Psychological Topics, 26 (2017), 1, 25-45

Original Scientific Paper – UDC – 159.947.5

Moving Forward with the BAS: Towards a Neurobiology of Multidimensional Model of Approach Motivation

Dino Krupić

Department of Psychology, Faculty of Philosophy,
University of J.J. Strossmayer in Osijek, Croatia

Philip J. Corr

Department of Psychology, City University London, United Kingdom

Abstract

One of the hottest topics in neuroscience is the study of brain-behavioural circuits underlying the processing of reward-related stimuli. A growing body of studies has shed new light on the neural structure of this reward system. In this paper, we discuss the significance of these studies from the perspective of a neuropsychological theory of personality, namely the Reinforcement Sensitivity Theory (RST). RST assumes that variation in sensitivity/reactivity of the reward system is the cause of individual differences in approach motivation (e.g. desire or need for achievement, persistence, and positive emotionality). Within RST, these individual differences are contained in the construct of the Behavioural Approach System (BAS). However, there is an ongoing debate as regards the nature of the BAS. This fact motivated us to review the latest refinements in the neuroscience of the BAS in the context of the reward system. In this review, we identity four distinctive aspects of the BAS: *wanting*, *incentive motivation*, *striving* and *liking*. Their behavioural effects are compared with the behavioural manifestations of testosterone, dopamine, serotonin and endogenous opioids, respectively. We conclude that the unidimensional view of the BAS is overly oversimplified; and we suggest that it should be studied as a multidimensional construct and, by implication, so too should the reward system.

Keywords: reward system, wanting, incentive motivation, striving, liking

Moving Forward with the BAS: Towards a Neurobiology of Multidimensional Model of Approach Motivation

In psychology, the same constructs are frequently studied under different labels. In this paper, we contend that this is especially the case with the Behavioural

✉ Dino Krupić, Department of Psychology, Faculty of Philosophy, University of J.J. Strossmayer in Osijek, L. Jaegera 9, 31000 Osijek, Croatia. E-mail: *dkrupic@ffos.hr*

Approach System (BAS) and, the more general, reward system. On the one hand, the reinforcement sensitivity theory (RST) of personality focuses on the importance of individual differences of the BAS in the prediction of approach behaviour, emotion and cognition. On the other hand, the reward system is frequently studied within a neuroscience framework that aims to find the neural and biological correlates of approach motivation. Even though the BAS and the reward system are studied by different methods and scientific agendas, they may be seen to be highly complementary. After more than two decades of study of the BAS and the reward system, largely in isolation from each another, we argue that the time has come to attempt to unite these fields. To this end, we review the relevant literature; specifically, we have two main aims. First, to introduce the terminology that would ease the theoretical integration of the BAS and the reward system. Secondly, to provide directions for the further study of the neurobiology of the BAS, which we anticipate should also open up new research topics in the study of the reward system.

The BAS (in terms of brain activity) and the reward system represent endophenotypes of personality. This is evident in Penke, Denissen, and Miller's (2007) evolutionary framework for the study of personality psychology which recognises four distinct levels. First, the genetic level explains the role of alleles that are responsible for psychological mechanisms on the second endophenotypic level (e.g. reward system). These mechanisms underlie personality traits on the third, dispositional, level (e.g. the scores on the BAS scale). The adaptiveness of these dispositions (i.e. personality traits) are studied on the fourth, adaptive, level (e.g. resource acquisition strategy, reproductive effort). This adaptiveness of dispositions highly depends on environmental conditions (i.e. the particular personality trait can have different level of adaptiveness in different environmental circumstances). Out of these four layers, the dispositional level is the most frequently studied in psychology. In a typical personality study, traits are correlated with other personality traits or social, emotional and behavioural criteria. These data tell us a lot about the importance of personality traits, but do not tell us much about the traits themselves. The reward system and BAS correspond to the second (endophenotypic) and third (dispositional level), respectively. The scores on the BAS scales (dispositional level) represent the manifestation of the brain activity (endophenotypic level). Although the boundaries between these levels is fuzzy, as long as the BAS is measured by self-report instruments, it should continue to be studied at the third, dispositional, level.

Our review is organized into three sections. First, we introduce the reward system and the BAS. Then, we review the literature supporting the idea that existing BAS measures reflect individual differences in activity of the reward system. Third, we review each of the BAS processes within a biobehavioural perspective. In conclusion, we summarize the characteristics of each BAS process in order to arrive at an agenda for the future study of, what we claim to be, a multidimensional BAS and, by extension, a multidimensional reward system.

The Reward System

Berridge and Robinson (2003) introduced three components of reward system: *learning*, *liking*, and *wanting*. Since the learning component is out of the scope of this paper, we focus only on the wanting and liking components. Wanting represents the motivation to achieve goals, whereas liking reflects affective or emotional aspect of the reward system. Put simply, wanting is necessary for attaining a reward, while liking reflects the reaction on receiving the desired reward. In this literature, wanting is dominantly related to dopaminergic functioning, whereas liking is more related to the opioidergic system.

The evolutionary relevance of the reward system resides in enhancing chances for survival and reproduction. This system directs behaviours toward evolutionarily important resources, such as food, social status, and mates. Enjoying or consuming these resources are followed by the subjective experience of pleasure; and, in the longer term, this system is essential for a normal sense of wellbeing (Berridge & Kringelbach, 2013). The importance of the reward system in normal functioning is the most obviously reflected in consequences of its impairment. Reward Deficiency Syndrome (RDS) refers to an insufficiency of usual feelings of satisfaction, which is a consequence of a low level of dopaminergic and opioidergic neurotransmission (Blum, Cull, Braverman, & Comings, 1996; Blum et al., 2000). For instance, the RDS has been found to relate to severe problems in normal functioning, such as drug abuse and overeating (Blum, Gardner, Oscar-Berman, & Gold, 2012), anhedonia (Wise, 2008), depression (Naranjo, Tremblay, & Busto, 2001), and schizophrenia (Heinz, Schmidt, & Reischies, 1994).

The BAS

The BAS is an underlying neuropsychological mechanism that reflects the cause of individual differences in approach-related personality traits, such as extraversion and impulsivity (Gray & McNaughton, 2003). Its primary function is to move the animal up the temporo-spatial gradient, from a start state (e.g. the idea of, or the physical distance to a source of food), towards the final biological reinforcer (e.g. consumption of food) (Corr, 2013; Corr & Krupić, 2017). Deficits in the BAS are related to bipolar disorder (e.g. Alloy et al., 2012), mania (Carver & Johnson, 2009), drug abuse (Hundt, Kimbrel, Mitchell, & Nelson-Gray, 2008), and other problems similar to the dysfunctions of the RDS (see above).

