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Deficits in executive functions but not in decision making under risk in individuals with problematic social-network use

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ABSTRACT

Background: The tendency to strive for immediate gratification by neglecting potential negative long-term outcomes characterizes addictive behaviors, such as substance use or gaming disorder. Problematic social-network use is currently discussed as another potential addictive behavior, which is considered to result from an imbalance between affective and cognitive processes, indicated by traits such as increased impulsivity and/or decreased executive functions and decision-making abilities.
Methods: This study investigates the respective functions in social-network users by use of the Cards and Lottery Task (CLT) – a decision-making task under risk conditions in which options contain conflicting immediate and long-term outcomes at the same time. A sample of German and Spanish participants ($N = 290$) performed the CLT as well as the Modified Card Sorting Test (MCST), Barratt Impulsiveness Scale (BIS), the short Internet Addiction Test specified for social-networking (sIAT-SNS), and screeners on other potentially problematic behaviors.
Results: Comparing extreme groups based on sIAT-SNS scores (1SD above/below mean), individuals with problematic social-network use ($n = 56$), as compared to those with non-problematic social-network use ($n = 50$), showed increased attentional impulsivity and reduced executive functions. No differences were observed in decision-making performance.
Conclusion: The findings indicate that problematic social-network use is related to attentional rather than general decision-making deficits. Furthermore, problematic social-network use is likely to co-occur with other problematic Internet-use behaviors, particularly gaming or shopping.

1. Introduction

The usage number of smartphones is expected to be 3.8 billion users by the year 2021 [1]. Most common smartphone applications are communication and social-networking applications, such as WhatsApp, Twitter, or Instagram [2]. Most people use these applications in a functional and enriching way, however, some individuals report to suffer from an uncontrolled use of social networks [3].

A growing number of studies support the assumption that problematic social-network use may constitute a disorder due to addictive behaviors [3–5] comparable to gambling disorder and gaming disorder, which are classified in the DSM-5 [6] and upcoming ICD-11 [7]. Main features of problematic social-network use are considered similar to those of gaming disorder including impaired control over the use, growing priority given to the use, and continuation of use despite the experience of negative consequences [3]. Even if problematic social network-use is not yet classified officially, it has recently been argued to potentially fit the ICD-11's categorization of "other specified disorders due to addictive behaviors" (code: 6C5Y) in case specific criteria (clinical relevance, empirical evidence, and theoretical embedding) are fulfilled [8]. Nevertheless, empirical evidence regarding specific features of problematic social-network use is still rare compared to, for example, gaming disorder [9].

Theoretically, problematic addiction-like behaviors are assumed to result from an imbalance between two neural systems: an emotion-based impulsive system and a cognitive-control-based reflective system, which interact during decision-making [10]. Hyperactive impulsive processing and/or hypoactive reflective processing may make it harder to resist temptations and, over time, may cause addictive behaviors ([11], see also [12]). Individual predisposing factors, such as trait impulsivity and executive-control functions, may affect the way in which situational behavior-related cues are perceived as assumed by, for example, the I-PACE model on behavioral

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addictions [13]. Executive functions, comprising cognitive control processes of varying complexity [14–16], and decision-making abilities are suggested essential for reflection about options and the control of quick affective responses to external or internal triggers ([17,18], see also [19,20]). Reversely, weak executive-control functions and high impulsivity can foster specific behaviors in terms of preferring immediate gratifications despite negative long-term consequences – a pattern that is characteristic of addictive behaviors (e.g., [21]). High impulsivity can also contribute to this effect and is a common correlate of symptoms of specific potentially addictive behaviors such as gambling, gaming, substance-use, or problematic sexual behavior [22–28]. Such problematic behaviors are also likely to co-occur [28,29].

