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Gray's Reinforcement Sensitivity Theory as a framework for research on personality–psychopathology associations ☆

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ABSTRACT

Gray's Reinforcement Sensitivity Theory (RST) presupposes individual differences in the sensitivity of basic brain systems that respond to punishing and reinforcing stimuli. These differences are thought to underlie the personality dimensions of anxiety and impulsivity, and to have relevance for psychopathology. The present article aims at reviewing RST-based research on personality–psychopathology associations. First, RST and its revisions are described and the link between RST systems and personality dimensions is discussed. Second, studies investigating associations between RST systems and specific types of psychopathology are summarized. Although the available research yields a rather consistent picture with respect to constellations of BIS/BAS sensitivity that are associated with specific types of psychopathology, it also provides a clear indication that much work remains to be done. The discussion section highlights several topics that deserve future research attention.

Contents

1. Development of Gray's Reinforcement Sensitivity Theory

Jeffrey A. Gray's (1970, 1982) Reinforcement Sensitivity Theory (RST) is an application of animal learning research to individual differences in human personality. It encompasses two primary motivational systems:

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the behavioral inhibition system (BIS) and the behavioral activation system (BAS). Each system responds to a separate subset of reinforcing events with specific types of behavior and is supposed to be mediated by a separate set of interacting brain structures. The Behavioral Inhibition System (BIS) is responsible for organizing behavior in response to stimuli that signal conditioned aversive events, more specifically stimuli associated with punishment and with the omission or termination of reward (i.e., nonreward) but also with extreme novelty, high intensity stimuli, and innate fear stimuli (e.g., snakes, blood). These stimuli elicit behavioral inhibition (interruption of any ongoing behavior), an increment in the level of arousal (such that the next behavior to occur is carried out with extra vigor and/or speed), and an increment in attention (such that more information is taken in). The Behavioral Approach System (BAS) — sometimes referred to as Behavioral Activation System (Fowles, 1980) — is responsible for organizing behavior in response to appetitive stimuli. The BAS is appetitive and sensitive to stimuli that signal unconditioned reward and the relief from punishment (i.e., nonpunishment). Activity in the BAS is involved in approach behavior. Over the years, RST developed to include a third major system: the Fight-Flight System (FFS; Gray, 1987). Whereas the BIS responds to conditioned aversive stimuli, the FFS responds to unconditioned aversive stimuli, to unconditioned punishment or unconditioned nonreward. Behavior elicited by these stimuli consists of unconditioned defensive aggression (fight) or escape behavior (flight).

In 2000, Gray and McNaughton presented a major revision of RST (for an extensive discussion: Corr, 2008). This revised theory still postulates three systems but with different stimuli supposed to activate them. The BAS is now assumed to be responsive to all positively valenced stimuli, unconditioned as well as conditioned. The FFS not only incorporates fight and flight reactions but also freezing reactions occurring in the presence of unavoidable threat stimuli. It is renamed the Fight/Flight/Freeze System (FFFS) and supposed to mediate reactions to all aversive stimuli, unconditioned as well as conditioned. As such, the FFFS adopts the punishment system role that — in the original version of RST — was ascribed to the BIS. Finally, the BIS is no longer considered to mediate reactions to conditioned aversive stimuli, but is now believed to be responsible for the resolution of goal conflict in general. Goal conflicts can emerge in situations including both reward and threat (i.e., both the BAS and the FFFS have been activated). If reward outweighs threat, the BIS will resolve the conflict by engaging the BAS and inhibiting the FFFS, resulting in approach. If threat outweighs reward, the BIS will further activate the FFFS and inhibit the BAS, resulting in avoidance. Goal conflict is not restricted to approach-avoidance conflicts: approach-approach conflicts (where one stimulus is less rewarding and therefore frustrative) and avoidance-avoidance conflicts (where one stimulus is less punishing and therefore relieving) are also possible. In such cases, the BIS resolves conflicts by changing the valence of stimuli until behavioral resolution occurs in favor of approaching or avoiding one of the stimuli.

Another attempt to refine Gray's original theory concerns the degree of interdependence of the RST systems. In the original theory, BIS and BAS were assumed to function independently of one another (i.e. the separable subsystems hypothesis; SSH): responses to reward were expected to be the same at all levels of BIS, and responses to punishment were expected to be the same at all levels of BAS. In this view, just one subsystem is in exclusive control at any time and the behavioral outcome results from which subsystem dominates the other. As only limited empirical support was found for this hypothesis, Corr (2001) put forward the joint subsystems hypothesis (JSH). It assumes that under certain circumstances, BIS and BAS may act as interdependent systems and jointly influence behavior. In fact, the JSH is expected to be valid under typical human experimental conditions, whereas the SSH is expected to apply only to extreme personality groups or conditions of extreme appetitive or aversive stimulation (Corr, 2002). Both hypotheses may be seen as complementary accounts within a two-process model of BIS/BAS functioning (Corr, 2001).

2. Personality dimensions underlying RST systems

RST is composed of two main components: (a) a state description of neural systems and associated, relatively short-term, emotions and behaviors; and (b) a trait description of longer-term dispositions to such emotions and behaviors (Corr & McNaughton, 2008). As to the former component, Gray (1982) assumed that BIS and BAS facilitate the expression of aversive and appetitive motivation; as to the latter, he was convinced that individual differences in BIS and BAS sensitivity underlie the personality dimensions of anxiety and impulsivity, respectively.

Gray and McNaughton's (2000) revision of RST has implications for the way the corresponding personality traits are conceptualized, especially with respect to BIS. Although in the original RST anxiety was already viewed to be a result of BIS activation and fear a result of FFS activation (e.g., Gray, 1987), in practice BIS had implicitly subsumed both responsibilities and the difference between fear and anxiety was vague (Smillie, Pickering, & Jackson, 2006). In the revised RST, the role of FFFS is given greater attention and a clear-cut distinction is made between anxiety, mediated by the BIS, and fear, mediated by the FFFS. It is postulated that the function of anxiety is to cautiously motivate individuals towards danger, whereas fear is supposed to motivate individuals away from danger (McNaughton & Corr, 2004). With respect to BAS, Gray and McNaughton's (2000) revisions have had no major implications for the conceptualization of corresponding personality traits: BAS is associated with impulsivity in both the original and the revised version of RST.