The author of the original version of the theory, Jeffrey Gray, postulated that the BAS acts as a unified system (Gray, 1982). After the revision of the theory (Gray & McNaughton, 2003), Corr (2008) developed a framework to study the BAS as a multidimensional construct. He argued that moving along the temporo-spatial gradient to the final biological reinforcer demands some form of "subgoal scaffolding", which entail the following processes: (a) identification of the biological

reinforcer; (b) planning behaviour; and (c) execution of the plan. This approach behaviour entails a series of subprocesses, some of which oppose each other (Corr, 2013; Corr & Cooper, 2016; Corr & Krupić, 2017). In spite of a growing body of evidence favouring this multidimensional conceptualisation, researchers worldwide have tended to overlook the importance of this differentiation of BAS processes. As we argue later, these subprocesses are most likely related to different neurotransmitter systems. As such, ignoring the differences between the BAS processes represent an oversimplification of the construct, which may account for the inconsistencies found in the RST literature.

The BAS – Individual Differences in Reward System Activity

The neuroscientific study of the reward system is based on controlled laboratory settings. Specifically, the aim is to depict the brain-behavioural mechanisms responsible for the psychological functioning of the reward system. However, the use of neuroscientific methodology in real life contexts has practical limitations and, thus, possesses limited external validity. For instance, neuroimaging tools are not suitable for studies on larger samples that are a requirement for correlational studies. In addition, in order to measure (e.g. EEG brain activity) in a real life situation, a non-invasive mobile instrument would be required that did not interfere with participants' behaviour. Therefore, in comparison to neuroimaging, personality questionnaires are much more appropriate instruments for studies examining the relevance of the reward system in everyday situations. But, currently, there are no self-report measures of individual differences in the reward system. Here, we suggest that BAS scales may be sufficient to fill this gap.

However, theoretical integration of the BAS with the reward system is not straightforward. We argue, this is especially the case because both the BAS and reward system are multidimensional constructs, which renders a mapping of one to the other much more complex than one based on a unidimensional notion.

Distinguishing the BAS Scales

Besides theoretical considerations, there are measurement issues that need to be carefully considered. Currently, there are several viable operationalisations of the BAS (for a detailed discussion see Corr, 2016; Krupić, Corr, Ručević, Križanić, & Gračanin, 2016; Walker & Jackson, 2017). For the purpose of this paper, we review the group of the most recently published and the most widely used BAS measures. To ease understanding of these BAS scales, in Table 1 we provide representative items for each scale.

Table 1. *Item Example for the BAS Scales*

Questionnaire	Item example
The BIS/BAS Scales (Carver & White, 1994)	
Drive	*When I want something, I usually go all-out to get it.*
Fun Seeking	*I crave excitement and new sensations.*
Reward Responsiveness	*When I get something I want, I feel excited and energized.*
Sensitivity to Punishment Sensitivity to Reward (SPSRQ; Torrubia et al., 2001)	
Sensitivity to Reward	*Do you often do things to be praised?*
Jackson 5 (J5) (Jackson, 2009)	
BAS	*I like to do things which are new and different.*
Reinforcement Sensitivity Questionnaire (RSQ; Smederevac et al., 2014)	
BAS	*I readily accept new and exciting situations.*
Reuter-Montag's Revised Reinforcement Sensitivity Theory Questionnaire (rRST-Q; Reuter et al., 2015)	
BAS	*Most of the time I have a thirst for action.*
Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ; Corr & Cooper, 2016)	
Reward Interest	*I regularly try new activities just to see if I enjoy them.*
Goal Drive Persistence	*I will actively put plans in place to accomplish goals in my life.*
Reward Reactivity	*I get a special thrill when I am praised for something I've done well.*
Impulsivity	*If I see something I want, I act straight away.*

Generally, there were two broad approaches to defining the BAS. The first group of questionnaires contain a unidimensional perspective. Sensitivity to Reward (SR) within the Sensitivity to Punishment Sensitivity to Reward Questionnaire (Torrubia, Ávila, Moltó, & Caseras, 2001) assumes impulsivity to represent the BAS personality trait. It is conceptualised upon original RST, with impulsivity correlating positively with both neuroticism and extraversion (Gray, 1982). This questionnaire has been widely used in the RST literature. In the original version, it contains 24 dichotomous items, and ten in the short version (Aluja & Blanch, 2011). Several years later, Jackson (2009) introduced the Jackson-5 questionnaire. His BAS scale contains six items, answered on five-point Likert scale. It was designed upon revised RST and conceptualized more similarly to extraversion. Still another instrument, the Reinforcement Sensitivity Questionnaire (RSQ), operationalised the BAS as sensitivity to signals of reward (closely related to impulsivity), and openness to new and exciting situations (Smederevac, Mitrović, Čolović, & Nikolašević, 2014). Finally, Reuter, Cooper, Smillie, Markett, & Montag's (2015) BAS scale contains item measuring approach and goal-directed behaviour, with high scorers described as bold, adventurous, showing higher energy and drive when approaching appetitive stimuli.

The second group of BAS scales conform to a multidimensional view of the BAS. They comprise the BIS/BAS Scales (Carver & White, 1994) and Reinforcement Sensitivity Theory – Personality Questionnaire (RST-PQ, Corr & Cooper, 2016). The BIS/BAS Scales contain three BAS related subscales: Drive, Fun Seeking and Reward Responsiveness. The Drive contains items reflecting persistence in pursuit of the desired goal; Fun Seeking reflects a desire for new rewards and willingness to approach them at the spur of the moment; and Reward Responsiveness focuses on positive reactions on the occurrence of the reward (Carver & White, 1994). Drive and Reward Responsiveness correlate more with extraversion, whereas the Fun Seeking correlates more strongly with impulsivity than extraversion (Smillie, Jackson, & Dalgleish, 2006). The latest published RST questionnaire, the RST-PQ (Corr & Cooper, 2016), separates the BAS into four interrelated processes. Reward Interest represent the first stage of approach motivation: it reflects the search for new rewards. Goal-Drive Persistence measures persistence in achieving desired goals. Reward Reactivity measures emotional reactivity to reward. Impulsivity reflects fast reactions at the final stage of capturing the reinforcer.

Setting the Terminology for Theoretical Integration

As stated at the beginning of this paper, often the same constructs are studied under different labels. In order to integrate neuroscientific findings of the reward system with the neuropsychological study of the BAS, in this section, we offer a new terminology, which fosters theoretical integration.

The above-mentioned operational definitions of the BAS scales indicate conceptual differences among them. However, the majority of RST research studies continue to treat these scales as if they measured the same underlying construct. In order to systemize the state of art in the RST literature, Krupić, Corr et al. (2016) examined convergent validity of five of the most frequently used RST questionnaires. The results of a confirmatory factor analysis classified the BAS scales from the five questionnaires into four groups: wanting, striving, liking, and capturing – these constructs parallel the BAS factors in the RST-PQ. But, these labels are not used in this article: we introduce new labels in order to conform to the most recent developments in the field of motivation. The labels *wanting and incentive motivation* will be used instead to represent capturing and wanting from the Krupić, Corr et al. (2016), respectively. On the other hand, the labels *striving* and *liking* remain the same as in Krupić, Corr et al. (2016) (see Table 2 for clarification). In order to avoid confusion in the following text, since we discuss the same-name constructs from different models that do not have the same operational definition, we denote Berridge & Robinson's (2003) labels as 'wanting' and 'liking', whereas the new terminology introduced in this paper has them written in italics; *wanting, incentive motivation, striving* and *liking*.