In the context of problematic social-network use, studies confirm the importance of impulsivity as a potential risk factor [30–32]. Cognitive-control skills can support overcoming social-network-related temptations from the environment [33,34]. Individuals with problematic (unspecified/mixed) Internet use show deficits in executive functions measured by the Stroop test, Stop-Signal, Go/No-Go, and working memory tasks [35]. In part, this is also reported for individuals with problematic social-network use [36–38], however, others report no associations with general executive functions (e.g., [39]). The meta-analysis by Ioannidis, Hook [35] also showed that problematic Internet use is associated with deficits in decision making as measured by different risky choice tasks including the Iowa Gambling Task, Balloon Analogue Risk Task, Cambridge Gambling Task, and Game of Dice Task – Tasks for which reduced performance has also been reported in individuals with substance use disorders [40]. Research on risky decision making in the special context of problematic social-network use is relatively rare. First studies indicate that individuals with problematic social-network use show reduced performance (i.e. increased risk-taking) in the Iowa Gambling Task [41,42]. However, in the Balloon Analogue Risk Task, problematic social-network use was associated with decreased risk-taking [43]. Both tasks represent decisions under ambiguous risk, as the risks of potential consequences are initially unknown [44]. Decision-making under objective risk has, to the best of our knowledge, not yet been studied in individuals with problematic social-network use. Using intertemporal choice tasks, which have been shown to predict various addictive behaviors [45], Turel, He [46] identified that problematic social-network use is associated with a preference for immediate gains (i.e. steeper delay discounting) indicating "improperly weighing of future consequences" (p. 702) potentially grounded in differences in insular cortex morphology. However, brain regions associated with executive control functions do not appear to be correlated with symptoms of problematic social-network use [46–49].

Overall, impulsivity, executive functions, and decision making appear to be critically involved in addictive behaviors. Research on these functions in problematic social-network use is fragmented and findings are inconsistent. This study adds to previous findings by providing first empirical data on decision making under objective risk in problematic social-network use. We used a decision-making paradigm that measures the ability to advantageously weigh conflicting short- and long-term consequences: The Cards and Lottery Task (CLT). The CLT simulates decision making in addiction, in which striving for immediate gratification increases the risk of negative long-term outcomes (e.g. deficits in social or work life), while sacrifice (e.g. resisting temptations) increases the likelihood of positive long-term effects. We hypothesized that individuals with problematic social-network use show increased trait impulsivity as well as deficits in executive functions and decision making under risk as compared to individuals with non-problematic use. Additionally, we had an explorative look at whether problematic social-network use co-occurs with other problematic behaviors.

2. Material and methods

2.1. Participants

This study obtained data from a total of 290 participants (74% females) between 18 and 31 years of age. The sample was subdivided a posteriori into two extreme groups based on the mean scores of the measure of problematic social-network use ($\pm 1SD$). This resulted in a "problematic" group of $n = 56$ participants (79% females; age: 18–26, $M = 20.63$, $SD = 1.95$) scoring "high" (1SD above the mean) and a "non-problematic" group of $n = 50$ participants (64% females; age: 18–31, $M = 22.70$, $SD = 3.25$) scoring "low" (1SD below the mean).

Data collection took place in the cities of Madrid (Spain) and Duisburg (Germany) in the period from November 2017 to March 2019. Participants were mainly recruited at the university campuses and psychology classes which is reflected in the high number of females. Participants were investigated in a one-to-one laboratory setting after they have been given informed consent. The procedure was approved by the ethics committee of the division of Computer Science and Applied Cognitive Sciences at the Faculty of Engineering of the University of Duisburg-Essen (Duisburg, Germany) as well as by the Comité de Ética de Investigación de la Universidad Francisco de Vitoria (Madrid, Spain) in accordance with the Declaration of Helsinki.

2.2. Instruments

2.2.1. Short Internet Addiction Test specified for social networking sites

As a measure of problematic social-network use, we used the short version of Young's Internet Addiction Test specified for social networking sites (sIAT-SNS) in the Spanish and German versions used previously [50,51]. The scale comprises 12 items measuring general subjective impairments in everyday life due to the (active or passive) use of social networks including online-communication applications and social-media sites. Each item is rated on a five-point Likert scale from 1 (= never) to 5 (= very often) resulting in a sum score between 12 and 60. Due to missing official measures and cut-off criteria, we classified individuals as showing problematic and non-problematic social-network use by building extreme groups of those scoring 1SD above ("problematic") and below ("non-problematic") the sample's mean (see also [52]). In this study's sample ($N = 290$), the mean sIAT-SNS score was $M = 27.64$, $SD = 7.52$ (range: 35–54). Accordingly, participants with sIAT-SNS scores ≥35 were grouped as "problematic" ($n = 56$) and participants with sIAT-SNS scores ≤20 formed the "non-problematic" group ($n = 50$).