In addition to the trait manifestations of the BIS and BAS, the activation of both systems is also thought to give rise to affective dimensions of positive and negative mood. Activation of the BIS by punishment would lead to increased negative affect, whereas activation of the BAS by reward would lead to increased positive affect. As a result, individual differences in BIS and BAS reactivity are thought to correspond to stable individual differences in positive and negative affectivity. Relevant to mention in this respect is a study by Jorm et al. (1999), who administered measures of BIS and BAS and of positive affectivity and negative affectivity to a large Australian community sample. They performed a principal component analysis and found that BIS loaded on the same factor as negative affectivity, whereas BAS loaded on the same factor as positive affectivity. Similar patterns of associations have been reported by Campbell-Sills, Liverant and Brown (2004) in a large sample of patients with anxiety and mood disorders.

3. RST and psychopathology

RST assumes that individuals at the far poles of the BIS and BAS dimensions are at increased risk for developing psychopathology (Pickering & Gray, 1999) and empirical evidence supports the association between extreme BIS/BAS scores and adjustment problems (Knyazev, Wilson, & Slobodskaya, 2008; Slobodskaya, 2007). Predictions as to the link between BIS/BAS sensitivity and vulnerability to psychopathology differ according to which version of RST (original versus revised) is taken as frame of reference and whether separable or joint effects are expected (separable versus joint subsystems hypothesis).

In the original RST, BIS and BAS were considered as the two primary motivational systems. They were postulated to underlie the personality dimensions of Anxiety and Impulsivity, which already indicate the nature of related adjustment problems that can be expected. In broad terms, elevated BIS activity has been put forward as a vulnerability factor to internalizing disorders, whereas elevated BAS

activity has been assumed to make individuals more prone to externalizing problems (Slobodskaya, 2007). Studies using broadband measures of psychopathology have provided evidence in support of these predictions (Colder & O'Connor, 2004; Muris, Meesters, De Kanter, & Timmerman, 2005; Slobodskaya, 2007).

Several authors have raised hypotheses as to associations between BIS/BAS sensitivity and specific types of psychopathology: high BIS engagement has been related to anxiety (Gray, 1982), low BIS engagement to attention-deficit hyperactivity disorder (Quay, 1997) and psychopathy (Fowles, 1980), high BAS engagement to conduct disorder (Quay, 1993) and low BAS engagement to depression (Depue, Krauss, & Spoont, 1987). The large bulk of studies investigating the associations between BIS/BAS and specific types of psychopathology have taken the original RST as frame of reference and — as detailed in the review below — the resulting empirical evidence is mixed: some of the expected links between BIS/BAS and psychopathology are supported but for others the evidence is less consistent. Recent studies have also focused on the associations between RST systems and other forms of psychopathology than the prototypical internalizing and externalizing disorders, such as substance use problems, eating disorders, schizophrenia and personality disorders.

3.1. Anxiety disorders

In line with Gray's (1982) hypothesis, studies in both community samples and clinical groups have shown that anxiety symptoms generally show positive associations with BIS sensitivity and no or very weak associations with BAS sensitivity (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Johnson, Turner, & Iwata, 2003; Jorm et al., 1999; Kimbrel, Nelson-Gray, & Mitchell, 2007; Muris et al., 2005; Segarra et al., 2007). Some researchers have investigated the associations of BIS/BAS with specific types of anxiety disorders and, as detailed below, these studies largely replicate findings with anxiety in general, evidencing consistent associations with BIS sensitivity but no or only weak associations with BAS sensitivity.

Social anxiety measures show quite consistent positive associations with BIS sensitivity but are largely unrelated to BAS sensitivity (Coplan, Wilson, Frohlick, & Zelenski, 2006; Kimbrel, Cobb, Mitchell, Hundt, & Nelsib-Gray, in press). Individuals with subclinical obsessive–compulsive symptoms show higher sensitivity to punishment (i.e., higher BIS activation) compared to normal controls but do not differ from controls with respect to sensitivity to reward (Fullana, Mataix-Cols, Trujillo et al., 2004). Moreover, in patients with obsessive–compulsive disorder, only sensitivity for punishment and not sensitivity for reward emerges as a significant predictor of the presence of hoarding symptoms (Fullana, Mataix-Cols, Caseras et al., 2004).

3.2. Depression

Several authors have linked depression to a hyporeactivity of reward systems, resulting in a general lowered motivation to appetitive stimuli (e.g., Depue & Iacono, 1989). In support of this hypothesis, clinical groups of depressed patients have been found to report lower BAS levels relative to nondepressed controls (Kasch, Rottenberg, Arnow, & Gotlib, 2002; Pinto-Meza et al., 2006) and in community samples, negative associations between BAS sensitivity and depressive symptoms have been reported (Beevers & Meyer, 2002; Coplan et al., 2006; Jones & Day, 2008; Kimbrel et al., 2007). Furthermore, in clinical groups, low BAS has been significantly associated with persistence of depression over a 6- to 8-month interval (Campbell-Sills et al., 2004; Kasch et al., 2002; McFarland, Shankman, Tenke, Bruder, & Klein, 2006), suggesting that low BAS sensitivity is not only a potential marker of a vulnerability to depression, but may also be useful in predicting the course of the disorder. There is also tentative evidence that RST may help guide treatment development. Behavioral activation interventions, in which depressive patients are increasingly exposed to positive activities in an attempt to reverse the pattern of low approach, have shown good results for treating depressive episodes (e.g., Jacobson et al., 1996) and reducing relapses (e.g., Fava, Rafanelli, Grandi, Conti, & Belluardo, 1998).