Table 2. *Summary of the BAS Processes and Terminology Clarification*

BAS process	**Scales**	**Description**	**Dominant neurotransmitter**	**Big five correlates**
Wanting (capturing)	SR, Impulsivity and Fun Seeking*	Desire to possess resources	Testosterone	Extraversion, Agreeableness (-) and Conscientiousness (-)
Incentive motivation (wanting)	BAS-RSQ, BAS-J5 and Reward Interest	Identification and seeking new resources	Dopamine	Openness and Extraversion
Striving (striving)	Drive and Goal/Drive Persistence	Investing effort in goal-achievement	Serotonin	Conscientiousness and Extraversion
Liking (liking)	Reward Responsiveness and Reward Reactivity	Reactions to receiving a reward	Endogenous opiates	Extraversion and Agreeableness

**Note:* To ease comprehension of the relabelling of descriptive terms of BAS processes, former labels from Krupić, Corr et al. (2016) are placed in brackets. In addition, Berridge and Robinson's (2003) labels 'wanting' and 'liking' corresponds to the definition of *incentive motivation* and *liking*, respectively;
*Fun Seeking only partially represents of the *wanting* BAS process due to its too narrow content.

The purpose of these new labels is to provide a fine distinction of these intertwined processes. 'Wanting' and 'liking' are the most recognised components of the reward system, while *striving and incentive motivation* are less studied. In addition, neuroscience studies do not have a clear terminology for separating 'wanting' and 'incentive motivation' (e.g. Berridge & Robinson, 2003, 2016), whereas we here want to emphasize their differences: having wishes (*wanting*) and taking action to attain those wishes (*incentive motivation*). In a recent paper calling for the general theory of motivation, Baumeister (2015) emphasized the importance of differentiation between *wanting* and doing (i.e. *incentive motivation*): *Wanting* without doing is no more than a wishful thinking - without subsequent processes, it is not sufficient to achieve the desired resource. In order to attain the resource, one must take necessary actions. Thus, *wanting* and *incentive motivation* needs to be terminologically distinguished, since they obviously represent different processes within reward system.

Neurotransmitters and Reward Processes

In this section, we review the similarities in the workings of basic neurobiological systems and the BAS scales. Namely, dopamine is not the only neurotransmitter related to the workings of reward system. Recent studies have shown the importance also of testosterone, serotonin, and opioids neurotransmitters

in reward processing. As discussed below, the behavioural manifestation of these four transmitters highly correspond to the four descriptive labels of the BAS scales, *wanting, incentive motivation, striving* and *liking*, respectively.

Wanting and Testosterone

Wanting can be described as the agentic part of extraversion (Morrone-Strupinsky & Depue, 2004). Individuals high on *wanting* are highly ambitious and desire more resources. The BAS scales representing *wanting* are the SR and RST-PQ Impulsivity, and partly Fun Seeking. These scales correlate positively with extraversion, and negatively with conscientiousness, whereas the SR and Fun Seeking additionally correlate negatively with agreeableness (Corr & Cooper, 2016; Mitchell et al., 2007; Segarra, Poy, López, & Moltó, 2014). Contrary to Krupić, Corr et al. (2016), where Fun Seeking did not fit into this category, some studies show that it represents a form of impulsivity (e.g. Smillie et al., 2006). Items in Fun Seeking reflect the readiness and willingness to obtain or consume reward resources, just as the SR and Impulsivity-RST-PQ. The problem with Fun Seeking is that it focuses on seeking for entertainment, while the other two scales capture a broader description of impulsivity. Hence, because of its narrow content validity, Fun Seeking may be assumed to be only partly a representative of this group of the BAS scales.

The available literature suggests testosterone is a key neurotransmitter of *wanting*. Here, we present three key findings that suggest the direct relationship between testosterone and *wanting*: neurobiological studies of the SR; dominance and status seeking; and antisocial tendencies interpreted as an aspect of fast lifestyle within life history theory (LHT).

Testosterone and the SR

Currently, only two studies serve as evidence of the direct relationship of *wanting* and testosterone. They both used only the SR in the studies - it has been much more used than the recently published RST-PQ Impulsivity. Lombardo et al. (2012) showed that increased level of testosterone is followed by the increase of behavioural approach tendencies (measured by SR) on positive valenced cues by biasing caudate, putamen, and nucleus accumbens. Similarly, Yildirim and Derksen (2012) reported that high fetal/circulating testosterone plays an important role in maturation and functionality of mesolimbic dopaminergic circuitry and right orbitofrontal cortex that are important areas of reward system. In addition, they related testosterone to low social sensitivity, and dampened regulation of strong motivational/emotional processes. On contrary, studies examining the relation between testosterone and the BAS scales using the BIS/BAS Scales did not find any relationship (e.g. Hermans et al., 2010), which might be due to the problem of too narrow content of the Fun Seeking scale. This clearly demonstrates the importance of using all the four types of the BAS scales in RST studies.

Domination and Social Status

Ambitiousness, and therefore the desire for dominance or social status, is an important characteristic of individuals high on *wanting*. We base the *wanting*-testosterone connection on studies examining the relationships of constructs from the endophenotypic (testosterone) and dispositional levels (*wanting*) with the constructs at the adaptive level. First, testosterone has been related to desire to attain higher social status (e.g. Mazur & Booth, 1998), signalising dominance (e.g. Swaddle & Reierson, 2002) and short-term mating strategies (Slatcher, Mehta, & Josephs, 2011). In addition, testosterone is highly sensitive to situational cues. Testosterone levels in men rise when they win, and fall when they lose (e.g. Schultheiss et al., 2005; Stanton, Beehner, Saini, Kuhn, & LaBar, 2009). Some researchers argue that the role of testosterone in status achieving (Mehta & Josephs, 2010) and social aggression (Montoya, Terburg, Bos, & van Honk, 2012; Terburg, Morgan, & van Honk, 2009) is high only when high testosterone is accompanied with low levels serotonin and cortisol. This implies an interplay of neurotransmitters on the endophenotypic level of personality, and that the role of the testosterone should not be studied isolated from the other neurotransmitters.

The role of *wanting* in social status relies on MacDonald (1995) and Depue & Collins (1999), both of whom studied the biobehavioural nature of extraversion. They recognised two important subsystems under the umbrella term of approach motivation. One reflects the agentic or resource-oriented system, while the other represents the system of affiliation or nurturance. In a recent study (Krupić, Gračanin, & Corr, 2016), RST questionnaires were found to be correlated with competitive (agentic) and cooperative (affiliative) resource strategies. The group of motives such as a desire to achieve high social status, displaying wealth, to impress the others, etc. were operationalised as competitive tendencies. Only BAS scales representing *wanting* correlated with the competitive, whereas the rest of the BAS-types of scales correlated with cooperative tendencies.

