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Development and validation of the Reward Deficiency Syndrome Questionnaire (RDSQ-29)

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Abstract

Background: The reward deficiency syndrome (RDS) integrates psychological, neurological, and genetic factors of addictive, impulsive, and compulsive behaviors. However, to date, no instrument has been validated to assess the RDS construct.

Aims: The present study developed and tested a tool to assess RDS.

Methods: Data were collected on two college and university samples. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were performed on Sample 1 ($N=1726$), and confirmatory analysis was conducted on an independent sample ($N=253$). Impulsivity and sensation-seeking were assessed.

Results: Based on EFAs, a 29-item Reward Deficiency Syndrome Questionnaire (RDSQ-29) was developed, containing four subscales (lack of sexual satisfaction, activity, social concerns, and risk-seeking behavior). CFA indicated good fit (comparative fit index (CFI)=0.941; Tucker–Lewis index (TLI)=0.933; root mean square error of approximation (RMSEA)=0.068). Construct validity analysis showed strong relationship between sensation-seeking and the RDS scale.

Conclusion: The RDSQ-29 is an adequate scale assessing psychological and behavioral aspects of RDS. The RDSQ-29 assesses psychological and behavioral characteristics that may contribute to addictions generally.

Keywords

Reward deficiency syndrome, Reward Deficiency Syndrome Questionnaire (RDSQ-29), addictive behaviors, substance use disorder, impulsive behaviors, compulsive behaviors

Introduction

The concept of Reward Deficiency Syndrome (RDS) was first introduced in 1996 by Blum and colleagues (Blum et al., 1996b; Blum et al., 1996a). The model unites addictive, impulsive, and compulsive behaviors and personality disorders. It proposes that the syndrome may emerge based on a combination of specific genetic variations, environmental stressors, and molecular effects relating to prolonged substance use or behavioral habituation. It suggests that due to these effects, a deficiency in reward mechanisms may emerge in which individuals seek out behaviors that may potentially stimulate reward pathways, with dopaminergic contributions hypothesized. The behaviors relating to RDS include substance use or other potentially addictive or risk-taking behaviors.

The hypodopamineric state/trait proposed as part of the RDS model states that hypodopaminergic function predisposes drug seeking and behaviors to release dopamine in reward circuits of the brain to overcome dopamine deficits (e.g., Blum et al., 2012). On the other hand, critiques of the RDS model

suggest that it is not clear if dopamine receptor availability or sensitivity is deficient in this syndrome. Moreover, there is little consensus about the deficiency's basis or how it might increase drug use, and that drug seeking may be precipitated by increases in dopamine transmission rather than decreases (Leyton, 2014). Therefore, although it might would be more precise to employ a more generic description for this state such as deficit in dopamine receptor signaling, then (should this be 'then' or 'than'?) labeling it as 'hypodopamineric state/trait', since the theory itself refers to the involved neurobiological background as 'hypodopamineric', the same term is used here to adhere the original concept. I'm finding it a little hard to understand from a grammatical perspective. Maybe Marc could rephrase a little

The RDS model also proposes that specific molecular genetic factors have an important role in RDS-related behaviors. The hypothesized hypodopamineric state/trait is proposed to involve polygenetic factors. Reward-related genes highlighted in the addiction literature, second messengers, other enzymes and epigenetic messenger ribonucleic acid (mRNA) are proposed to influence neurotransmitter function in dopaminergic, serotonergic, opioidergic, GABAergic, adrenergic, and cholinergic pathways (Blum et al., 2017b). The initial concept of RDS emphasized the relevance of *DRD2* in RDS – a gene coding for the dopamine D2 receptor – since this variant has been shown to be an important factor in several addictions based on the extant literature (Blum et al., 1996b). The *DRD2* had already been implicated in addictive behaviors, such as alcoholism (Noble et al., 1991; Blum et al., 1990) and other impulsive-addictive-compulsive behaviors (Blum et al., 1995a). The RDS model proposed that the A1 allele of the DRD2 genotype has a high predictive value of specific addictive behaviors. They used a mathematical method (i.e., Bayes Theorem) to predict the probability of specific addictive behaviors. They analyzed if the possession of the A1 allele associated with addictions by including addict groups and participant controls (Blum et al., 1995b, 1996b): A1 carriers have a 74% chance of developing one of the RDS-related disorders. The predictive value of the A1 allele in specific compulsive behaviors were as follows: severe alcoholism 14.3%, severe cocaine dependence 12.3%, polysubstance abuse 12.8%, chemical dependency 28.3%, severe overeating

18.6%, ingestion behaviors 35.0%, ADHD 16.0%, cigarette smoking 41.5%, pathological gambling 4.6%, and Tourette's syndrome 5.5%. However, subsequently, the extent to which the A1 allele relates to the dopamine D2 receptor versus other entities has been questioned, especially given linkage disequilibrium between *DRD2* and ANKK1 (Yang et al., 2007). Besides, genetic basis of addictions is far from being completely identified, therefore further genetic markers of RDS are also possible.

More recently, Blum et al. (2014a) summarized findings regarding common neurogenetic factors implicated in addictions and described the relevance of dopamine pathways in the nucleus accumbens and striatrum to drug addictions. RDS also has implications for addiction treatment approaches (Gold et al., 2015). The theory of the 'Reward Deficiency Solution System' (Blum et al., 2014a; Blum et al., 2017a; Blum et al., 2015a) incorporates neurogenetic testing and meso-limbic manipulation. Blum and colleagues proposed that combinations of early genetic risk diagnosis, medical monitoring, and a nutrigenomic dopamine agonist may contribute to prevention, treatment with better recovery, and relapse prevention. However, given that dopamine agonists (e.g., in the setting of Parkinson's disease) have been associated with gambling problems and other addictive behaviors (Weintraub et al., 2010), these approaches should be considered cautiously and tested directly, especially since data indicate dopamine D2-like receptors might have a stronger role in specific substance addictions (e.g., stimulant use disorders) than in behavioral addictions (Potenza, 2018; Nutt et al., 2015).

Based on animal and human experiments some studies have suggested that a pro-dopamine regulator (i.e., KB220Z) may be a good medical compound to attenuate addictions (McLaughlin et al., 2018; Febo et al., 2017; Blum et al., 2015b; McLaughlin et al., 2013). KB220Z may enhance functional connectivity between reward and cognitive brain areas (nucleus accumbens, anterior cingulate gyrus, anterior thalamic nuclei, hippocampus, prelimbic and infralimbic loci), suggesting a possible mechanism for enhancing cognitive control over reward-driven behaviors.

As mentioned above, the concept of genetic risk factors for RDS has become more nuanced. The authors of the RDS model developed a so-called GARS model (Genetic Addiction Risk Score; Blum et al., 2014b) in which they proposed multiple genes, their polymorphisms, and associated risks for

RDS. The list of the 11 proposed genetic risk factors mainly contains dopamine-related polymorphisms and gene variants related to the methylation and deacetylation of chromatin structure. This likely represents an incomplete list as genetic factors identified by genome-wide association studies (Gelernter et al., 2014b; Gelernter et al., 2015; Gelernter et al., 2014a; Kranzler et al., 2019) and incorporated into polygenic risk scores for substance and behavioral addictions (Lang et al., 2016) also warrant consideration.