However, some negative findings have been reported too. In the study of Jorm et al. (1999), levels of depressive symptoms were unrelated to BAS sensitivity. In the same line, the epidemiological study of Johnson et al. (2003) revealed no association between BAS and life-time diagnoses of major depressive disorder. And Muris et al. (2005) found no significant correlation between BAS scores and self-reported depressive symptoms in a community sample of elementary school children. These negative findings may be due to the fact that no distinction was made between anhedonic depression and mixed anxiety–depression, which Gray (1991) hypothesized to differ in terms of BAS activity. Some recently published findings are consistent with this idea. Both Kimbrel et al. (2007) and Hundt, Nelson-Gray, Kimbrel, Mitchell, and Kwapil (2007) found that low BAS predicted anhedonic depression symptoms but not mixed anxiety–depression symptoms, underscoring the need to distinguish between these types of depression.

Although initially BIS was thought to be a specific diathesis for anxiety and not explicitly linked with depression, many studies have reported significant positive associations between BIS reactivity and depressive symptoms (e.g., Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Coplan et al., 2006; Hundt et al., 2007; Johnson et al., 2003; Jones & Day, 2008; Jorm et al., 1999; Kasch et al., 2002; Muris et al., 2005; Pinto-Meza et al., 2006). Strong BIS activity should be considered as a common factor to different types of emotional problems (anxiety as well as depression), whereas weak BAS activity is specific to depression. In a recent review of how RST fits into the clinical literature on depression and anxiety, Zinbarg and Yoon (2008) point to the fact that this is largely consistent with Clark and Watson's (1991) tripartite model of anxiety and depression, which acknowledges both substantial overlap and meaningful differentiation between anxiety and depression. In this model anxiety and depression share a non-specific component of generalized distress, i.e., negative affectivity (which has been linked to BIS). Only depression, however, is also associated with low levels of positive affectivity (which has been linked to BAS).

Some evidence suggests that the function of BIS in depression differs from that of BAS. In two short-term prospective studies, BIS levels were not found to predict the course or severity of depressive symptoms, whereas BAS levels did (McFarland et al., 2006; Pinto-Meza et al., 2006). Moreover, whereas both BIS and BAS levels differentiated patients with major depressive disorder from non-psychiatric controls, only BAS levels differentiated recovered patients from controls (Pinto-Meza et al., 2006). These findings suggest that BIS hyperactivity functions as a state-dependent characteristic of depression, whereas BAS hyporeactivity truly represents a trait-vulnerability marker.

3.3. Bipolar disorder

RST has also been put forward as an interesting frame of reference to understand bipolar disorder. About two decades ago, Depue et al. (1987) suggested that individuals with bipolar disorder experience extreme fluctuations in activation and deactivation of the BAS, resulting in the rollercoaster of hypomanic/manic highs and depressives lows. According to such BAS hypersensitivity model, vulnerability to bipolar disorder is reflected in an overly sensitive BAS that is hyper-reactive to relevant cues and leads individuals to experience great variability in their state levels of BAS activation across situations and over time. Alloy et al. (2006) tested the BAS hypersensitivity model in a sample of undergraduates, using a behavioral high-risk

design. Participants with high BAS sensitivity were significantly and substantially more likely to have a life-time bipolar spectrum disorder diagnosis than participants with only moderate BAS sensitivities, which is consistent with the predictions from the BAS hypersensitivity model. Also consistent with this model is the finding that clinically diagnosed bipolar patients report higher levels of reward sensitivity and equal levels of punishment sensitivity compared to normal controls (Salavert et al., 2007; Alloy et al., 2008).

Several studies have investigated the extent to which BIS/BAS levels are associated with either manic or depressive symptoms or both. Among college students at increased risk for bipolar spectrum disorder, Meyer, Johnson, and Carver (1999) found that high BAS was the only predictor of concurrent mania symptoms, whereas both high BIS and low BAS predicted concurrent depressive symptoms. In clinically diagnosed bipolar patients, Meyer, Johnson, and Winters (2001) found that BIS scores were positively associated with severity of depressive symptoms but neither to severity of manic symptoms nor to symptom changes following recovery. BAS scores were unrelated to the severity of both types of symptoms but did predict the relative intensification of manic symptoms over time. In a study of bipolar spectrum disorders, Alloy et al. (2006) found high BAS scores to be marginally associated with greater proneness to hypomanic symptoms over time and high BIS scores to be associated with both current depression levels and proneness to depressive symptoms. In another study of bipolar patients, Alloy et al. (2008) found that high BAS sensitivity prospectively predicted a shorter time of onset of hypomanic and manic episodes, whereas high BIS sensitivity was a marginally significant predictor of a shorter time of onset of major depressive episodes.

Although the pattern of findings is not entirely consistent, the body of evidence thus far seems to support the BAS hypersensitivity model of bipolar disorder, with higher levels of BAS predicting vulnerability to bipolar disorder as well as proneness to manic episodes in bipolar patients. In addition, BIS sensitivity appears to be relevant in predicting depressive episodes. The latter association is mainly found in symptomatic bipolar samples (e.g., Meyer et al., 2001) and not in euthymic bipolar samples (e.g., Salavert et al., 2007), suggesting that BIS sensitivity functions as a state-dependent characteristic of depressive symptoms rather than as a vulnerability factor.

3.4. Attention deficit hyperactivity disorder (ADHD)

Quay (1997) hypothesized that hyporeactivity of the BIS underlies the hyperactivity and impulsivity observed in ADHD. An underactive BIS is supposed to provide little input leading to an extinction of behavioral inhibition following a cue signaling punishment or nonreward, as manifested in hyperactive–impulsive ADHD behaviors. According to Nigg (2001), however, an underactive BIS is only one possible pathway to ADHD that has received consideration within an RST-based framework. Alternative pathways include an overresponsive BAS (Newman & Wallace, 1993) and poor response modulation (Patterson & Newman, 1993). The first account states that the person fails to inhibit responses in the presence of strong reward cues, resulting in characteristic hyperactive–impulsive ADHD symptoms. According to the second pathway, impulsive behaviors emerge from a deficient response modulation between the BIS and the BAS: when cues of reward are present and activate the BAS, the BAS activity becomes dominant and the BIS cannot interrupt despite the presence of punishment cues.