Fast Lifestyle

The LHT is a midlevel theory providing an account of the evolutionary basis of individual differences. It represents an evolutionary-economic framework to study the optimal allocation of bioenergetic and material resources (for more details, see Sherman, Figueredo, & Funder, 2013). Individual differences within the LHT are described by a continuum from slow to fast lifestyle. The "fast" individuals are more exploitative/antisocial, bold, active, aggressive, less sociable, impulsive, prone to risk-taking, and dominant (Del Giudice, 2014; Réale et al., 2010; Sih & Del Giudice, 2012; Wolf, van Doorn, Leimar, & Weissing, 2007); whereas, in contrast, "slow" individuals are more agreeable, conscientious, and honest (Manson, 2015). "Fast" individuals favour the use of resource acquisition strategies with immediate benefits, while "slow" individuals are more likely to employ long-term strategies. For instance, fast individuals would rather compete with or trick others in some business

opportunity, while "slow" individuals would try to cooperate in order to establish stable relationships with others. Thus, fast individuals prefer quick payoffs, while slow individuals prefer a long-term exchange of resources based on reciprocity with others.

One of the rare studies that used both testosterone and the BAS scales representing *wanting* revealed that both are related to a number of a fast lifestyle correlates: low social sensitivity (Yildirim & Derksen, 2012), mistrust, low social bonding and social aggression (Bos, Terburg, & van Honk, 2010; Terburg et al., 2009). On the other hand, *wanting* has been found to correlate with fast lifestyle (Krupić, Banai, & Corr, 2017) and negatively with cooperative motives (e.g. kin altruism, mutual exchange, etc.) (Krupić, Gračanin et al., 2016). Hence, evidence suggest that *wanting* and testosterone share many phenotypic features: the desire to achieve social status/domination; implementation of fast lifestyle strategy of increasing fitness associated with low social sensibility (i.e. care for other people).

Incentive Motivation and Dopamine

The second group of BAS scales, labelled *incentive motivation*, consists of the BAS scale from Jackson-5 questionnaire (BAS-J5) and RSQ (BAS-RSQ) and Reward Interest from RST-PQ. The common feature of these scales are items reflecting a desire and seeking for new rewards. Their operational definition highly corresponds to Berridge's (2009) 'wanting' (see above for the terminology clarification), which is dominantly related to the workings of dopamine (Berridge & Robinson, 1998). These three BAS scales represent the incentive motivation that promotes approach toward rewards (i.e. taking actions or proactivity). They entail: (a) openness to experience as a tendency toward cognitive exploration (i.e. the tendency to seek, detect, appreciate, understand, and utilize both sensory and abstract information; DeYoung, Grazioplene, & Peterson, 2012); and (b) extraversion as a motivational force to approach these new potential rewards. Both Reward Interest and BAS-J5 correlate positively with openness and extraversion (Corr & Cooper, 2016; Jackson, 2009; Walker & Jackson, 2014), whereas Reward Interest in addition correlates with the tendency of exploring the environment (Krupić, Gračanin et al., 2016).

Reward Interest may reflect individual differences in activity of dopaminergic circuits. There is no direct evidence of a relationship between *incentive motivation* and dopamine. There are two reasons for this. First, the BAS scales representing *incentive motivation* are not represented in the most used RST questionnaires – the BIS/BAS Scales and SPSRQ (see Krupić, Corr et al., 2016). On the other hand, more recently published questionnaires that attempt to account for the *incentive motivation* (Jackson-5, RSQ and RST-PQ) have not yet been used in the study of dopamine-personality relationships. However, a number of studies have established the role of dopamine underlying incentive motivation (or 'wanting') part of the reward circuit

(e.g. Berridge, 2007), explorative behaviour and novelty seeking (e.g. Braver & Barch, 2002; DeYoung, 2013; Dulawa, Grandy, Low, Paulus, & Geyer, 1999; Zald et al., 2008), which corresponds to the definition of *incentive motivation*. In addition, novelty seeking correlates with dopamine, whereas the other BAS subscales from the BIS/BAS scales do not (Stuettgen, Hennig, Reuter, & Netter, 2005). Hence, it is most likely that *incentive motivation* (measured by the BAS scales with RSQ, Jackson-5 and Reward Interest) are associated with the individual differences in activity of dopaminergic brain circuits that are found to play important role in the incentive motivation (e.g. Knutson, Westdorp, Kaiser, & Hommer, 2000).

Striving and Serotonin

The third group of BAS scales, labelled *striving*, encompasses Drive from the BIS/BAS Scales and Goal-Drive Persistence from RST-PQ (Krupić, Corr et al., 2016). These two scales contain items reflecting persistence in, and willingness to achieve, desired goals. Both scales correlate with conscientiousness and extraversion, but Goal-Drive Persistence in addition correlates with agreeableness (Corr & Cooper, 2016), while Drive with openness (Križanić, Greblo, & Knezović, 2015).

Although dopamine and opioids are the most acknowledged reward-related neurotransmitters (e.g. Berridge, 1996), in the last decade there is a growing body of evidence of the importance of serotonin in reward processing (e.g. Kranz, Kasper, & Lanzenberger, 2010). Delay gratification, that has a key role in achieving long-term goals, enables an individual to resist temptation that would otherwise attract his attention away from the desired goal and it helps to overcome motivation drawbacks during attaining the goal (Schweighofer, Tanaka, & Doya, 2007; Tanaka et al., 2007).

A recently published study (Johnson, Carver, Joormann, & Cuccaro, 2016) showed that *striving* (measured by the Drive scale) relates to the workings of the serotonergic system. Moreover, Pearson, McGeary, and Beevers (2014) found that the interaction of genetic variations in the serotonergic system and childhood adversity contributes to individual differences in reward sensitivity, especially in Drive. In addition, Cloninger's Self-Directedness scale - ability to adapt and control one's behaviour to fit situations in accord with chosen goals (similar to the operational definition of *striving*) - is related to serotonin transporter density (Tuominen et al., 2013). This may explain similarities in behavioural correlates of serotonin and *striving*. Namely, similarly to the Drive (Corvi, Juergensen, Weaver, & Demaree, 2012), serotonin plays an important function in waiting behaviour in prospect of forthcoming rewards (Miyazaki, Miyazaki, & Doya, 2011; Miyazaki et al., 2014; Welberg, 2012), delay discounting (Schweighofer et al., 2008), self-control (Carver, Johnson, & Joormann, 2014; Ranade, Pi, & Kepecs, 2014), and cognitive flexibility (Coppens et al., 2010), while in rats, serotonin participates in control of impulsive behaviour (Bizot, Le Bihan, Puech, Hamon, & Thiébot, 1999). The above-

mentioned processes are the prerequisite for establishing cooperation (Crockett et al., 2013) which explains prosocial tendencies in individuals high on *striving* (measured by Goal-Drive Persistence) (Krupić, Gračanin et al., 2016).