In summary, the Reward Deficiency Syndrome is proposed to have a dopaminergic background. Authors of the model integrated dopamine-related neurological and genetic factors in the model based on selective literature reviews. The available case studies or empirical data regarding RDS are based on addictive disorders. There is an urgent need to have a well-defined phenomenological and behavioral description of RDS assessed utilizing a standardized tool to capture a specific set of neurological and genetic factors which drive these behaviors. The RDS model integrates psychological characteristics that may contribute to a wide range of psychiatric disorders often involving poor behavioral control (Blum et al., 1996a). A meta-analysis found inhibitory deficits associated with heavy use of or dependence on cocaine, 3,4-Methylenedioxymethamphetamine (MDMA), methamphetamine, tobacco, and alcohol, as well as in gambling disorder, supporting the view that substance and behavioral addictions are associated with impairments in inhibitory control (Smith et al., 2014). Zilverstand et al. (2018) systematically reviewed 105 task-related neuroimaging studies involving individuals with drug addictions and reported that specific brain networks (executive network, reward network) may have different roles in different stages of addiction (e.g., initiation versus compulsive use), but activities in these brain networks are similar in different types of drug addictions.

Furthermore, another review identified differences in brain function across addictions and proposed an integrative model, suggesting that neural deficits in the dorsal anterior cingulate cortex may constitute a hallmark neurocognitive deficit underlying addictive behaviors, such as impaired control (Luijten et al., 2014). A study investigated the relationship between inhibitory control, reward,

and punishment sensitivity with respect to adolescent substance use. Based on structural equation modeling analyses, evidence of a moderating role for inhibitory control was observed in the association between reward sensitivity and substance use onset, suggesting that inhibitory control regulates reactivity toward incentives that may ultimately determine substance use behaviors (Kim-Spoon et al., 2016). With respect to potentially addictive behaviors, a meta-analysis found that individuals with internet gaming disorder were more likely to exhibit impaired response inhibition on neurocognitive tasks (Argyriou et al., 2017). A meta-analysis of 40 studies examining the cognitive performance of problematic internet use found that problematic internet use was also associated with impairment in inhibitory control (attentional inhibition, motor inhibition), decision-making, and working-memory performance (Ioannidis et al., 2019).

Impulsivity is an important transdiagnostic construct linked to substance (Verdejo-García et al., 2008; Acton, 2003; Coskunpinar et al., 2013; Stautz and Cooper, 2013) and behavioral (Grant and Chamberlain, 2014) addictions. Novelty-seeking and risk-taking personality features have also be implicated as possible predictors of substance use (Wills et al., 1994; Ersche et al., 2010; Wingo et al., 2016; Wills et al., 1998; Bidwell et al., 2015; Foulds et al., 2017; Zuckerman, 2007; Horvath et al., 2004) and non-substance addictive behaviors (Nower et al., 2004; Mehroof and Griffiths, 2010).

Anxiety, depression and anhedonia have been observed in substance-using populations (e.g., Garfield et al., 2014) and people with behavioral addictions (Müller et al., 2019; Andreassen et al., 2016; Marmet et al., 2019; Hou et al., 2019). These constructs have been linked to severity of gambling (Rømer Thomsen et al., 2009), compulsive internet use and video-gaming (Guillot et al., 2016).

These data suggest that RDS-related behaviors and disorders share common characteristics, impulsivity and sensation seeking are core psychological elements of these behaviors. The RDS proposes that besides these, a general *'insufficiency of usual feelings of satisfaction'* also characterize them (p. 2 in Blum et al., 2012). However, empirical studies demonstrating the phenomenological concept of the RDS are lacking, and related psychological factors are speculative based on the RDS model and the clinical descriptions of the associated behaviors and disorders.

In summary, evidence supports the concept of the RDS, and the RDS model reflects psychological and behavioral aspects of addictive, compulsive, and impulsive behaviors. Even though the neurological and genetic background of RDS have been investigated, to date no studies have sought to develop a scale to assess the RDS and examine measures linked to the RDS. Taking this into consideration, the present study sought to develop an instrument to assess the RDS and explore its correlates. We hypothesized that a scale assessing the RDS construct would be psychometrically sound (demonstrate good validity and reliability) and would relate to transdiagnostic constructs of impulsivity and sensation-seeking.

Methods

Here we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. The datasets of the current study are available from the corresponding author on reasonable request. The final version of the developed tool, the RDSQ-29 is freely available in Appendix 1.

Participants and procedures

All data were collected in a pen-and-paper manner. Participants were recruited on a voluntary basis and received no compensation. Both samples included students of various disciplines. Measures were administered in Hungarian.

Sample 1. Sample 1 was a convenient sample of Hungarian young adults recruited from Hungarian colleges and universities. The data collection was conducted as part of the Psychological and Genetic Factors of the Addictive Behaviors (PGA) Study in the third and fourth data collection waves (Kotyuk et al., 2019). This sample included 1726 participants with a mean age of 21.0 years (SD±2.0). The male/female ratio was 42.9%/57.1%. For exploratory factor analysis, this sample was randomly divided into four non-overlapping subsamples: Subsample 1 (n=424), Subsample 2 (n=424), Subsample 3 (n=424), Subsample 4 (n=454). Also see ‘Data analysis strategy’ section.

Sample 2. This independent sample was a convenient university sample that included 253 Hungarian university students. The target sample size for the confirmatory factor analysis was based on the 'rule of thumb' which suggest 5 to 10 participants per item (Tinsley and Tinsley, 1987). Recruitment was advertised in university courses, and students participated on a voluntary basis. Mean age of the sample was 23.4 years (±5.1). Females were overrepresented (72.7%) as compared to males (27.3%). Participants completed the final 29-item version of the RDSQ (see Appendix 1).

Ethics. All participants provided written informed consent for the administered surveys. The study protocol was designed in accordance with guidelines of the Declaration of Helsinki and was approved by the Scientific and Research Ethics Committee of the Medical Research Council (ETT TUKEB). Survey data were based on self-report.

Measures and development of the instrument

Reward Deficiency Syndrome Questionnaire – The process of item generation. Despite the aforementioned neurobiological and genetic studies, the psychological (i.e., phenomenological) description of the syndrome has never been attempted previously. However, based on the aforementioned data and the psychiatric problems related to the syndrome, the following description was articulated. *A person with RDS has reckless tendencies and frequently seeks new rewarding stimuli. Natural rewards, such as eating, intimacy, sex, exercising or other pleasurable activities of everyday life do not provide such individuals sufficient satisfaction. For this reason, they are predisposed to overuse these behaviors and/or to seek other behaviors that may provide additional stimulation. Individuals with RDS do not tend to experience relaxation in their lives. Instead, they are typically active and have difficulties quitting rewarding activities. Inactivity makes them feel bored and empty*. As a next step in developing the Reward Deficiency Syndrome Questionnaire, the authors generated 72 items based on this definition based on available literature: Blum referred to RDS for example as 'an insufficiency of usual feelings of satisfaction' (Blum et al., 2012: 2), as '*an inability to derive reward from ordinary, everyday activities*' or as *'…an imbalance that…supplant an individual's*

feeling of well being with anxiety, anger or a craving for a substance that can alleviate the negative emotions' (Blum et al., 1996a: 132). Based on these studies, a prototypic profile of RDSQ was described and this description was turned into the 72 items. This was necessary because Participants completed the first 72-item version of the Reward Deficiency Syndrome Questionnaire (RDSQ, see below) for scale construction. Participants were instructed to read the statements referring to everyday human behaviors and to indicate the extent to which the statements were true for themselves on a 1 (totally disagree) to 4 (totally agree) Likert-type scale. As a first step, three independent experts were invited to review these 72 items in view of the initial statical analyses (including frequency tables and correlations) as well as the content of the items. Based on this initial review, the experts suggested excluding 21 items due to redundancy or not being properly related to the theoretical concept. Examples for the items removed at this stage: *'I usually get bored'*, *'I can even get bored of my favorite activities or hobbies if I engage in them for too long', 'I often change friends', 'I usually long for the next experience so intensely that I can't think about anything else'.* Factor structure and psychometric properties of this 51-item version of the scale was assessed on Sample1 based on the factor analysis, a final 29-item version was developed (RDSQ-29, see Appendix 1) and tested on an independent sample (Sample2). Items of the RDSQ-29 try to capture the core nature of RDS, covering satisfaction, fulfillment, pleasure, activity in general and in regard to special, 'unusual' behaviors such as extreme sexual activity or sports.