Experimental studies assessing ADHD disinhibition within the RST framework provide strong support for the overresponsive BAS and response modulation accounts (Nigg, 2001). The only two studies thus far on the associations between self-reported BIS/BAS sensitivity and ADHD symptoms have produced similar results. Kepley (2002) compared ADHD combined and inattentive subtypes with respect to self-reported BIS/BAS sensitivity and found that BAS scores differentiated between patients with and without hyperactive–impulsive symptoms. In the same line, Mitchell and Nelson-Gray (2006) reported that BAS scores were significant predictors of hyperactive–impulsive ADHD symptoms, whereas BIS scores were not. Taken together, the evidence thus far fails to support an underactive BIS account of ADHD but quite consistently suggests that hyperactive–impulsive ADHD symptoms are associated with BAS hyperactivity instead.

3.5. Psychopathy

Gray (1970) suggested that psychopaths tend to seek reward with no fear of punishment and that their recidivism reflects a relative insensitivity to punishment, implying a weak BIS combined with a normal (or possibly strong) BAS. Fowles (1980) underscored the match between predictions from the weak BIS hypothesis and the clinical features of psychopathy. Evidence has accumulated, however, supporting the notion that psychopathy is a heterogeneous construct with discrete subtypes (Skeem, Poythress, Edens, Lilienfeld, & Cale, 2003). Karpman (1941) distinguished between primary psychopathy, representing the core emotional deficit and interpersonal manipulation, and secondary psychopathy, referring to nonessential but associated characteristics such as antisociality and neurotic tendencies. Lykken (1995) further developed the psychopathy subtypes theory by detailing the expected temperamental characteristics of primary and secondary psychopathy. He proposed that primary psychopaths are born with an innate fearless temperament, as a consequence of which they show diminished sensitivity and responsiveness to the threats and punishments their parents may apply in trying to shape their behavior. Given the role of punishment in socialization, individuals with a fearless temperament are more difficult to socialize. In contrast, secondary psychopaths manifest many overt features similar to primary psychopaths, but their underlying deficit is hypothesized to be an abnormal sensitivity to cues of rewards. Building on Gray's (1970) and Fowles' (1980) work, Lykken (1995) thus embedded the typology of primary vs. secondary psychopathy in the RST framework and hypothesized that primary psychopathy is associated with a weak BIS and average BAS, whereas secondary psychopathy is associated with a hyperreactive BAS and average BIS. Newman, MacCoon, Vaughn, and Sadeh (2005) tested these predictions in a sample of incarcerated individuals. They found that, compared with non-psychopathic inmates, primary psychopaths reported weak BIS sensitivity and average BAS sensitivity, whereas secondary psychopaths reported strong BAS sensitivity and (depending on the questionnaire used) average to strong BIS sensitivity.

More recently, five studies investigated the associations between psychopathic traits and BIS/BAS sensitivity using a correlational design. Three of these studies used community samples of undergraduates (Hundt, Kimbrel, Mitchell, & Nelson-Gray, 2008; Kimbrel et al., 2007; Ross et al., 2007), whereas the other two included both undergraduate students and inmates (Ross, Benning, Patrick, Thompson, & Thurston, 2009; Uzieblo, Verschuere, & Crombez, 2007). In all studies, BAS sensitivity (either a more global BAS measure or one or more subaspects) was positively related to both types of psychopathy, which is inconsistent with the results of Newman et al. (2005). According tot Kimbrel et al. (2007), such discrepancy in findings may result from the fact that Newman et al. (2005) compared psychopathic inmates to non-psychopathic inmates and did not include a non-clinical comparison group. Since many crimes are characterized by impulsive, reward-seeking behavior, it is possible that all convicted criminals are higher on BAS than the rest of the population. In other words, primary psychopaths may be normal on BAS when compared to other inmates, but abnormally high on BAS when compared to non-clinical controls. With respect to BIS sensitivity, results of the investigations by Kimbrel et al. (2007), Ross et al. (2007), Ross et al.

(2009), and the inmates sample in the study by Uzieblo et al. (2007) were, as expected, showing that BIS is negatively associated with primary psychopathy and unrelated to secondary psychopathy. In the study by Hundt et al. (2008), BIS did not show a significant association with any of the psychopathy scales and in the community sample of Uzieblo et al. (2007), BIS showed a significant negative association with both psychopathy scales (albeit the strongest one with primary psychopathy).

Two other studies took a somewhat different approach to studying associations between RST variables and psychopathy. Book and Quinsey (2004) compared psychopathic offenders, non-psychopathic offenders, and two community samples with respect to the ratio of behavioral inhibition to behavioral activation (BIS:BAS) and found that psychopathic participants scored significantly lower than all the other groups, suggesting that their BIS is less reactive than their BAS. Falkenbach, Poythress, and Creevy (2008) performed a model-based cluster analysis on self-report measures of psychopathy, BIS/BAS sensitivity, and anxiety gathered from college students. They identified prototypes resembling subclinical primary and secondary psychopathy but there were some inconsistencies in terms of the associated BIS/BAS scores. BIS scores of the primary psychopathy group were lower than those of the secondary psychopathy group, but they equalled those of the normal temperament group and were higher than those of a non-psychopathic low-anxious group. BAS scores of the secondary psychopathy group tended to be higher than the scores of the other groups, but the difference was only marginally significant.

Although the findings are not entirely consistent, the available research evidence suggests that BAS hypersensitivity represents a vulnerability factor to both primary and secondary psychopathy, whereas BIS hypoactivity is specifically related to primary psychopathy. However, the use of the concept of BIS sensitivity and questionnaires designed to assess this sensitivity for testing Lykken's (1995) theory of primary psychopathy has been criticized. According to Poythress et al. (2008), Lykken considered low fear to be the critical deficit characterizing primary psychopathy, whereas the BIS subscales of currently available BIS/BAS questionnaires tap anxiety rather than fearlessness. Worth mentioning in this respect is the recent attempt by Heym, Ferguson, and Lawrence (2008) to distinguish BIS (underlying anxiety) from FFFS (underlying fear) in Carver and White's (1994) BIS/BAS Scales. Thus far, no study on psychopathy has taken this approach yet.