2.2.2. Barratt Impulsiveness Scale

We measured trait impulsivity with the German [53] and the Spanish [54] 15-item short versions of the Barratt Impulsiveness Scale (BIS-15). Each item is rated on a four-point Likert scale from 1 ("rarely/never") to 4 ("almost always/always"). Sum scores are calculated for the three subscales non-planning, motor, and attentional impulsivity, respectively.

2.2.3. Modified Card Sorting Test

General executive functions are measured by a computerized version of Nelson's [55] Modified Card Sorting Test (MCST). The task is to sort a card with specific symbols to one of four decks by applying specific rules (i.e., sorting by color, shape, or quantity of presented symbols). The rules have to be learned from given positive/negative feedback after each sorting. After some time, the computer tells that the sorting rule has changed which requires the participant to adapt their response behavior. Accordingly, the MCST serves as a measure of executive functions including feedback processing, rule detection, and cognitive flexibility. The scores comprise perseverative errors (due to

perseveration in the outdated rule) and non-perseverative errors (comprising other incorrect responses).

2.2.4. Cards and Lottery Task

The Cards and Lottery Task (CLT; [56,57]) is a computerized risky decision-making task in which each choice has conflicting immediate and future consequences at the same time. In the CLT, participants are instructed to choose several times consecutively between two decks of cards. From the chosen deck, one card is drawn randomly, which results in A) a direct gain/loss (immediate consequence) of virtual money and, additionally, in B) a change in the probability of winning/losing a jackpot at the end of the game (future consequence). A) is represented by a card's value (positive/negative), while B) is represented by a card's symbol (star/bomb). Symbol cards are collected over the course of the game with stars increasing the chance to win and bombs increasing the risk of losing the jackpot at the end. In each of the 36 rounds, participants are explicitly informed about possible gain/loss values and amounts of star/bomb cards included in the two decks of cards. As this information can be used to infer chances/ risks/ expected values and to develop a strategy prior to making choices, the CLT depicts decisions under objective risk conditions [56]. After each decision, feedback about the drawn card is presented, the accounts are updated, and two new decks of cards including another compilation of included values and symbols are presented.

The CLT was developed based on assumptions about decision making in addiction, where immediate and future consequences are in conflict with each other. Accordingly, in the CLT, the two options vary systematically: One deck primarily includes high immediate gains but also high risk of increasing negative outcomes (i.e., many bomb-cards) while the other deck includes low gains/immediate losses but a high chance to increase positive long-term outcomes (i.e., many star-cards). In most CLT decision situations, the choice of immediate gratification is, overall, disadvantageous (with respect to expected value), however, now and then, the choice of that option can also be advantageous (depending on the individual's previous decisions). For a detailed description of the CLT's contingencies see Mueller, Schiebener [56]. The main scores represent the expected value of the final outcome (CLT_EV) and the number of advantageous decisions (CLT_NAD) which can reach values between 0 and 36.

2.2.5. Screening for other problematic (internet-use) behaviors

In addition to the sIAT-SNS, we asked participants to indicate other activities they do online including shopping, gaming, gambling, and pornography use. For each of those activities the participant had indicated to do (besides social networking), the participant answered four additional anchor items of the sIAT specified for the respective activity (see [58]). The sum score for each behavior can reach values between 4 and 20. Converted from the cut-offs proposed for the 12-item version [52], a sum score of ≥10 was used to indicate potential problematic behavior. Using this classification, the number of problematic Internet-use behaviors was accumulated with possible values between 0 and 4.

We additionally screened for problematic drinking using the AUDIT alcohol consumption questions (AUDIT-C; [59]) as well as nicotine dependence using a short version of the Fagerström Test for Nicotine Dependence by Diaz, Jané [60].

3. Results

Statistical analyses were carried out with IBM SPSS Statistics version 26. The mean sIAT-SNS scores of the "problematic" and "non-problematic" groups were 38.69 ($SD = 3.79$) and 16.90 ($SD = 2.64$), respectively. Comparing the two groups regarding sex and age distributions revealed no difference in sex distribution ($U = 1196$, $z = 1.66$, $p = .098$), but a difference in mean age with the "problematic" group being significantly younger than the "non-problematic" group ($MD_{age} = 2.07$ years), $t(78.30) = 3.93$, $p < .001$. Accordingly, we controlled for age in the following analyses.