Revised Barratt Impulsivity Scale – BIS-R-21. Participants in the confirmatory factor analysis sample also completed the revised Barratt Impulsivity Scale (BIS-R-21) (Patton et al., 1995). The BIS-R-21 includes 21 items and is scored on a four-point Likert-type scale from 1 (rarely/never) to 4 (almost always/always). It assesses three impulsivity factors: Cognitive Impulsiveness, Behavioral Impulsiveness, and Impatience and Restlessness. The Hungarian BIS-R-21 showed good validity values (Kapitány-Fövény et al., 2020). The total and the scale scores are the sum of all the items, with higher values representing higher impulsivity. The cognitive impulsivity scale measures lack of

planning, instability and emotional imbalance (e.g., *'I plan tasks carefully'*, revised item). The behavioral impulsivity scale reflects a form of impulsivity which has a mainly behavioral, motor manifestation (e.g., *'I do things without thinking'*). The impatience and restlessness scale measures difficulties in concentrating on tasks or implementing behavior (e.g., '*I change hobbies'*). Earlier studies reported sufficient internal consistency values (Varga et al., 2012; Maraz et al., 2016). The mean total BIS-R-21 score on Sample 2 in the present study was 52.48 (SD±5.1) and the Cronbach alpha was 0.803.

The Brief Sensation Seeking Scale – BSSS. The Brief Sensation Seeking Scale demonstrated good psychometric properties (Hoyle et al., 2002). It comprises eight items and assesses sensation seeking on four subscales: thrill and adventure seeking (e.g., *'I like to do frightening things'*), experience seeking (e.g., '*I would like to take off on a trip with no pre-planned routes or timetables'*), disinhibition (e.g., *'I like wild parties'*), and boredom susceptibility (e.g., *'I get restless when I spend too much time at home'*). Participants rate how much they agree with the scale statements on a summative scale ranging between 1 (do not agree) and 5 (agree). The scale is scored as the sum of the items, where higher mean score represents higher sensation seeking. The total mean score on the BSSS in the present study was 23.00 (SD±5.5), and the Cronbach alpha was 0.745.

Both the Barratt Impulsivity Scale and the Brief Sensation Seeking Scale have been studied extensively in relation to addiction. For example, it has been shown that impulsivity measured by the Barratt Impulsivity Scale is a marker for vulnerability to eating problems (Meule et al., 2017), it correlates for example with alcohol use (Coskunpinar et al., 2013) and with internet addiction (Choi et al., 2014) as well. It is also a powerful predictor of addiction treatment outcomes (e.g., López-Torrecillas et al., 2014). The BSSS is a strong predictor of the intention to try cannabis in the future, and also worked at identifying adolescents at risk for drinking and smoking (Sargent et al., 2010; Stephenson et al., 2007).

Data analysis strategy

To achieve the study goals, we applied increasingly restrictive solutions of latent structure including a series of exploratory factor analyses (EFAs) and two separate confirmatory factor analyses (CFAs). Both EFAs and CFAs were performed with MPLUS 7.4. All items were treated as an ordinal scale; therefore, we applied diagonally weighted least squares (WLSMV) estimation method in both EFAs and CFAs.

In the EFAs, we applied multiple sources during the decision of factor number: (i) selecting the solution where eigenvalues level off; and, (ii) goodness of fit indices including the root-mean-square error of approximation (RMSEA) which should be equal or smaller than 0.05 for a good fit , and Tucker-Lewis index (TLI) which should reach 0.90, but its optimal value is above 0.95 (Hu and Bentler, 1999). In the EFAs, we applied bifactor rotation (bi-geomin). We have selected the bifactor rotation because we assumed that reward deficiency syndrome as a hypodopaminergic trait is a general, overarching construct or dimension reflected in different behavioral domains. The bi-factor model is a useful statistical approach to describe dimensionality, especially when a general factor is assumed theoretically (Cai et al., 2011). The bifactor measurement model allows for the items to load on an overall primary factor such as reward deficiency and also to have a secondary loading on a specific dimension such as sensation-seeking. In a bifactor measurement model, the general and specific factors are not assumed to correlate with each other; therefore, they are orthogonal to each other.

In the CFAs, goodness of fit was evaluated using RMSEA and its 90% confidence interval (90% CI), a *p*-value smaller than .05 for test of close fit, standardized root-mean-square residual (SRMR), comparative fit index (CFI), and Tucker-Lewis Fit Index (TLI). As Brown and Kline (2005) recommended, multiple indices were selected in order to provide different information for evaluating model fit. To conduct the analyses, we randomly selected four non-overlapping groups from Sample 1. Subsample 1 (*N*=424) was used to perform an initial EFA of the original 51 items (see Appendix). Subsample 2 (*N*=424) was used to conduct a separate EFA to cross-validate the factor structure found in the first analysis. In this step, we established the number of factors and we selected the items for

further analyses. Subsample 3 (*N*=424) was used to conduct an EFA on the selected 51 items to cross-validate the factor structure and reinforce the item selection. Subsamples 1–3 informed the specification of an appropriate CFA solution in Subsample 4 (*N*=454). In order to validate the measurement model on an independent sample, we conducted a CFA using a separate university sample (Sample 2; *N*=253). We also performed a CFA with covariates involving gender, sensation-seeking, and impulsivity in order to provide support for the new scale's construct validity.

In order to quantify the degree of uni-dimensionality in bi-factor models, the percent of common variance attributable to the general factor was determined by calculating the explained common variance (ECV; Ten Berge and Sočan, 2004; Bentler, 2009). We also used omega and omega hierarchical indices to assess how precisely a self-reported symptom scale score assessed the combination of general and specific constructs and a certain target construct (e.g., Brunner et al., 2012) (e.g., Brunner et al., 2012). Omega may assist in determining which composite scales possess sufficient reliable variance to be interpreted. It is a model-based reliability estimate that combines higher-order and lower-order factors. In the case of a bi-factor model, omega-hierarchical (in contrast) is the model-based reliability estimate of one target construct with the influences of the others removed. There is no clearly defined cut-off for an omega-hierarchical coefficient. Reise et al. (2013) tentatively proposed relatively strict advice to evaluate omega-hierarchical values for specific factors: namely, the minimum value would be greater than 0.50 and the preferred value would be closer to 0.75 (see also Reise, 2012).

Results

Exploratory factor analyses

EFAs with bifactor geomin rotation in two non-overlapping subsamples (Subsample 1 and Subsample 2) were performed to establish the number of factors and the items for further analyses. Table 1 summarizes the results of these factor analyses. To keep the results more comparable and to make it visually easier to follow the similar patterns by the subsamples, the results are presented by

the eigenvalues and fit indices for all three analyses. Based on the eigenvalues and fit indices, five-factor solutions were selected. The decrease of eigenvalues levelled off after the fifth factor in both samples, e.g., in case of Subsample 1 the eigenvalue dropped from 1.9 to 1.82, and in case of Subsample 2 the eigenvalue dropped from 2.02 to 1.82 from the fifth to the sixth factor. The fit indices support both four-factor and five-factor solutions. RMSEA dropped below 0.05 and TLI approached 0.90 closely in both samples. In order to avoid under-factoring, we selected five-factor solutions.