3.6. Eating disorders

For quite some time, RST systems have not been studied in relation to eating disorders. Nevertheless, few people will question that the RST-based personality traits have relevance in these disorders (Dawe & Loxton, 2004; Pallister & Waller, 2008, with respect to impulsivity and anxiety, respectively, in eating disorders). To our knowledge, only two studies have compared BIS/BAS levels of eating disorders patients and controls. Kane, Loxton, Staiger, and Dawe (2004) found evidence for elevated levels of both BIS and BAS sensitivity in bulimic patients (with and without comorbid alcohol problems) compared to controls. Claes, Nederkoorn, Vandereycken, Guerrieri, and Vertommen (2006) studied BIS/BAS sensitivity in different types of eating disorders and controls: anorexia nervosa patients reported lower levels of BAS sensitivity compared with controls and bulimia nervosa patients, whereas restrictive anorexia nervosa patients showed higher levels of BIS sensitivity compared to purging anorexia nervosa patients and controls. Beck, Smits, Claes, Vandereycken, and Bijttebier (2009) compared different types of eating disorders on BIS/BAS reactivity. Anorexic and bulimic patients did not differ from each other on BIS reactivity; however, BAS reactivity (more specific Fun Seeking) was elevated in binge/purge eating disordered patients compared to restrictive anorexic patients.

BIS/BAS sensitivity has not only been studied in relation to clinical eating disorders, but also to risky or dysfunctional patterns of food intake and body change behavior in non-clinical samples. Four studies in community samples of either adolescents (Hasking, 2006) or undergraduates (Loxton & Dawe, 2001, 2006, 2007) reported significantly positive associations of both BIS and BAS sensitivity with dysfunctional eating patterns, such as bingeing, purging, and preoccupation with weight and dieting. Furthermore, in a sample of female college students, BAS sensitivity was found to be positively associated with different aspects of food craving as well as with relative body weight, suggesting to consider BAS hyperactivity as a potential important variable in relation to the development of obesity (Franken & Muris, 2005). In non-clinical men, Mussap (2006) found BAS sensitivity to be positively associated with risky forms of body development (muscle/size preoccupation, obligatory exercise, use of chemical supplements), whereas BIS sensitivity was positively associated with unhealthy weight loss (weight preoccupation, fasting, bingeing/purging).

3.7. Substance abuse

Since activity in the BAS makes a person vigorously pursue an action that might result in reward, with little attention for the possibility of negative consequences, BAS sensitivity can be expected to play a role in the development of substance use problems too. Some authors have advanced the concept of a reward deficit syndrome as possible contributing factor to the development of substance use disorders (Blum et al., 2000). Consistent with this, the epidemiological study of Johnson et al. (2003) revealed a significant association between BAS sensitivity and life-time diagnoses of drug abuse and alcohol abuse without comorbid anxiety problems. In the same line, individuals with problematic substance use such as drug addicted inpatients (Franken, Muris, & Georgieva, 2006), alcohol misusing high school girls (Loxton & Dawe, 2001) and hazardous drinking men and women (Kambouropoulos & Staiger, 2007) were found to report higher levels of BAS sensitivity compared to controls. Staiger, Kambouropoulos, and Dawe (2007) emphasized the importance of considering personality traits such as BAS sensitivity when refining treatment programs. Relevant in this respect is the finding that therapeutic interventions in which alternative sources of reward are provided were more successful than standard cognitive behavior therapy in stimulant-dependent individuals (Rawson et al., 2006) as well as in cocaine addicts (Rawson et al., 2002).

A large number of studies on the association between BIS/BAS sensitivity and substance use problems in community samples report significantly positive associations between BAS sensitivity and alcohol abuse (Franken & Muris, 2006; Hundt et al., 2008; Jorm et al., 1999; Kimbrel et al., 2007; Loxton & Dawe, 2006, 2007; Loxton, Nguyen, Casey, & Dawe, 2008; O'Connor, Stewart, & Watt, 2009; Pardo, Aguilar, Molinuevo, & Torrubia, 2007), illicit drug abuse (Franken & Muris, 2006; Hundt et al., 2008; Kimbrel et al., 2007; Simons, Dvorak, & Batien, 2008), tobacco use (O'Connor et al., 2009), or composite measures of substance use problems (Genovese & Wallace, 2007; Knyazev, 2004). Moreover, in both clinical and non-clinical groups, BAS sensitivity emerged as a significant predictor of reactivity to alcohol cues (Glautier, Bankart, & Williams, 2000; Kambouropoulos & Staiger, 2001, 2004; Zisserson & Palfai, 2007) and craving (Franken, 2002). Only the study of Hasking (2006) in younger adolescents (mean age 14 years) failed to find a significant association between BAS sensitivity and substance use problems, probably due to a lack of variance in substance use behavior in this sample.

The role of BIS sensitivity in substance use problems is less clear. About half of the studies investigating associations of reinforcement sensitivity with substance use problems in community samples reported a significant negative correlation between substance use problems and BIS sensitivity (Franken & Muris, 2006; Genovese &

Wallace, 2007; Hundt et al., 2008; Kimbrel et al., 2007; Pardo et al., 2007; Simons et al., 2008). About the same number of the community studies, however, failed to find a significant association (Jorm et al., 1999; Knyazev, 2004; Loxton & Dawe, 2006, 2007; Loxton et al., 2008; O'Connor et al., 2009) and none of the studies comparing BIS/BAS levels of individuals with and without problematic substance use revealed any group differences in BIS reactivity (Franken et al., 2006; Loxton & Dawe, 2001; Kambouropoulos & Staiger, 2007).