Liking and Opioid

The well-explored 'liking' part of the reward system or "pleasure system" refers to a brain-behavioural mechanism for creating subjective hedonistic reaction to stimuli in the environment (Berridge & Kringelbach, 2013), and this is primarily related to endogenous opiates (Davis et al., 2009). Scales that represent the self-report measures of the *liking* system (i.e. reflect individual differences in the emotional impact of a reward) are Reward Responsiveness and Reward Reactivity from the BIS/BAS Scales and RST-PQ, respectively (Krupić, Corr et al., 2016). The main characteristic of these scales is positive emotionality, which could be interpreted as a lower threshold of rewarding value to elicit psychological reaction. In Corr's (2013) sub-scaffolding framework, it represents the final stage of approach motivation, since it occurs after the reinforcer has been captured/attained. This part of the reward system has the importance in maintaining motivation for the reinforcer in the future actions.

The relationship between Berridge's 'liking' and the RST's *liking* is the most straightforward, since the both are associated with working of opioidergic system. Wanigasekera et al. (2012) reported the direct relationship between Reward Responsiveness and opioid system, while the other provide only partial support (Karjalainen et al., 2016). Recent study of Johnson et al. (2016) has shown that the interaction of opioid system and early adversity may determine the level of Reward Responsiveness. This is reasonable to assume, since the opioid system has strong impact on social emotions and behaviour (Machin & Dunbar, 2011; Panksepp, Herman, Vilberg, Bishop, & DeEskinazi, 1980; Vanderschuren, Niesink, & Van Ree, 1997), infant attachment behaviour (Kalin, Shelton, & Lynn, 1995; Moles, Kieffer, & D'Amato, 2004), and relationship with kin (D'amato & Pavone, 1993). These findings are well in line with the study relating self-report measures of *liking* and cooperative motives (Krupić, Gračanin et al., 2016) and quality relationship with others as an aspect of slow lifestyle (Krupić et al., 2017). In addition, Elvemo, Landrø, Borchgrevink, & Haberg (2015) recently found that the *liking* (measured by Reward responsiveness) is reduced in chronic pain patients, which they interpret as a manifestation of a low level of opioids.

Conclusion

Reviewed evidence from neuroscience, neuropharmacology and neuropsychology, summarized in Table 2, suggest that the reward system should not be studied as a unified construct; and nor should the BAS. Rather, they represent a composite of interrelated processes with distinctive brain-behavioural mechanisms and neurobiological systems. We argue that *wanting* (the SR and Impulsivity) reflects behavioural manifestation of testosterone; *incentive motivation* (BAS-J5, BAS-RSQ and Reward Interest), individual differences in activity of dopamine; *striving* (Goal-Drive Persistence and Drive), serotonin; and *liking* (Reward Responsiveness and Reward Reactivity), opioid neurotransmitter system. These putative associations are supported by (still scarce) evidence relating personality scales to the workings of these neurotransmitter systems.

We represented the relationships between the BAS scales and the dominant neurobiological factors in order to provide a parsimonious model. However, we are aware of the complex interrelationship among the endocrine systems (e.g. Bowirrat & Oscar-Berman, 2005; Katz, 1999; Montoya et al., 2012). For instance, levels of cortisol highly fluctuate after winning and losing in individuals with high, but not in those with low levels of testosterone (Mehta, Jones, & Josephs, 2008). Such interplay with cortisol may explain why high *wanting*, individuals experience high negative affect following negative feedback (e.g. Krupić & Corr, 2014). Nevertheless, at this point, the future agenda of the BAS is to establish the link between the most salient biological markers of the BAS scales. Later, the effects of their mutual interactions may be explored in greater detail.

Lastly, it is important to emphasize that different scientific disciplines study the reward system within different conceptual schemes and using different labels. For example, neuroscientific techniques capture a momentary activation of brain location in a (artificial) laboratory setting. Thus, they provide information on the reward system with limited ecological validity. In contrast, personality psychology, which relies on correlational studies with self-report instruments, provide information on the reward system in terms of fairly stable individual differences (i.e. it provides information on the importance of the reward system in real life context). Often the limitations of one approach represent the strengths of the other. Relating BAS scales with reward-related neurobiology and neural activity of the brain should allow combining the strengths of the different approaches to the study of the reward system.

To sum up, RST provides a promising framework to study individual differences in the reward system. The most important goal in future RST studies should be to relate individual differences in the BAS scales to individual differences in activity of corresponding neurobiology substrates and brain regions. If the results confirm that the BAS scales truly represents the behavioural manifestation of neurobiological agents, this would open novel, and potentially important, lines of research.

References

Alloy, L.B., Bender, R.E., Whitehouse, W.G., Wagner, C.A, Liu, R.T., Grant, D.A., ... Abramson, L.Y. (2012). High Behavioral Approach System (BAS) sensitivity, reward responsiveness, and goal-striving predict first onset of bipolar spectrum disorders: A prospective behavioral high-risk design. *Journal of Abnormal Psychology*, *121*(2), 339-351.

Aluja, A., & Blanch, A. (2011). Neuropsychological Behavioral Inhibition System (BIS) and Behavioral Approach System (BAS) assessment: A shortened Sensitivity to Punishment and Sensitivity to Reward Questionnaire version (SPSRQ–20). *Journal of Personality Assessment*, *93*(6), 628-636.

Baumeister, R.F. (2015). Toward a general theory of motivation: Problems, challenges, opportunities, and the big picture. *Motivation and Emotion*, *40*(1), 1-10.

Berridge, K.C. (1996). Food reward: Brain substrates of wanting and liking. *Neuroscience & Biobehavioral Reviews*, *20*(1), 1-25.

Berridge, K.C. (2007). The debate over dopamine's role in reward: The case for incentive salience. *Psychopharmacology*, *191*(3), 391-431.

Berridge, K.C. (2009). Wanting and liking: Observations from the neuroscience and psychology laboratory. *Inquiry (Oslo)*, *52*(4), 1-18.

Berridge, K.C., & Kringelbach, M.L. (2013). Neuroscience of affect: Brain mechanisms of pleasure and displeasure. *Current Opinion in Neurobiology*, *23*(3), 294-303.

Berridge, K.C., & Robinson, T.E. (1998). What is the role of dopamine in reward: Hedonic impact, reward learning, or incentive salience? *Brain Research Reviews*, *28*(3), 309-369.

Berridge, K.C., & Robinson, T.E. (2003). Parsing reward. *Trends in Neurosciences*, *26*(9), 507-513.

Berridge, K.C., & Robinson, T.E. (2016). Liking, wanting, and the incentive-sensitization theory of addiction. *American Psychologist*, *71*(8), 670-679.

Bizot, J.C., Le Bihan, C., Puech, A.J., Hamon, M., & Thiébot, M.H. (1999). Serotonin and tolerance to delay of reward in rats. *Psychopharmacology*, *146*(4), 400-412.