After the decision regarding the number of factors, we performed the item selection procedure. We included items which had salient factor loadings (≥0.30) at least on the general factor in Subsample 1 and Subsample 2 (Table 2). We also considered the relative homogeneity of factor loadings in the two separate samples. After the extensive selection of items, we performed another EFA with Subsample 3 which again supported the five-factor solution. For fit indices of different factor solutions in Subsample 3, see Table 1. The five factors comprise four specific factors, and the general factor (Table 3). The general factor represented a *reward deficiency tendency*. The first specific factor refers to the '*Lack of sexual satisfaction*' because the items reflect difficulties feeling sexually satisfied and having multiple sexual partners. The second specific factor reflected a tendency for *risk-seeking behaviors*. Some items here had a specific focus on searching for risky behavior in sports, while other items covered risk-seeking behavior more generally. The third factor named *activity* reflected difficulties tolerating inactivity and frequent seeking of activity. The fourth specific factor, named *social concerns*, contains two items reflecting significant others' worries about individuals' lifestyle and overstimulation. There are an additional fourteen items which only load on the general reward deficiency tendency factor without generating another independent factor.

Confirmatory factor analyses

In order to cross-validate the model, we performed a bifactor CFA on Subsample 4. Because of the difficulty of the model identification in the strictly CFA model, we applied bifactor exploratory structural equation modeling approach (Marsh et al., 2014). All items were used as indicators of

general factors. Items having a salient factor loading (>0.40) on other factors in the EFAs were also used as anchor indicator of a specific factor. Cross loadings were allowed. Orthogonal target rotation was used. However, some items loaded only on the general factor (Table 4). The fit indices were close to acceptable (χ^2=1146.6, df=323, p<0.001; RMSEA=0.075 90%CI [0.070-0.080]; CFI=0.910; TLI=0.887); therefore, we examined the modification indices in order to identify local misfits. Freeing the error covariance between two items ("*Often I want to feel stimulated no matter what I have to do to get it.*" And "*I often want a good time no matter what I have to do to get it*") improved the model fit to the acceptable level (χ^2=1045.8, df=322, p<0.001; RMSEA=0.070 95%CI [0.066-0.075]; CFI=0.921; TLI=0.901; SRMR=0.062). Factor loadings, explained common variance, omega, and omega hierarchicals are presented in Table 4. All items loaded significantly on the general factor and their respective specific factors (see salient factor loadings in bold in Table 4). Estimation of the ECV for the bi-factor model showed that the general reward deficiency factor explained 68% of the common variance. The ECVs for the four specific factors ranged from 5% to 10%.

In order to evaluate measurement precision of each subscale in assessing the blend of general reward deficiency and specific tendencies, we calculated coefficient omega. For assessing whether a specific factor measured only specific tendencies as intended or merely general reward deficiency, we computed the omega hierarchical coefficient with the modification that is necessary to take into account correlations between specific factors. Omega coefficients ranged from 0.66 to 0.97 (see Table 4). The omega hierarchical is very strong in case of the general factor (0.94) which implies that variance in the sum score is explained by the general factor supporting the uni-dimensionality of the construct. In addition, the range of omega hierarchical of specific factors was between 0.27-0.55, which is below what Reise (2012) would generally recommend. However, in the case of three factors, lack of sexual satisfaction, activity and social concerns, the omega hierarchicals were close to 0.50. Therefore, the variance of the three factor scores represent relatively largely their specific meanings. In case of risk-seeking, the specific score should be used cautiously.

We performed further cross-validation with an independent university sample (Sample 2). In this case we performed the traditional CFA analysis. In order to solve the identification problem we fixed the factor loadings of item 13 and 18 to be equal. Two error covariances were allowed between Items 15 and 24 (‘*I need more stimulation than others’; ‘I need more excitement than others’*) and between Items 25 and 29 *(‘I often want a good time no matter what I have to do to get it’; ‘Often, I want to feel stimulated no matter what I have to do to get it’*) due to the close similarity in their content. The model yielded an acceptable degree of fit (χ^2=800.7, df=361, p<0.001; RMSEA=0.069 90%CI [0.063-0.076]; CFI=0.938; TLI=0.93, SRMR=0.080). The factor loadings explaining common variance, omega, and omega hierarchicals are presented in Table 5. All factor loadings were significant. Estimation of the ECV for the bi-factor model provided evidence that the general reward deficiency factor explained 69% of the common variance. The ECVs for the four specific factors ranged from 4% to 10%. The omega hierarchical of the general factor was 0.90, similar to the previous analysis. The omega hierarchical coefficients of specific factors ranged from 0.33 to 0.58 (Table 5).

Confirmatory factor analyses with covariates

As a next step, the relationship between RDS and RDS linked dimensions was explored. In order to investigate the construct validity of the general reward deficiency factor and the specific factors, we performed a CFA on the confirmatory sample (Sample 2) with covariates, in which the general and specific factors were regressed on gender, sensation-seeking, and impulsivity (Table 6). The analysis was first carried out on the full model. However, in this case the suppressor effect of the general factor resulted in counter-intuitive negative correlations. Therefore, Partial Model 1 (for the general factor) and Partial Model 2 (for the four specific factors) were also calculated to provide a more precise description of the relationship between the factors and the further assessed personality traits. The general reward deficiency factor was associated with gender, sensation-seeking and impulsivity. Males showed stronger reward deficiency tendencies (males were coded as 2 in the database). Higher sensation-seeking and higher impulsivity statistically predicted a higher degree of reward deficiency.

The regression coefficients on the specific factors also presented evidence of convergent validity of these constructs. Based on the Partial Model 2 in Table 6, where the reward deficiency tendency is excluded, higher levels of sensation-seeking and impulsivity were associated with higher levels of activity and social concerns. Higher sensation-seeking was also associated with higher scores on the risk-seeking behavior and lack of sexual satisfaction factors.

Descriptive statistics of the Reward Deficiency Scale

Gender differences in the RDSQ total score and on the subscales were also tested. Males showed significantly higher mean score on the RDSQ total scale and lack of sexual satisfaction, social concerns, and risk-seeking behavior subscales, while females showed a higher mean score on the activity subscale (Table 7). Table 7 also summarizes the descriptive statistics on the total Sample 1 and Sample 2 (means and standard deviations of the total RDSQ and subscales). The Cronbach alpha values of the RDSQ were sufficient. In Sample 1, the 72-item version of the RDSQ had a very good Cronbach alpha (α=0.865), as did the 51-item (α=0.843) and the 29-item (α=0.895) versions. Cronbach alpha on Sample 2 was 0.917 for the RDSQ-29.

Discussion

The goal of the present study was to develop and test the psychometric properties of the RDSQ instrument. Data suggest similarities in the symptomology, etiology, and pathophysiology of different types of behavioral addictions and substance-related disorders which may share psychological underpinnings. Integrative theories cover a wide range of behaviors. For example, the component model of addictions (Griffiths (2005) argues that addictions share six basic characteristics. The Obsessive-Compulsive Spectrum Disorder (OCSD) model (Hollander, 1993; Hollander and Wong, 1995) suggests that there are some shared obsessive-compulsive features in disorders from different diagnostic categories. Additionally, the Syndrome Model of Addiction (Shaffer et al., 2004) argues

that specific factors may lead to the development of an addiction syndrome, which can manifest in many different ways, suggesting that addictions can have multiple expressions but a common etiology.

The RDS is another model that attempts to conceptualize shared psychological and biological mechanisms of different disorders. Based on the RDS model and proposed biological correlates, the psychological manifestations of the RDS could include anhedonia, restlessness, seeking of new situations and adventures, and needing high levels of stimulation, given that "normal" rewards are not perceived as satisfactory. Although the RDS shows some relatedness to specific psychological constructs, such as sensation-seeking and impulsivity, it appears to have specific characteristics associated with reward and dissatisfaction.

While the neurobiological background of RDS has previously been described, the present study is the first attempt to measure the psychological features and behavioral tendencies related to the syndrome. Therefore, the primary aim of the present study was to develop a standardized psychometric tool to assess RDS severity. Based on exploratory and confirmatory factor analyses, a 29-item questionnaire was developed that assesses a general reward deficiency tendency and four sub-dimensions: lack of sexual satisfaction, activity, social concerns, and risk-seeking behavior. Construct validity of the RDSQ-29 was also tested. RDS severity showed a moderate correlation with sensation-seeking and a modest correlation with impulsivity. Consequently, the RDSQ-29 demonstrated some similarities with theoretically associated psychological constructs, but uniqueness of the assessed construct is also suggested.