At least two studies suggest that substance use problems may also be associated with a strong BIS. Kambouropoulos and Staiger (2004) found that, in aversive or nonrewarding drinking situations, BIS sensitivity is positively associated with negative urge for alcohol. Together with the finding that BAS sensitivity can also induce craving, these data suggest existence of two different motivational pathways to alcohol intake, consistent with the distinction between reward craving (related to BAS sensitivity) and withdrawal relief craving (related to BIS sensitivity) (Heinz et al., 2003). Another study in which high BIS sensitivity emerged as a relevant factor in substance use problems, has been conducted by Taylor, Reeves, James, and Bobadilla (2006). These authors used cluster analysis to derive groups based on personality traits (BIS/BAS sensitivity among others) and investigated to which extent the emerging profiles were associated with substance use problems in university students. As expected, one of the emerging trait profiles was a 'disinhibited' profile with a weak BIS and a strong BAS as key features. Across gender, this profile was associated with high levels of illicit drug problems. However, a second trait profile showed strong associations with drug problems across gender: a 'high affectivity' profile, with a strong BIS and high levels of negative affectivity as key features. These findings suggest that substance use problems may arise under two different constellations of personality traits.

3.8. Schizophrenia

Only one study thus far investigated BIS/BAS sensitivity in relation to schizophrenia (Scholten, van Honk, Aleman, & Kahn, 2006). Patients with schizophrenia reported higher levels of BIS sensitivity compared to controls and within the patient group, higher levels of BIS sensitivity were associated with a longer duration of illness and lower levels of negative symptoms. BAS scores were expected to vary with the positive (high BAS) and negative (low BAS) symptoms. However, no differences in BAS sensitivity were found between schizophrenic patients and controls, possibly due to the fact that all patients were treated with medication influencing dopaminergic reward pathways that are supposed to constitute the core neural substrate of BAS (Kalivas & Nakamura, 1999). Within the patient group, BAS sensitivity was unrelated to the duration of illness or levels of positive and negative symptoms.

3.9. Personality disorders

Given that individual differences in BIS and BAS sensitivity are supposed to underlie enduring personality dimensions, RST can be expected to have relevance not only for DSM-IV Axis I clinical disorders, but also for Axis II personality disorders (PDs). Nonetheless, only few studies thus far have explored how BIS/BAS sensitivity relates to PD symptoms. Caseras, Torrubia, and Farré (2001) studied BIS/BAS functioning in relation to cluster C PDs (avoidant, dependent, and obsessive–compulsive PD), which are characterized by high levels of anxiety and fearfulness. Consistent with their hypothesis that BIS hyperactivity would be a core vulnerability of these PDs, Caseras et al. found that sensitivity for punishment distinguished cluster C patients from patients with other PDs as well as from controls, even after controlling for concurrent Axis I anxiety or affective symptoms. In the same line, Fullana et al. (2004) found that patients with obsessive–compulsive PD showed higher sensitivity to punishment (i.e., higher BIS activation) compared to normal controls but did not differ from controls with respect to sensitivity to reward.

The aforementioned study of Taylor et al. (2006) studied BIS/BAS functioning also in relation to cluster B PD symptoms (antisocial, borderline, histrionic, and narcissistic PD), which are characterized by high levels of disinhibition. Across gender, the 'disinhibited' profile (weak BIS and strong BAS as key features) was associated with elevated features of antisocial PD and histronic PD. In men, it was additionally associated with elevated features of borderline and narcissistic PD. Somewhat unexpectedly, the 'high affectivity' profile (strong BIS and high negative affectivity as key features) also showed strong associations with cluster B features: it was associated with borderline and narcissistic PD symptoms across gender.

Pastor et al. (2007) examined the relationship between BIS/BAS sensitivity and MMPI-2 (Butcher, Dalhstrom, Graham, Tellegen, & Kaemmer, 1989) in college students. First, they hypothesized that cluster C PD symptoms would be positively associated with BIS sensitivity and this proved to be the case. In addition to the positive association with BIS sensitivity, avoidant PD symptoms were also negatively related to BAS sensitivity. Second, Pastor et al. (2007) hypothesized that cluster B symptoms would be positively associated with BAS sensitivity and again, evidence was in support of this hypothesis. In addition to the positive association with BAS sensitivity, narcissistic symptoms showed a negative association with BIS sensitivity and borderline symptoms showed a positive association with BIS sensitivity. Third, Pastor et al. (2007) hypothesized that cluster A symptoms (paranoid, schizoid, and schizotypal PD, all of which characterized by odd/eccentric behavior) would represent a mix of BIS and BAS activity. They found that both paranoid and schizotypal PD symptoms showed positive associations with BIS as well as BAS sensitivity, whereas schizoid symptoms were negatively related to BAS sensitivity.

More recently, Claes, Vertommen, Smits, and Bijttebier (submitted for publication) partially replicated and extended the findings of Pastor et al. (2007) in a mixed sample of psychiatric inpatients and normal controls using the Assessment of DSM-IV Personality Disorders (ADP-IV; Schotte, De Doncker, Vankerckhoven, Vertommen, & Cosyns, 1998) as a dimensional measure of personality disorder symptoms. Their findings were largely consistent with those of Pastor et al. (2007): (a) all cluster C scales were positively associated with BIS sensitivity; (b) all cluster B scales were positively associated with BAS sensitivity, and the borderline PD scale showed an additional positive association with BIS sensitivity; (c) cluster A scales showed a mixed pattern of associations with BIS/BAS with the paranoid PD scale being positively associated with BIS and the schizoid PD scale being negatively associated with BAS. Unlike the study by Pastor et al. (2007), the avoidant PD scale was unrelated to BAS sensitivity, the narcissistic PD scale was unrelated with BIS sensitivity, the antisocial PD scale showed a negative association with BIS sensitivity, the paranoid PD scale was unrelated to BAS sensitivity, and the schizotypal PD scale was unrelated to either BIS or BAS sensitivity. Interestingly, the Claes et al. (submitted for publication) study also included a measure of attentional control, which is an aspect of self-regulation: all PD scales were negatively related to attentional control. Moreover, several interactions between BIS/BAS levels and effortful control did emerge, suggesting that attentional control may serve as a protective factor buffering the impact of reactivity and as such decreasing the vulnerability to personality disorders.