Blum, K., Braverman, E.R., Holder, J.M., Lubar, J.F., Monastra, V.J., Miller, D., ... Comings, D.E. (2000). Reward deficiency syndrome: A biogenetic model for the diagnosis and treatment of impulsive, addictive, and compulsive behaviors. *Journal of Psychoactive Drugs*, *32*(Suppl 1), 1-112.

Blum, K., Cull, J.G., Braverman, E.R., & Comings, D.E. (1996). Reward Deficiency Syndrome. *American Scientist*, *84*(2), 132-145.

Blum, K., Gardner, E., Oscar-Berman, M., & Gold, M. (2012). "Liking" and "wanting" linked to Reward Deficiency Syndrome (RDS): Hypothesizing differential responsivity in brain reward circuitry. *Current Pharmaceutical Design*, *18*(1), 113-118.

Bos, P.A, Terburg, D., & van Honk, J. (2010). Testosterone decreases trust in socially naive humans. *Proceedings of the National Academy of Sciences of the United States of America, 107*(22), 9991-9995.

Bowirrat, A., & Oscar-Berman, M. (2005). Relationship between dopaminergic neurotransmission, alcoholism, and reward deficiency syndrome. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, *132*(1), 29-37.

Braver, T.S., & Barch, D.M. (2002). A theory of cognitive control, aging cognition, and neuromodulation. *Neuroscience and Biobehavioral Reviews, 6*(7), 809-817.

Carver, C.S., & Johnson, S.L. (2009). Tendencies toward mania and tendencies toward depression have distinct motivational, affective, and cognitive correlates. *Cognitive Therapy and Research, 33*(6), 552-569.

Carver, C.S., Johnson, S.L., & Joormann, J. (2014). Dual process models and serotonergic functioning. In J.P. Forgas & E. Harmon Jones (Eds.), *Motivation and its regulation: The control within* (pp. 55-78). New York: Psychology Press.

Carver, C.S., & White, T.L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology*, *67*(2), 319-333.

Coppens, C.M., de Boer, S.F., Koolhaas, J.M., Barr, C.S., Newman, T.K., Becker, M.L., ... Driscoll, P. (2010). Coping styles and behavioural flexibility: Towards underlying mechanisms. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 365*(1560), 4021-4028.

Corr, P.J. (2008). Reinforcement sensitivity theory (RST): Introduction. In P.J. Corr (Ed.), *The Reinforcement sensitivity theory of personality* (pp. 1-43). Cambridge: Cambridge University Press.

Corr, P.J. (2013). Approach and avoidance behaviour: Multiple systems and their interactions. *Emotion Review*, *5*(3), 285-290.

Corr, P.J. (2016). Reinforcement Sensitivity Theory of Personality Questionnaires: Structural survey with recommendations. *Personality and Individual Differences, 89*, 60-64.

Corr, P.J., & Cooper, A.J. (2016). The Reinforcement Sensitivity Theory of Personality Questionnaire (RST-PQ): Development and validation. *Psychological Assessment, 28*(11), 418 - 427.

Corr, P.J., & Krupić, D. (2017, in press). Motivating personality: Approach, avoidance, and their conflict. In A. Elliot (Ed.), *Advances in motivation science*. London: Elsevier.

Corvi, A.P., Juergensen, J., Weaver, J.S., & Demaree, H.A. (2012). Subjective time perception and behavioral activation system strength predict delay of gratification ability. *Motivation and Emotion*, *36*(4), 483-490.

Crockett, M.J., Apergis-Schoute, A., Herrmann, B., Lieberman, M.D., Lieberman, M., Müller, U., … Clark, L. (2013). Serotonin modulates striatal responses to fairness and retaliation in humans. *The Journal of Neuroscience, 33*(8), 3505-3513.

D'amato, F.R., & Pavone, F. (1993). Endogenous opioids: A proximate reward mechanism for kin selection? *Behavioral and Neural Biology*, *60*(1), 79-83.

Davis, C.A., Levitan, R.D., Reid, C., Carter, J.C., Kaplan, A.S., Patte, K.A., ... Kennedy, J.L. (2009). Dopamine for "wanting" and opioids for "liking": A comparison of obese adults with and without binge eating. *Obesity*, *17*(6), 1220-1225.

Del Giudice, M. (2014). An evolutionary life history framework for psychopathology. *Psychological Inquiry*, *25*(3-4), 261-300.

Depue, R.A., & Collons, P.F. (1999). Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences*, *22*(3), 491-569.

DeYoung, C.G. (2013). The neuromodulator of exploration: A unifying theory of the role of dopamine in personality. *Frontiers in Human Neuroscience*, *7*, 762.

DeYoung, C.G., Grazioplene, R.G., & Peterson, J.B. (2012). From madness to genius: The Openness/Intellect trait domain as a paradoxical simplex. *Journal of Research in Personality*, *46*(1), 63-78.

Dulawa, S.C., Grandy, D.K., Low, M.J., Paulus, M.P., & Geyer, M.A. (1999). Dopamine D4 receptor-knock-out mice exhibit reduced exploration of novel stimuli. *Journal of Neuroscience*, *19*(21), 9550-9556.

Elvemo, N.A., Landrø, N.I., Borchgrevink, P.C., & Håberg, A.K. (2015). Reward responsiveness in patients with chronic pain. *European Journal of Pain*, *19*(10), 1537-1543.

Gray, J.A. (1982). *The neuropsychology of anxiety: An investigation into the functions of the septo-hippocampal system* (1st edition) Oxford, England: Oxford University Press.

Gray, J.A., & McNaughton, N. (2003). *The neuropsychology of anxiety: An enquiry into the function of the septo-hippocampal system* (2nd edition). Oxford, England: Oxford University Press.

Heinz, A., Schmidt, L.G., & Reischies, F.M. (1994). Anhedonia in schizophrenic, depressed, or alcohol-dependent patients-neurobiological correlates. *Pharmacopsychiatry*, *27(Suppl 1)*, 7-10.

Hermans, E.J., Bos, P.A., Ossewaarde, L., Ramsey, N.F., Fernández, G., & van Honk, J. (2010). Effects of exogenous testosterone on the ventral striatal BOLD response during reward anticipation in healthy women. *NeuroImage*, *52*(1), 277-283.

Hundt, N.E., Kimbrel, N.A., Mitchell, J.T., & Nelson-Gray, R.O. (2008). High BAS, but not low BIS, predicts externalizing symptoms in adults. *Personality and Individual Differences*, *44*(3), 565-575.

Jackson, C.J. (2009). Jackson-5 scales of revised Reinforcement Sensitivity Theory (r-RST) and their application to dysfunctional real world outcomes. *Journal of Research in Personality*, *43*(4), 556-569.

Johnson, S.L., Carver, C.S., Joormann, J., & Cuccaro, M.L. (2016). Genetic polymorphisms related to behavioral approach and behavioral inhibition scales. *Personality and Individual Differences, 88*, 251-255.