In case of the subscales, the lack of sexual satisfaction subscale moderately correlated with sensation-seeking. Feeling as if one is never getting enough sex and having more than one sexual partner at any one time showed some relatedness with sensation-seeking. It appears that the overlap between sensation-seeking and lack of sexual satisfaction may be associated with urges to seek out sexual sensations (e.g., 'I regularly change my sexual partners.'). The activity subscale showed a moderate relationship with impulsivity and sensation-seeking, which is in line with the concept of RDS. Always seeking out new activities, looking for the next thing to do, and getting annoyed by

perceived inactivity share some dimensions with impulsivity and sensation-seeking (e.g., 'I'm almost always active.'). The moderate relationship between the social concerns factor, sensation-seeking, and impulsivity suggests that the factor concentrates on social opinions regarding one's sensation-seeking and impulsive activities (e.g., 'My friends and family often worry about my lifestyle.'. The risk-seeking behavior subscale showed a strong correlation with sensation-seeking, suggesting that living dangerously, engaging in extreme activities, and taking risks are strongly associated with sensation-seeking (e.g., 'Extreme sports stimulate me.'). In conclusion, the RDSQ-29 and its subscales showed moderate relationships with sensation-seeking and impulsivity. As the RDS model integrates psychological dimensions related to addictions, these results are in line with previous findings. Impulsivity and sensation-seeking have been implicated in addictive behaviors (Verdejo-García et al., 2008; Acton, 2003; Coskunpinar et al., 2013; Stautz and Cooper, 2013; Grant and Chamberlain, 2014; Ersche et al., 2010; Wills et al., 1994; Mehroof and Griffiths, 2010; Nower et al., 2004; Zuckerman, 2007; Horvath et al., 2004). Nonetheless, besides the strong relationship between the risk-seeking behavior scale of the RDSQ-29 and sensation-seeking, the other RDSQ subscales and total score only related to sensation-seeking and impulsivity moderately, suggesting that the RDS trait is a unique construct. There is an abundance of data pointing towards the association between addictive behaviors and psychological dimensions. The newly developed psychometric instrument, the RDSQ, tries to integrate such psychological elements which have been shown as important factors in addictions, developing a psychometric instrument that assesses the RDS.

The RDSQ was developed based on the theoretical concept of the RDS. Since little empirical evidence is available in the literature concerning the conceptualization of RDS, the empirical validation, exploration of the relationship between RDS tendencies and addictive behaviors, and related psychological dimensions are needed. Future studies should focus on investigating the link between RDS severity, impulsivity, sensation-seeking, inhibition processes, reward dependence, delay discounting, and personality disorders. Furthermore, the development of the RDSQ-29 was conducted

on a young, college and university sample. Replication is needed in other samples, especially on clinical samples with participants diagnosed with substance use disorders or behavioral addictions.

Limitations of the present study include the convenience self-selected samples, the self-report data and the Hungarian population only. Since data were collected only from undergraduates, further construct validity analyzes - with data from individuals likely to have RDS, addictions or the genetic risk factors associated with it - are necessary to prove the link between RDSQ and the definition of RDS as previously used in the literature. Also, the relationship between the score on the RDSQ and the severity of addictive behaviors and other factors that correspond to severity of RDS are need to be validated. To support the trait construct of RDS, RDSQ factor scores need to be tested over time to assess within individual stability. Measures of reward functioning and addiction associated clinical constructs (such as anhedonia, depression, and anxiety) need to be tested as part of future convergent validity analysis. Impulsivity and sensation-seeking are often associated with antisociality (or asociality) which might be present in four of the 14 unique-loading items of the general RDS scale (i.e., *"I desire to participate in all aspects of life no matter the limits"; "No pain or tiredness can deter me from doing something that I am passionate about"; "I often want a good time no matter what I have to do to get it"; "Often, I want to feel stimulated no matter what I have to do to get it."*). These items suggest a willful disregard for normal constraints on behavior indicating deviant motivation as a possible linked dimension of RDS. Future research of RDS should investigate the possible role of deficient punishment sensitivity in RDS. Also, the number of participants in Sample 2 might have been a bit small for carrying out confirmatory factor analysis for a 29-item questionnaire. It also has to be noted, that the present study does not provide data on causality, proving that the activities measured by the RDSQ are a direct result of the RDS state. For example, seeking out new adventures, enjoying activities that give an adrenaline rush can equally be explained by a hyperactive reward system resulting from an increased motivational drive to engage in reward and sensation seeking behavior (Leyton, 2014). Therefore, further studies investigating the Reward Deficiency Syndrome, and the RDSQ are needed.

In conclusion, this is the first attempt to operationalize the phenomenological, psychological aspects of the reward deficiency syndrome. The RDSQ-29 is an adequate and robust scale to assess the psychological features and behavioral tendencies associated with the RDS. The final 29-item version of the scale is relatively short and easy to administer and score (see Appendix 1). The RDS model suggests that impairments in the reward system circuitry can lead to the development of the RDS, which on a behavioral level can manifest in many different types of impulsive and addictive behaviors. The development of the RDSQ-29 provides an opportunity to investigate genetic, neurological, and psychological features related to the RDS, the role of the RDS in the development of addictions.

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Conflict of interest

Mark D. Griffiths' university currently receives research funding from Norsk Tipping (the gambling operator owned by the Norwegian Government). Mark D. Griffiths has also received funding for a number of research projects in the area of gambling education for young people, social responsibility in gambling and gambling treatment from Gamble Aware (formerly the Responsible Gambling Trust), a charitable body which funds its research program based on donations from the gambling industry. Mark D. Griffiths regularly undertakes consultancy for various gaming companies in the area of social responsibility in gambling. Marc Potenza discloses the following. Marc Potenza has consulted for Opiant Therapeutics, Game Day Data, the Addiction Policy Forum, AXA and Idorsia Pharmaceuticals; has received research support from Mohegan Sun Casino and the National Center

for Responsible Gaming; has participated in surveys, mailings or telephone consultations related to drug addiction, impulse-control disorders or other health topics; has consulted for and/or advised gambling and legal entities on issues related to impulse-control/addictive disorders; has provided clinical care in a problem gambling services program; has performed grant reviews for research-funding agencies; has edited journals and journal sections; has given academic lectures in grand rounds, CME events and other clinical or scientific venues; and has generated books or book chapters for publishers of mental health texts. Zsolt Demetrovics' university receives funding from Szerencsejáték Ltd. to maintain a telephone helpline service for problematic gambling. ZD has also been involved in research on responsible gambling funded by Szerencsejáték Ltd. and the Gambling Supervision Board and provided educational materials for Szerencsejáték Ltd's responsible gambling program.

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Table 1. Eigenvalues and fit indices of exploratory factor analyses in Subsample 1, Subsample 2, and Subsample 3.

Factors	Sample 1 Eigenvalues	Sample2 Eigenvalues	Sample 3 Eigenvalues*	Fit indices of different factor solutions in Sample 1				Fit indices of different factor solutions in Sample 2				Fit indices of different factor solutions in Sample 3*			
				χ^2	df	RMSEA	TLI	χ^2	df	RMSEA	TLI	χ^2	df	RMSEA	TLI
1	10.32	9.73	9.29	4958	1224	0.085	0.625	5825	1224	0.094	0.478	1687	377	0.091	0.808
2	4.52	5.00	2.37	3601	1174	0.070	0.746	3907	1174	0.074	0.677	1163	349	0.074	0.871
3	3.75	3.66	1.87	2513	1125	0.054	0.848	2796	1125	0.059	0.794	852	322	0.062	0.909
4	2.37	2.80	1.58	2009	1077	0.045	0.894	2130	1077	0.048	0.864	637	296	0.052	0.939
5	1.90	2.02	1.37	1795	1030	0.042	0.909	1840	1030	0.043	0.891	501	271	0.045	0.953
6	1.82	1.82	1.26	1599	984	0.038	0.923	1653	984	0.040	0.906	396	247	0.038	0.967

Notes: Subsample 1 *N*=424; Subsample 2 *N*=424. Subsample 3 N=424. Df=degree of freedom. RMSEA=Root Mean Square Error of Approximation.