4. Discussion and future perspectives

The studies summarized in this review have examined the associations between sensitivity of RST systems and a broad range of psychiatric disorders. Although the evidence is not entirely consistent, a couple of conclusions can be drawn. First, extreme (either high or low) levels of BIS and BAS sensitivity tend to cohere

with psychopathological symptoms. Second, specific constellations of BIS and BAS sensitivity are associated with specific types of psychopathology. Although in some cases the evidence is more consistent than in other, high BIS sensitivity is often found in association with anxiety, depression, restrictive anorexia nervosa, schizophrenia, and cluster C personality disorders, whereas low BIS sensitivity characterizes primary psychopathy. High BAS sensitivity is found in association with bipolar disorder, ADHD, psychopathy, bulimia, substance abuse and cluster B personality disorders, whereas low BAS sensitivity characterizes anhedonic depression. Third, the RST framework has the potential to map distinct pathways to apparently similar psychopathology symptoms and as such play a role in identifying important subtypes of psychiatric disorders. As detailed above, interesting work has already been done in the area of depression (anhedonic depression versus mixed anxiety–depression), psychopathy (primary versus secondary psychopathy), eating disorders (restrictive versus purging anorexia nervosa) and substance use problems (disinhibition versus high affectivity). Fourth, the RST framework has the potential to guide and refine treatment programs.

However, the findings so far are also limited in several respects and leave important questions unanswered, which we will discuss in more detail below.

4.1. Taking into account RST revisions

So far no studies on personality–psychopathology associations have been based on the revised RST (Gray & McNaughton, 2000). Nonetheless, several authors have explicitly put forward hypotheses in line with this revision that should be verified in future studies. As already pointed out above, Poythress et al. (2008) have emphasized the need to distinguish fear from anxiety in testing Lykken's (1995) theory of primary psychopathy. In the domain of anxiety, Kimbrel (2008) put forward a model of the development and maintenance of generalized social phobia that is largely based on the revised RST framework. It proposes that hyperactivity in both the BIS and the FFFS is the primary temperamental vulnerability underlying social phobia, but that the association between BIS/FFFS hyperactivity and social phobia is moderated by BAS sensitivity. Low BAS sensitivity is supposed to be an additional risk factor by facilitating FFFS activity, whereas high BAS sensitivity is supposed to be a protective factor by antagonizing FFFS activity.

These and other proposals consistent with the revised RST still await empirical testing. Such studies, however, are hindered by the fact that existing measures to assess the sensitivity of RST subsystems, such as the BIS/BAS Scales (Carver & White, 1994) and the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Avila, Molto, & Caseras, 2001), are based on the original theory and do not yield separate scores for sensitivity of the BIS versus FFFS. Worth mentioning in this respect are recent attempts to distinguish BIS and FFFS in the original BIS/BAS Scales (Heym et al., 2008) as well as the child version (Verstraeten, Vasey, Raes, Claes, & Bijttebier, submitted for publication). Another promising tool for the assessment of BIS- and FFFS-related responses has been proposed by Perkins and Corr (2006). These authors used the self-report-based paradigm (consisting of threat scenarios) that Blanchart, Hynd, Minke, Minemoto, and Blanchart (2001) have developed for the assessment of animal equivalents of fear and anxiety in human subjects, and mapped the responses to these scenarios onto existing measures of anxiety and fear. All this work will undoubtedly stimulate further research on personality–psychopathology associations based on the revised RST.

In contrast with the revision of Gray and McNaughton (2000), which only had a very limited impact on RST research thus far, Corr's (2001) introduction of the JSH has been referred to quite often. Although the JSH does not necessarily imply an interaction between BIS and BAS, most authors who incorporated it in their design explored BIS × BAS interactions and in some cases found evidence for interdependent effects, consistent with JSH (e.g., Knyazev, 2004). But the relevance of the joint subsystems hypothesis for the study of psychopathology can be disputed. As pointed out above, the JSH is expected to apply mainly in quite 'typical' conditions. Psychopathology, however, often occurs in rather 'atypical' conditions (e.g., extreme personality groups or extreme circumstances) and in these cases the SSH is expected to apply.

4.2. Modeling the personality–psychopathology relationship

The majority of studies on associations between personality and psychopathology are purely correlational, seeking to identify relationships between personality traits and forms of psychopathology but not necessarily to understand and explain them (Tackett, 2006). This is also true for RST-based psychopathology research. Nevertheless, various interesting models have been proposed to explain the relationship between personality and psychopathology, with four models in particular gaining acceptance (Shiner & Caspi, 2003; Nigg, 2006): a spectrum model (i.e., psychopathology represents the extreme end of a continuously distributed personality trait), a vulnerability model (i.e., personality may set in motion processes that cause the development of psychopathology), a pathoplastic model (personality may influence the form and prognosis of a disorder, even if it is not a component or cause of the disorder), and a scar model (psychopathology may influence the course of personality development). Most RST-based research seems to implicitly adopt a vulnerability perspective, but no studies thus far have tested the relative merits of these different models.

4.3. Taking into account moderating factors

In spite of the fact that considerable evidence supports the expected links between BIS/BAS and psychopathology, other research findings suggest that the magnitude of the associations is at best moderate. For example, in the epidemiological study of Johnson et al. (2003), who investigated to which extent levels of BIS and BAS relate to lifetime psychiatric diagnoses, diagnostic status accounted for only a modest 10% of the variance in BIS/BAS scores. These findings suggest that people with similar temperamental vulnerabilities can go on to develop quite differently due to a variety of moderating factors, which is consistent with the principle of multifinality (Cichetti & Rogosch, 1996).