Kalin, N.H., Shelton, S.E., & Lynn, D.E. (1995). Opiate systems in mother and infant primates coordinate intimate contact during reunion. *Psychoneuroendocrinology, 20*(7), 735-742.

Karjalainen, T., Tuominen, L., Manninen, S., Kalliokoski, K.K., Nuutila, P., Jääskeläinen, I. P., ... Nummenmaa, L. (2016). Behavioural activation system sensitivity is associated with cerebral μ-opioid receptor availability. *Social Cognitive and Affective Neuroscience, 11*(8), 1310-1316.

Katz, L.D. (1999). Dopamine and serotonin: Integrating current affective engagement with longer-term goals. *Behavioral and Brain Sciences, 22*(3), 527-527.

Knutson, B., Westdorp, A., Kaiser, E., & Hommer, D. (2000). FMRI visualization of brain activity during a monetary incentive delay task. *NeuroImage, 12*(1), 20-27.

Kranz, G.S., Kasper, S., & Lanzenberger, R. (2010). Reward and the serotonergic system. *Neuroscience, 166*(4), 1023-1035.

Križanić, V., Greblo, Z., & Knezović, Z. (2015). Mjere osjetljivosti bihevioralnoga inhibicijskog i aktivacijskoga sustava kao prediktori dimenzija petofaktorskoga modela ličnosti. *Psychological Topics, 24*(2), 305-324.

Krupić, D., Banai, B., & Corr, P.J. (2017, submitted). Slow and fast BAS: Correlation between Behavioural Approach System (BAS) with Life History Theory.

Krupić, D., & Corr, P.J. (2014). Individual differences in emotion elicitation in university examinations: A quasi-experimental study. *Personality and Individual Differences, 71*, 176-180.

Krupić, D., Corr, P.J., Ručević, S., Križanić, V., & Gračanin, A. (2016). Five reinforcement sensitivity theory (RST) of personality questionnaires: Comparison, validity and generalization. *Personality and Individual Differences, 97*, 19-24.

Krupić, D., Gračanin, A., & Corr, P.J. (2016). The evolution of the Behavioural Approach System (BAS): Cooperative and competitive resource acquisition strategies. *Personality and Individual Differences, 94*, 223-227.

Lombardo, M.V., Ashwin, E., Auyeung, B., Chakrabarti, B., Lai, M.C., Taylor, K., ... Baron-Cohen, S. (2012). Fetal programming effects of testosterone on the reward system and behavioral approach tendencies in humans. *Biological Psychiatry, 72*(10), 839-847.

MacDonald, K. (1995). Evolution, the five-factor model, and levels of personality. *Journal of Personality, 63*(3), 525-567.

Machin, A.J., & Dunbar, R. (2011). The brain opioid theory of social attachment: A review of the evidence. *Behaviour, 148*(9), 985-1025.

Manson, J.H. (2015). Life history strategy and the HEXACO personality dimensions. *Evolutionary Psychology, 13*(1), 48-66.

Mazur, A., & Booth, A. (1998). Testosterone and dominance in men. *Behavioral and Brain Sciences*, *21*(3), 353-397.

Mehta, P.H., & Josephs, R.A. (2010). Testosterone and cortisol jointly regulate dominance: Evidence for a dual-hormone hypothesis. *Hormones and Behavior*, *58*(5), 898-906.

Mehta, P.H., Jones, A.C., & Josephs, R.A. (2008). The social endocrinology of dominance: Basal testosterone predicts cortisol changes and behavior following victory and defeat. *Journal of Personality and Social Psychology*, *94*(6), 1078-1093.

Mitchell, J.T., Kimbrel, N.A., Hundt, N.E., Cobb, A.R., Nelson-Gray, R.O., & Lootens, C.M. (2007). An analysis of reinforcement sensitivity theory and the five-factor model. *European Journal of Personality*, *21*(7), 869-887.

Miyazaki, K., Miyazaki, K.W., & Doya, K. (2011). Activation of dorsal raphe serotonin neurons underlies waiting for delayed rewards. *The Journal of Neuroscience*, *31*(2), 469-479.

Miyazaki, K.W., Miyazaki, K., Tanaka, K.F., Yamanaka, A., Takahashi, A., Tabuchi, S., & Doya, K. (2014). Optogenetic activation of dorsal raphe serotonin neurons enhances patience for future rewards. *Current Biology*, *24*(17), 2033-2040.

Moles, A., Kieffer, B.L., & D'Amato, F.R. (2004). Deficit in attachment behavior in mice lacking the mu-opioid receptor gene. *Science*, *304*(5679), 1983-1986.

Montoya, E.R., Terburg, D., Bos, P.A., & van Honk, J. (2012). Testosterone, cortisol, and serotonin as key regulators of social aggression: A review and theoretical perspective. *Motivation and Emotion*, *36*(1), 65-73.

Morrone-Strupinsky, J.V., & Depue, R.A. (2004). Differential relation of two distinct, film-induced positive emotional states to affiliative and agentic extraversion. *Personality and Individual Differences*, *36*(5), 1109-1126.

Naranjo, C.A., Tremblay, L.K., & Busto, U.E. (2001). The role of the brain reward system in depression. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *25*(4), 781-823.

Panksepp, J., Herman, B.H., Vilberg, T., Bishop, P., & DeEskinazi, F.G. (1980). Endogenous opioids and social behavior. *Neuroscience & Biobehavioral Reviews*, *4*(4), 473-487.

Pearson, R., McGeary, J.E., & Beevers, C.G. (2014). Association between serotonin cumulative genetic score and the Behavioral Approach System (BAS): Moderation by early life environment. *Personality and Individual Differences*, *70*, 140-144.

Penke, L., Denissen, J.J., & Miller, G.F. (2007). The evolutionary genetics of personality. *European Journal of Personality*, *21*(5), 549-587.

Ranade, S., Pi, H.J., & Kepecs, A. (2014). Neuroscience: Waiting for serotonin. *Current Biology*, *24*(17), R803-R805.

Réale, D., Dingemanse, N.J., Kazem, A.J.N., Wright, J., Barber, I., Dingemanse, N.J., ... Butlin, R.K. (2010). Evolutionary and ecological approaches to the study of personality. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *365*(1560), 3937-3946.

Reuter, M., Cooper, A.J., Smillie, L.D., Markett, S., & Montag, C. (2015). A new measure for the revised reinforcement sensitivity theory: Psychometric criteria and genetic validation. *Frontiers in Systems Neuroscience, 9*, 1-38.

Schultheiss, O.C., Wirth, M.M., Torges, C.M., Pang, J.S., Villacorta, M.A., & Welsh, K.M. (2005). Effects of implicit power motivation on men's and women's implicit learning and testosterone changes after social victory or defeat. *Journal of Personality and Social Psychology*, *88*(1), 174-188.

Schweighofer, N., Bertin, M., Shishida, K., Okamoto, Y., Tanaka, S.C., Yamawaki, S., & Doya, K. (2008). Low-serotonin levels increase delayed reward discounting in humans. *The Journal of Neuroscience*, *28*(17), 4528-4532.