TLI=Tucker-Lewis Index. *The analysis was performed on the selected items only.

Table 2. Exploratory factor analyses of the 50 items with bifactor rotation on in Subsample 1 and Subsample 2.

	General factor		F1		F2		F3		F4	
item No	Subsample 1	Subsample 2	Subsample 1	Subsample 2	Subsample 1	Subsample 2	Subsample 1	Subsample 2	Subsample 1	Subsample 2
1	0.15	0.19	-0.08	-0.10	0.14	-0.06	-0.04	-0.12	-0.11	-0.02
2	**0.49**	**0.48**	**0.07**	**-0.04**	**0.52**	**-0.35**	**-0.05**	**0.05**	**0.03**	**0.23**
4	**0.35**	**0.24**	**0.02**	**0.10**	**0.02**	**-0.05**	**0.08**	**-0.12**	**0.32**	**0.46**
5	0.21	0.24	-0.12	-0.11	0.54	-0.42	0.02	-0.20	0.01	0.07
6	**0.67**	**0.62**	**0.15**	**0.14**	**0.14**	**-0.16**	**-0.08**	**0.10**	**0.22**	**0.30**
8	-0.06	0.07	0.74	0.63	-0.15	0.18	0.00	-0.03	0.01	0.01
9	**0.29**	**0.40**	**0.14**	**-0.07**	**-0.05**	**0.28**	**0.05**	**-0.04**	**-0.03**	**-0.07**
10	0.10	0.17	0.41	0.49	0.15	0.02	0.13	-0.05	-0.13	-0.20
11	**0.35**	**0.34**	**-0.18**	**0.05**	**-0.08**	**-0.07**	**0.07**	**0.05**	**0.05**	**0.14**
12	0.16	0.46	-0.08	0.02	-0.05	0.03	0.81	-0.35	-0.02	-0.42
13	0.02	0.17	0.60	0.54	0.10	-0.01	-0.03	0.01	0.01	-0.14
14	-0.23	-0.17	-0.12	-0.18	0.15	-0.27	0.11	-0.09	-0.15	-0.16
15	0.06	0.15	0.12	-0.06	0.34	-0.17	0.26	0.04	-0.25	-0.40
16	**0.67**	**0.59**	**0.11**	**0.11**	**-0.17**	**-0.10**	**0.03**	**0.31**	**-0.10**	**-0.06**
18	0.01	0.08	0.37	0.39	-0.34	0.47	0.03	-0.06	0.03	0.08
19	-0.05	0.00	0.34	0.37	-0.02	-0.07	0.03	0.09	-0.07	-0.05
20	**0.39**	**0.30**	**0.06**	**0.00**	**-0.33**	**0.31**	**0.03**	**0.30**	**-0.08**	**0.18**
22	0.21	0.46	0.16	0.24	0.12	-0.04	0.48	-0.27	0.14	-0.29
23	**0.70**	**0.53**	**-0.10**	**-0.31**	**-0.03**	**0.21**	**-0.03**	**0.33**	**-0.19**	**-0.04**
25	**0.29**	**0.25**	**0.04**	**0.02**	**-0.36**	**0.41**	**0.06**	**-0.03**	**0.44**	**0.54**

29	**0.35**	**0.40**	**-0.01**	**-0.62**	**0.01**	**0.55**	**-0.24**	**-0.01**	**-0.20**	**-0.04**
30	-0.16	-0.05	0.21	0.32	-0.32	0.35	0.07	0.05	-0.11	-0.06
31	**0.74**	**0.47**	**0.06**	**-0.01**	**-0.33**	**0.06**	**-0.07**	**0.72**	**-0.31**	**-0.07**
32	**0.66**	**0.60**	**-0.01**	**-0.12**	**0.12**	**-0.21**	**0.03**	**0.26**	**-0.04**	**0.14**
34	0.21	0.50	0.01	0.03	0.01	0.02	0.65	-0.33	0.01	-0.34
35	0.23	0.22	0.01	-0.08	0.44	-0.32	0.20	-0.15	-0.01	-0.06
36	**0.45**	**0.62**	**0.05**	**-0.10**	**-0.30**	**0.37**	**0.14**	**0.01**	**0.08**	**-0.03**
37	-0.28	-0.27	0.06	0.14	-0.26	0.21	-0.05	0.06	-0.06	-0.12
38	**0.49**	**0.49**	**-0.01**	**-0.64**	**0.03**	**0.54**	**-0.19**	**0.00**	**-0.14**	**0.01**
39	**0.53**	**0.45**	**-0.06**	**-0.18**	**-0.01**	**0.17**	**0.17**	**0.01**	**0.16**	**0.05**
40	**0.74**	**0.66**	**0.06**	**0.07**	**-0.10**	**0.04**	**-0.05**	**0.35**	**0.18**	**0.19**
41	**0.39**	**0.38**	**0.05**	**0.14**	**0.01**	**0.01**	**-0.03**	**-0.04**	**0.74**	**0.71**
42	0.05	0.17	0.80	0.77	-0.10	0.18	-0.01	0.00	0.11	0.14
43	-0.08	-0.26	0.12	0.10	-0.20	0.15	-0.23	0.08	0.07	0.25
44	**0.78**	**0.53**	**-0.04**	**0.07**	**-0.41**	**-0.06**	**-0.06**	**0.72**	**-0.31**	**-0.05**
46	0.06	0.22	0.74	0.74	-0.03	0.14	-0.01	-0.02	-0.03	-0.01
48	-0.09	0.14	0.39	0.34	0.07	0.04	0.17	-0.12	-0.22	-0.26
49	**0.79**	**0.75**	**-0.01**	**-0.11**	**0.06**	**-0.12**	**0.01**	**0.24**	**0.07**	**0.14**
50	**0.50**	**0.44**	**-0.09**	**-0.16**	**0.48**	**-0.39**	**-0.05**	**-0.11**	**0.20**	**0.18**
51	**0.47**	**0.44**	**-0.29**	**-0.35**	**0.15**	**-0.02**	**0.19**	**-0.05**	**-0.06**	**-0.04**
52	**0.61**	**0.53**	**-0.02**	**0.02**	**-0.18**	**0.19**	**0.10**	**0.17**	**0.32**	**0.31**
54	**0.85**	**0.67**	**-0.09**	**-0.13**	**-0.06**	**0.06**	**-0.03**	**0.47**	**-0.10**	**-0.03**
55	**0.41**	**0.52**	**0.23**	**0.17**	**0.21**	**-0.06**	**0.24**	**0.06**	**0.03**	**-0.23**
57	**0.48**	**0.56**	**-0.01**	**0.03**	**0.07**	**-0.08**	**0.27**	**-0.07**	**-0.06**	**-0.12**
58	**0.42**	**0.42**	**-0.01**	**0.00**	**0.08**	**-0.03**	**-0.01**	**-0.15**	**0.62**	**0.63**
59	**0.52**	**0.44**	**-0.25**	**-0.33**	**0.02**	**0.03**	**0.16**	**-0.04**	**-0.02**	**0.04**

62	**0.71**	**0.58**	**-0.02**	**0.12**	**-0.27**	**0.04**	**-0.03**	**0.39**	**-0.06**	**0.05**
64	**0.65**	**0.62**	**-0.10**	**-0.06**	**-0.02**	**-0.07**	**0.25**	**0.03**	**0.01**	**-0.09**
65	0.12	0.47	0.03	0.06	-0.07	0.06	0.82	-0.43	0.02	-0.44
68	0.31	0.27	0.00	-0.04	0.27	-0.11	0.04	0.02	-0.01	-0.10
70	0.10	0.19	0.02	0.03	0.46	-0.41	0.19	-0.02	-0.18	-0.20

Notes: Reported values are factor loadings of the exploratory factor analysis on Subsample 1 (*N*=424) and Subsample 2 (*N*=424). Boldfaced items were selected for further analyses. Numbering of the 51 items follows the numbering of the original 72 item version.