Current theories of vulnerability for psychopathology (e.g., Lonigan, Vasey, Phillips, & Hazen, 2004; Nigg, 2006) emphasize the influence of self-regulatory processes enabling persons to modulate their emotional reactions and as such decrease the risk associated with this reactivity. Central to this line of thinking is the notion of "effortful control," introduced by Rothbart (1989) to describe a self-regulatory capacity that emerges in the course of development, allowing the individual to gain active control over prepotent behavioral and emotional responses. It includes behavioral forms of self-control, such as the ability to inhibit behavior effortfully when appropriate (inhibitory control) or the ability to activate behavior when needed (activation control), as well as more covert attentional processes, such as the ability to voluntarily focus or shift attention when needed (attentional control). There is increasing evidence that vulnerability to psychopathology is associated with a personality characterized by extreme levels of reactivity in combination with low levels of effortful control (e.g., Calkins & Fox, 2002; Lonigan & Phillips, 2001). So far, RST-based psychopathology research has overlooked the potential influence of individual differences in self-regulatory capacity. One notable exception is the study by Claes et al. (submitted for publication), whose findings suggest that vulnerability to some personality disorders is associated with an interactive effect of BIS/BAS sensitivity and self-regulation. Worth mentioning too is a recent

study by Dennis (2007), who found that depressed mood is associated with interactive patterns of BIS/BAS sensitivity and emotion regulation (the latter being related to effortful control).

Besides interactions between different types of personality factors, it may also be important to take into account personality–environment interactions. RST states that an individual is predisposed to certain levels of BIS and BAS sensitivity by genetic and biological factors, but that environmental contingencies and learning processes modify these predispositions through development (Hundt et al., 2007). An interesting example of such an approach is the expanded BAS disregulation model of bipolar disorder, recently proposed by Urosevic, Abramson, Harmon-Jones, and Alloy (2008). According to this model, the vulnerability of weak BAS regulation alone is not sufficient to explain why a vulnerable individual experiences manic versus depressive symptoms at a given point in time. The authors rather believe that weak BAS regulation interacts with occurrence of BAS activation-relevant and BAS deactivation-relevant environmental stimuli to predict manic and depressive episodes respectively. Thus far, however, there is a lack of studies focusing on how RST variables interact with environmental factors to predict behavioral outcomes. An exception is the investigation by Hundt et al. (2007), who reported an interactive effect of BIS/BAS sensitivity and life stress on internalizing symptoms: in conditions of high stress, both anhedonic depression and mixed anxiety–depression were predicted by high BIS; in conditions of low stress, anhedonic depression was associated with high BIS and low BAS, whereas mixed anxiety–depression was associated with high BIS and high BAS.

4.4. In search of underlying mechanisms

Given that across studies a quite consistent pattern of associations between patterns of BIS/BAS sensitivity and specific types of psychopathology emerges, a critical issue involves the processes or mechanisms through which individual differences in BIS/BAS sensitivity translate into higher levels of vulnerability to specific disorders. Psychopathology models are often limited in that they focus either on specific factors thought to be proximal causes of psychopathology (e.g., distorted information processing mechanisms) or on more general distal factors (e.g., temperament or personality characteristics). It is, however, far more interesting to combine both perspectives and use mediational models to investigate to which extent distal factors contribute to psychopathology by way of more proximal mechanisms.

Some mediational hypotheses directly follow from Gray's theory. Given that one of the outputs of BIS is increment in attention, RST predicts that individual high on BIS sensitivity should acquire stronger attentional biases to threat. In recent theoretical work, distorted information processing mechanisms have indeed been suggested as potentially valuable candidates to mediate temperament–psychopathology associations, because they show significant associations with both temperamental reactivity (e.g., BIS/BAS sensitivity) and psychopathological symptoms (Lonigan et al., 2004; Muris & Ollendick, 2005). According to Lonigan et al. (2004), attentional bias toward threat- and negative emotion-relevant information may, for example, provide one path by which personality traits may lead to disregulation of negative affect and development of psychopathology. Only few studies have explicitly tested such hypotheses. Field (2006) found that BIS sensitivity facilitates an automatic attentional bias in favor of threat cues in children, which in turn increases the risk for the development of anxiety. In undergraduate students, Beevers and Meyer (2002) found the association between low BAS reactivity and depressive symptoms to be mediated by a lack of positive experiences and positive expectancies. Knyazev (2004) found that, in adolescents and young adults, excessive affiliation with peers and conflict with adults mediate the association between high BAS sensitivity and substance use problems. Some other studies are relevant to mention because they link either BIS/BAS sensitivity or psychopathological symptoms to potentially interesting mechanisms, albeit without explicitly testing a mediational model. For example, BAS sensitivity has been found to predict craving (Franken, 2002) and these mechanisms have been shown to influence alcohol intake (e.g., Heinz et al., 2003).

There is a wide range of mechanisms through which personality traits may put an individual at risk for development of psychopathology. Shiner and Caspi (2003) outlined different types of such mechanisms, many of which may be interesting to consider in future RST-based research on psychopathology: (a) learning processes (i.e., BIS/BAS sensitivity shapes the individual's experience of classical and operant conditioning), (b) environmental elicitation (i.e., BIS/BAS sensitivity shapes the response of the environment to the individual), (c) environmental construal (i.e., BIS/BAS sensitivity shapes the ways that individuals process information and interpret the environment and their own experiences), (d) environmental selection (i.e., BIS/BAS sensitivity shapes the individual's choices about their day-to-day environments), and (e) environmental manipulation (i.e., BIS/BAS sensitivity shapes the ways that children alter, modify, and manipulate their environments).

4.5. Developmental perspective

Gray's RST is of great potential interest to the field of developmental psychopathology because it offers an opportunity to integrate multiple levels of influence such as biologically based individual differences with contextual risk and protective factors into a theoretical framework for studying pathways to psychopathology (Colder & O'Connor, 2004). Unfortunately, in most studies on personality–psychopathology associations using the RST framework, the developmental perspective is lacking. Only a handful of studies has explored psychopathology correlates of BIS/BAS sensitivity in children or adolescents (Blair, 2003; Colder & O'Connor, 2004; Coplan et al., 2006; Field, 2006; Muris et al., 2005; Slobodskaya, 2007) and none of these studies have used a prospective longitudinal design.

5. Conclusion

Although the summary of studies in this review yields a rather consistent picture with respect to which constellations of BIS/BAS sensitivity are associated with specific types of psychopathology, it also provides a clear indication that much work remains to be done. In the discussion section, a number of topics that deserves future research attention have been highlighted. Given that the literature in this domain is rapidly expanding, it can be hoped that several of these topics will be addressed and resolved before long.

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