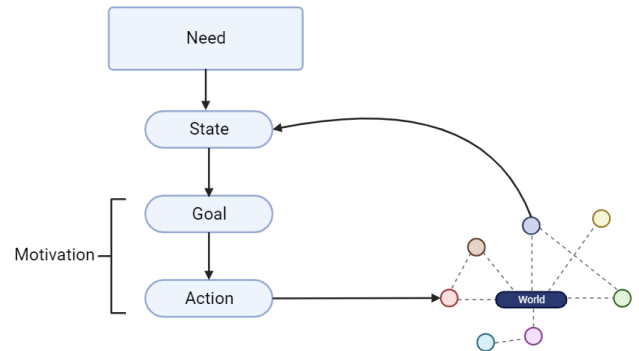
Figure 1. Level of analysis.

Psychological motivational theories have been historically based on questionnaires or behavior observations. The purpose of this figure is to show the likely foundation of all behaviors in brain circuits, molecular interactions, and genes foundation. The purpose of this paper is to inquire about a possible better foundation for psychological theories based on neurobiological processes mainly at the circuit level. (Adapted from Insel et al., 2010).

Figure 2. Motivation definition.

Motivation is always created because of a desired goal. Neuroscientists try to understand

the neural processes stimulating the selection and the action toward that goal.



The goals come from needs. Those can be physiological needs (thirst and hunger) or psychological needs (relatedness, competence, and predictability). As those needs ask to be fulfilled, they trigger a state that motivates a goal definition as a way to reach the state. The mental processes that combine goal selection and triggered action is what we call motivation.

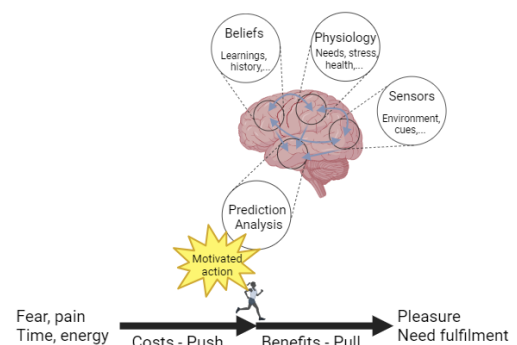


Figure 3. Behavioral neuroscience cost/benefit analysis as the source of motivated action.

Behavioral neuroscience analysis categorizes three independent variables that enter a cost-benefit analysis. The three factors influencing motivation are the organism's internal physiological states, the current environmental conditions, as well as the

organism's history and experiences. The three factors enter into a cost/benefit calculation to compute the motivation. The winning goals depend greatly on the strength of the mental representation influenced by internal and external stimuli.

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