Table 3. Exploratory factor analysis of the selected items on Subsample 3.

		General factor	F1 Lack of sexual satisfaction	F2 Risk-seeking behavior	F3 Activity	F4 Social concerns
38	It can happen that I have more than one sexual partner at once.	**0.54**	**0.56**	-0.08	-0.06	0.01
9	I can never get enough sex.	**0.34**	**0.48**	0.01	0.02	-0.3
29	I regularly change my sexual partners.	**0.46**	**0.45**	-0.07	-0.14	0.01
44	Extreme sports stimulate me.	**0.63**	-0.06	**0.70**	-0.10	0.06
31	I like experimenting with extreme sports.	**0.61**	-0.02	**0.60**	-0.06	-0.04
20	I've tried many sports in my life.	**0.27**	0.11	**0.45**	0.05	-0.09
62	I look for extreme challenges in my work, sports, or anything else.	**0.68**	-0.06	**0.42**	0.16	0.02
54	I like to live dangerously.	**0.74**	0.13	**0.37**	-0.02	0.07
41	I cannot stand inactivity.	**0.41**	-0.03	-0.06	**0.64**	-0.03
25	I'm almost always active.	**0.22**	0.04	0.03	**0.55**	0.01
58	Being inactive really annoys me.	**0.44**	-0.03	-0.17	**0.52**	0.03
52	Most people think I can't sit still.	**0.47**	0.06	0.19	**0.46**	0.04
4	While doing a task or work, I find myself already planning the next task.	**0.31**	-0.14	-0.10	**0.40**	-0.03
51	My friends and family often worry about my lifestyle.	**0.51**	0.03	-0.05	0.00	**0.56**
59	My friends or my family warned me several times that I overdo my recreational activities.	**0.55**	-0.04	0.05	0.07	**0.52**
50	If nothing special happens during the day, I feel empty and bored.	**0.43**	**-0.33**	-0.24	-0.01	0.03

36	I desire to participate in all aspects of life no matter the limits.	**0.59**	**0.31**	0.01	0.03	**-0.35**
2	I don't receive gratification from everyday life.	**0.49**	-0.29	-0.11	-0.03	-0.12
16	I like activities that'll give me an adrenaline rush.	**0.64**	-0.10	**0.25**	-0.04	-0.13
40	I like to be always active.	**0.62**	0.11	0.16	**0.24**	-0.14
6	I consistently seek new situations and adventures.	**0.62**	-0.18	-0.09	0.13	**-0.24**
23	Others would consider my activities dangerous.	**0.63**	0.21	0.19	0.06	0.24
64	Often I want to feel stimulated no matter what I have to do to get it.	**0.74**	0.03	-0.10	-0.11	0.22
49	I need more excitement than others.	**0.78**	-0.29	0.04	0.02	-0.16
57	I often want a good time no matter what I have to do to get it.	**0.59**	0.00	-0.24	-0.21	0.15
39	No pain or tiredness can deter me from doing something that I am passionate about.	**0.50**	0.1	0.03	-0.09	0.15
11	I prefer being active when going out with friends rather than just talking with each other.	**0.29**	0.03	-0.03	0.01	-0.09
32	I need more stimulation than others.	**0.69**	-0.19	0.08	-0.02	-0.07
55	When I'm doing something pleasurable I can hardly stop myself.	**0.37**	0.14	-0.10	-0.02	0.00

Notes: Reported values are factor loadings of the exploratory factor analysis on Subsample 3 (N=424). Numbering of the 51 items follows the numbering of the original 72-item version.

Table 4. Exploratory structural equation modeling of selected items in Subsample 4.

	Item	Reward deficiency tendency	Lack of sexual satisfaction	Activity	Social concerns	Risk-seeking behavior
29	I regularly change my sexual partners.	**0.47**	**0.63**	-0.03	0.03	0.03
38	It can happen that I have more than one sexual partner at once.	**0.47**	**0.71**	-0.18	0.08	-0.01
9	I can never get enough sex.	**0.40**	0.26	-0.11	-0.18	-0.01
4	While doing a task or work, I find myself already planning the next task.	**0.39**	-0.02	**0.30**	0.00	-0.16
25	I'm almost always active.	0.24	-0.05	**0.42**	-0.19	0.07
41	I cannot stand inactivity.	**0.47**	-0.21	**0.73**	-0.11	-0.06
52	Most people think I can't sit still.	**0.65**	0.06	0.21	0.09	0.07
58	Being inactive really annoys me.	**0.39**	0.00	**0.60**	0.02	-0.08
51	My friends and family often worry about my lifestyle.	**0.45**	0.03	-0.17	**0.46**	-0.19
59	My friends or my family warned me several times that I overdo my recreational activities.	**0.42**	0.02	-0.08	**0.62**	-0.02
20	I've tried many sports in my life.	**0.40**	0.14	0.10	-0.09	**0.50**
31	Extreme sports stimulate me.	**0.60**	-0.01	-0.10	-0.09	**0.66**
44	I like to live dangerously.	**0.66**	-0.07	-0.07	-0.04	**0.57**
54	I look for extreme challenges in my work, sports, or anything else.	**0.82**	0.08	-0.23	0.09	0.09
62	I like experimenting with extreme sports.	**0.69**	-0.07	-0.05	0.06	**0.30**

2	I don't receive gratification from everyday life.	**0.47**				
6	I consistently seek new situations and adventures.	**0.58**				
11	I like activities that'll give me an adrenaline rush.	**0.39**				
16	I prefer being active when going out with friends rather than just talking with each other.	**0.70**				
23	I desire to participate in all aspects of life no matter the limits.	**0.73**				
32	Others would consider my activities dangerous.	**0.65**				
36	I like to be always active.	**0.62**				
39	I need more stimulation than others.	**0.60**				
40	No pain or tiredness can deter me from doing something that I am passionate about.	**0.73**				
49	I need more excitement than others.	**0.83**				
50	If nothing special happens during the day, I feel empty and bored.	**0.42**				
55	I often want a good time no matter what I have to do to get it.	**0.46**				
57	When I'm doing something pleasurable, I can hardly stop myself.	**0.47**				
64	Often, I want to feel stimulated no matter what I have to do to get it.	**0.58**				
Explained common variance		68%	8%	10%	5%	9%
Omega[#]		0.97	0.75	0.79	0.66	0.82

Omega hierarchical[##]	0.94	0.55	0.41	0.40	0.27

Notes: N=454. The upper part of the table presents the factor loadings. The salient factor loadings (0.30<) are in bold type. The rotation was target (orthogonal), correlations among specific factors were set to zero.

#Omega refers to the proportion of explained variance in the scale score attributed to the global and specific factors.

##Omega hierarchical refers to the proportion of explained variance of the scale score attributed to the specific factor. Numbering of the 51 items follows the numbering of the original 72-item version.

Table 5. Confirmatory factor analysis of the Reward Deficiency Syndrome Questionnaire (RDSQ-29) in an independent university sample (Sample2).