Schweighofer, N., Tanaka, S.C., & Doya, K. (2007). Serotonin and the evaluation of future rewards: Theory, experiments, and possible neural mechanisms. *Annals of the New York Academy of Sciences, 1104*(1), 289-300.

Segarra, P., Poy, R., López, R., & Moltó, J. (2014). Characterizing Carver and White's BIS/BAS subscales using the Five Factor Model of personality. *Personality and Individual Differences, 61-62*, 18-23.

Sherman, R.A, Figueredo, A.J.J., & Funder, D.C. (2013). The behavioral correlates of overall and distinctive life history strategy. *Journal of Personality and Social Psychology, 105*(5), 873-888.

Sih, A., & Del Giudice, M. (2012). Linking behavioural syndromes and cognition: A behavioural ecology perspective. *Philosophical Transactions of the Royal Society B-Biological Sciences, 367*(1603), 2762-2772.

Slatcher, R.B., Mehta, P.H., & Josephs, R.A. (2011). Testosterone and self-reported dominance interact to influence human mating behavior. *Social Psychological and Personality Science, 2*(5), 531-539.

Smederevac, S., Mitrović, D., Čolović, P., & Nikolašević, Ž. (2014). Validation of the measure of revised Reinforcement Sensitivity Theory constructs. *Journal of Individual Differences, 35*(1), 12-21.

Smillie, L.D., Jackson, C.J., & Dalgleish, L.I. (2006). Conceptual distinctions among Carver and White's (1994) BAS scales: A reward-reactivity versus trait impulsivity perspective. *Personality and Individual Differences, 40*(5), 1039-1050.

Stanton, S.J., Beehner, J.C., Saini, E.K., Kuhn, C.M., & LaBar, K.S. (2009). Dominance, politics, and physiology: Voters' testosterone changes on the night of the 2008 United States presidential election. *PLoS ONE, 4*(10), e7543.

Stuettgen, M.C., Hennig, J., Reuter, M., & Netter, P. (2005). Novelty seeking but not BAS is associated with high dopamine as indicated by a neurotransmitter challenge test using mazindol as a challenge substance. *Personality and Individual Differences, 38*(7), 1597-1608.

Swaddle, J.P., & Reierson, G.W. (2002). Testosterone increases perceived dominance but not attractiveness in human males. *Proceedings. Biological Sciences/The Royal Society, 269*(1507), 2285-2289.

Tanaka, S.C., Schweighofer, N., Asahi, S., Shishida, K., Okamoto, Y., Yamawaki, S., & Doya, K. (2007). Serotonin differentially regulates short-and long-term prediction of rewards in the ventral and dorsal striatum. *PLoS One*, *2*(12), e1333.

Terburg, D., Morgan, B., & van Honk, J. (2009). The testosterone-cortisol ratio: A hormonal marker for proneness to social aggression. *International Journal of Law and Psychiatry*, *32*(4), 216-223.

Torrubia, R., Ávila, C., Moltó, J., & Caseras, X. (2001). The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences*, *31*(6), 837-862.

Tuominen, L., Salo, J., Hirvonen, J., Någren, K., Laine, P., Melartin, T., ... Keltikangas-Järvinen, L. (2013). Temperament, character and serotonin activity in the human brain: A positron emission tomography study based on a general population cohort. *Psychological Medicine*, *43*(4), 881-894.

Vanderschuren, L.J., Niesink, R.J., & Van Ree, J.M. (1997). The neurobiology of social play behavior in rats. *Neuroscience and Biobehavioral Reviews*, *21*(3), 309-326.

Walker, B.R., & Jackson, C.J. (2014). How the five factor model and revised reinforcement sensitivity theory predict divergent thinking. *Personality and Individual Differences*, *57*, 54-58.

Walker, B.R., & Jackson, C.J. (2017). Examining the validity of the revised Reinforcement Sensitivity Theory scales. *Personality and Individual Differences*, *106*, 90-94.

Wanigasekera, V., Lee, M.C., Rogers, R., Kong, Y., Leknes, S., Andersson, J., & Tracey, I. (2012). Baseline reward circuitry activity and trait reward responsiveness predict expression of opioid analgesia in healthy subjects. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(43), 17705-17710.

Welberg, L. (2012). Reward: Serotonin promotes patience. *Nature Reviews Neuroscience*, *13*(9), 603-603.

Wise, R.A. (2008). Dopamine and reward: The anhedonia hypothesis 30 years on. *Neurotoxicity Research*, *14*(2-3), 169-183.

Wolf, M., van Doorn, G.S., Leimar, O., & Weissing, F.J. (2007). Life-history trade-offs favour the evolution of animal personalities. *Nature*, *447*(7144), 581-584.

Yildirim, B.O., & Derksen, J.J. (2012). A review on the relationship between testosterone and the interpersonal/affective facet of psychopathy. *Psychiatry Research*, *197*(3), 181-198.

Zald, D.H., Cowan, R.L., Riccardi, P., Baldwin, R.M., Ansari, M.S., Li, R., ... Kessler, R.M. (2008). Midbrain dopamine receptor availability is inversely associated with novelty-seeking traits in humans. *The Journal of Neuroscience*, *28*(53), 14372-14378.

Avanzando con el SAC: Hacia la neurobiología del modelo multidimensional de la motivación de acercamiento

Resumen

Uno de los temas candentes en la neurociencia es es el estudio de circuitos cerebro-conductuales que están en la base del procesamiento de estímulos relacionados con la recompensa. El número creciente de investigaciones han arrojado una nueva luz sobre la estructura neuronal de este sistema de recompensas. En este trabajo discutimos la importancia estos estudios desde la perspectiva de la teoría neuropsicológica de la personalidad, más concreto, la Teoría de la Sensibilidad al Refuerzo (TSR). TSR supone que la variación en la sensibilidad/reactividad del sistema de recompensas es la causa de diferencias individuales en la motivación de acercamiento (p. ej. deseo o necesidad de logro, perseverancia y emocionalidad positiva). Dentro de TSR estas diferencias individuales se encuentran en el constructo del Sistema de activación conductual (SAC). Sin embargo, existe un debate sobre la índole de SAC. Este hecho nos ha motivado a revisar los últimos hallazgos en la neurociencia de SAC en el contexto del sistema de recompensas. En esta revisión identificamos cuatro aspectos distintivos de SAC: carencia, motivación de incentivo, esfuerzos y gustos. Sus efectos conductuales se comparan con las manifestaciones de testosteronas, dopamina, serotonina y opioides endógenos, respectivamente. Concluimos que la vista unidimensional de SAC es demasiado simplificada y sugerimos estudiarlo como un constructo multidimensional, lo que implica lo mismo para el sistema de recompensas.

Palabras claves: sistema de recompensas, carencia, motivación de incentivo, esfuerzos, gustos

Received: January 18, 2017