	Item	Reward deficiency trait	Lack of sexual satisfaction	Activity	Social concerns	Risk-seeking behavior
11	I regularly change my sexual partners.	0.58	0.74			
16	It can happen that I have more than one sexual partner at once.	0.54	0.72			
6	I can never get enough sex.	0.27	0.34			
2	While doing a task or work, I find myself already planning the next task.	0.32		0.34		
7	I'm almost always active.	0.35		0.60		
17	I cannot stand inactivity.	0.48		0.74		
22	Most people think I can't sit still.	0.68		0.34		
26	Being inactive really annoys me.	0.47		0.58		
13	My friends and family often worry about my lifestyle.	0.56			0.56	
18	My friends or my family warned me several times that I overdo my recreational activities.	0.56			0.56	
9	I've tried many sports in my life.	0.52				0.41
19	Extreme sports stimulate me.	0.63				0.61
23	I like to live dangerously.	0.80				0.30
27	I look for extreme challenges in my work, sports, or anything else.	0.74				0.31
14	I like experimenting with extreme sports.	0.57				0.82

21	If nothing special happens during the day, I feel empty and bored.	0.55				
1	I don't receive gratification from everyday life.	0.46				
3	I consistently seek new situations and adventures.	0.67				
4	I like activities that'll give me an adrenaline rush.	0.67				
5	I prefer being active when going out with friends rather than just talking with each other.	0.43				
8	I desire to participate in all aspects of life no matter the limits.	0.54				
10	Others would consider my activities dangerous.	0.83				
12	I like to be always active.	0.72				
15	I need more stimulation than others.	0.87				
20	No pain or tiredness can deter me from doing something that I am passionate about.	0.54				
24	I need more excitement than others.	0.92				
25	I often want a good time no matter what I have to do to get it.	0.53				
28	When I'm doing something pleasurable, I can hardly stop myself.	0.44				
29	Often, I want to feel stimulated no matter what I have to do to get it.	0.67				
Explained common variance		69%	8%	10%	4%	9%
Omega#		0.96	0.82	0.83	0.77	0.86

Omega hierarchical##	0.90	0.58	0.47	0.38	0.33

Notes: N=253. The upper part of the table presents the factor loadings. For identification, the factor loadings of Items 13 and 18 were constrained to be equal. Specific factors were orthogonal (correlations among them were set to zero). Error covariance was allowed between Items 25 and 29. Numbering of the items present the final 29-item version of RDSQ.

#Omega refers to the proportion of explained variance in the scale score attributed to the global and specific factors. ##Omega hierarchical refers to the proportion of explained variance of the scale score attributed to the specific factor.

Table 6. Construct validity of Reward Deficiency Syndrome Questionnaire (RDSQ-29): Confirmatory factor analysis with covariates.

	Reward deficiency tendency	Lack of sexual satisfaction	Activity	Social concerns	Risk-seeking behavior
Full model					
Gender	**0.11****	0.09	**-0.25*****	0.13	0.08
Sensation-seeking	**0.58*****	0.03	**-0.26****	-0.22*	**0.39*****
Impulsivity	**0.22*****	0.03	**-0.24****	0.30**	-0.02
R^2	51.4%	1.1%	24.5%	9.2%	15.3%
Partial model 1					
Gender	**0.10***				
Sensation-seeking	**0.59*****				
Impulsivity	**0.20*****				
R^2	50.1%				
Partial Model 2					
Gender		0.15	-0.11	0.20*	**0.13***
Sensation-seeking		**0.42*****	**0.46*****	**0.28*****	**0.67*****
Impulsivity		0.17	0.02	**0.43*****	0.14*
R^2		29.7%	22.5%	39.9%	57.7%

Notes: Standardized regression coefficients. Males were coded as 2 in the database. *p<0.05; **p<0.01; ***p<0.001.

Table 7: Descriptive statistics of the RDSQ on Sample 1 and Sample 2.

		N	Mean	Std. Deviation	p	Cohen's d	Total sample mean	Total sample std. deviation
Sample 1								
Reward dependency (RDS)	Males	740	2.12	0.45	<0.001	0.21	2.07	0.44
	Females	989	2.03	0.43				
Lack of sexual satisfaction	Males	740	1.85	0.59	<0.001	0.38	1.72	0.55
	Females	985	1.63	0.50				
Activity	Males	740	2.37	0.60	<0.001	0.18	2.43	0.62
	Females	989	2.48	0.63				
Social concerns	Males	735	1.78	0.74	<0.001	0.37	1.63	0.71
	Females	985	1.52	0.67				
Risk seeking behavior	Males	740	2.02	0.73	<0.001	0.27	1.91	0.7
	Females	988	1.83	0.67				
Sample 2								
Reward dependency (RDS)	Males	69	2.14	0.46	0.014	0.36	2.02	0.45
	Females	184	1.98	0.43				
Lack of sexual satisfaction	Males	69	1.82	0.65	0.074	0.27	1.71	0.57
	Females	184	1.66	0.52				
Activity	Males	69	2.56	0.63	n.s.	0.10	2.6	0.64

	Females	184	2.62	0.64				
Social concerns	Males	69	1.82	0.74	0.041	0.28	1.67	0.7
	Females	184	1.62	0.68				
Risk seeking behavior	Males	69	2.06	0.74	0.005	0.39	1.86	0.69
	Females	184	1.79	0.66				

Note: RDS=Reward Dependency Scale.

Appendix 1

Reward Deficiency Syndrome Questionnaire (RDSQ-29)

Instuction: Below is a list of statements referring to everyday human behaviors. Simply indicate the extent to which each of the statements is true of yourself. There are no right or wrong answers.

		Totally	Somewhat	Somewhat	Totally agree
1	I don't receive gratification from everyday life.	1	2	3	4
2	While doing a task or work, I find myself already planning the next task.	1	2	3	4
3	I consistently seek new situations and adventures.	1	2	3	4
4	I like activities that'll give me an adrenaline rush.	1	2	3	4
5	I prefer being active when going out with friends rather than just talking with each other.	1	2	3	4
6	I can never get enough sex.	1	2	3	4
7	I'm almost always active.	1	2	3	4
8	I desire to participate in all aspects of life no matter the limits.	1	2	3	4
9	I've tried many sports in my life.	1	2	3	4
10	Others would consider my activities dangerous.	1	2	3	4
11	I regularly change my sexual partners.	1	2	3	4
12	I like to be always active.	1	2	3	4
13	My friends and family often worry about my lifestyle.	1	2	3	4
14	I like experimenting with extreme sports.	1	2	3	4
15	I need more stimulation than others.	1	2	3	4
16	It can happen that I have more than one sexual partner at once.	1	2	3	4
17	I cannot stand inactivity.	1	2	3	4
18	My friends or my family warned me several times that I overdo my recreational activities.	1	2	3	4

19	Extreme sports stimulate me.	1	2	3	4
20	No pain or tiredness can deter me from doing something that I am passionate about.	1	2	3	4
21	If nothing special happens during the day, I feel empty and bored.	1	2	3	4
22	Most people think I can't sit still.	1	2	3	4
23	I like to live dangerously.	1	2	3	4
24	I need more excitement than others.	1	2	3	4
25	I often want a good time no matter what I have to do to get it.	1	2	3	4
26	Being inactive really annoys me.	1	2	3	4
27	I look for extreme challenges in my work, sports, or anything else.	1	2	3	4
28	When I'm doing something pleasurable I can hardly stop myself.	1	2	3	4
29	Often I want to feel stimulated no matter what I have to do to get it.	1	2	3	4

Scoring: Reward Deficiency Trait is computed by taking the mean of all the 29 items.

Scoring of the subscales is calculated by taking the mean of specific items:

1. Lack of sexual satisfaction: 6, 11, 16 items;
2. Activity: 2, 7, 17, 22, 26 items;
3. Social concerns: 13, 18 items;
4. Risk seeking behavior: 9, 14, 19, 23, 27 items