3.1. Differences in impulsivity, executive functions, and decision making

Fig. 1 illustrates the distribution of the main variables separated by group. A MANCOVA was used to test differences in impulsivity, executive functions, and decision making between groups. Age was included as covariate. BIS-15 (non-planning, motor, attentional), MCST (total errors, perseverative errors), and CLT scores (NAD, EV_score) were included as dependent variables. There was a significant difference between individuals with problematic (high sIAT-SNS) and those with non-problematic social-network use (low sIAT-SNS) when considered jointly on the dependent variables, Wilk's $\Lambda = 0.842$, $F(7,97) = 2.61$, $p = 0.017$, $\eta_p^2 = 0.158$. Discriminant function analysis and univariate comparisons were performed to further explore effects on specific variables. The results are shown in Table 1. Applying Bonferroni correction to non-orthogonal variables, the groups significantly differed on BIS-15 attentional ($p < 0.017$) and MCST errors ($p < 0.025$), with the "problematic" group showing higher scores than the "non-problematic" group. Apart from age (−0.555), these two variables, especially BIS-15 attentional, best discriminated between the groups (see Table 1). According to Cohen [61], the effect sizes indicate a medium effect of attentional impulsivity and a small effect of reduced executive functions. Regarding decision making under objective risk, as measured by the CLT, the groups did not differ significantly (see Table 1). The covariate age did not have any significant effect.

3.2. Differences regarding other problematic (internet-use) behaviors

Additionally, we compared problematic and non-problematic social-network users with regard to indicators of other problematic Internet-use behaviors. Looking at the sum scores of the anchor-items for online

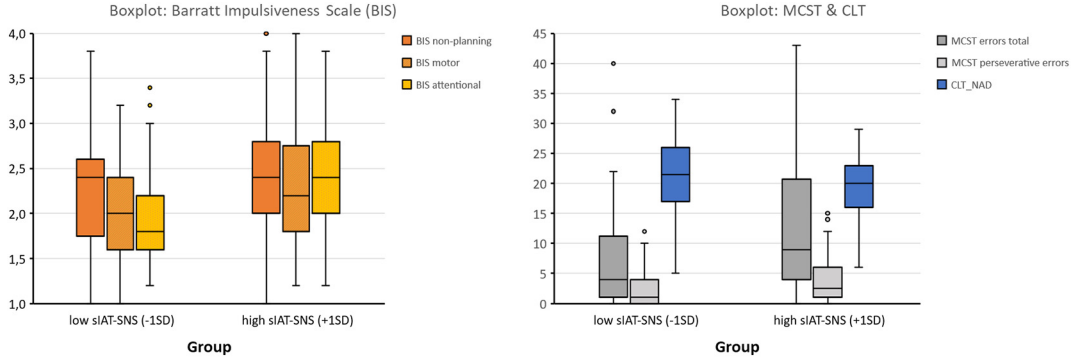

Fig. 1. Boxplots of the Barratt Impulsiveness Scale (BIS), the Modified Card Sorting Test (MCST), and Cards & Lottery Task (CLT) measures. *Note.* sIAT-SNS = short Internet Addiction Test specified for social-networking sites; NAD = Number of advantageous decisions.

Table 1
Descriptive statistics and coefficients of the discriminant function analysis and univariate ANCOVAs comparing individuals with problematic (high sIAT-SNS) and non-problematic (low sIAT-SNS) social-network use.

	high sIAT-SNS (n = 56)		low sIAT-SNS (n = 50)		Standardized canonical discriminant function coefficient	Univariate comparisons		
	M	*SD*	*M*	*SD*		*F*	*p*	η^2_p
BIS-15 non-planning	2.41	0.69	2.27	0.64	−0.107	0.78	0.379	0.008
BIS-15 motor	2.23	0.68	2.03	0.52	−0.057	1.68	0.198	0.016
BIS-15 attentional	2.44	0.56	1.94	0.54	0.709	15.11	<0.001	0.128
MCST errors total	12.96	11.40	7.48	8.86	0.308	5.26	0.024	0.049
MCST pers. errors	3.73	3.77	2.50	3.07	0.088	1.94	0.166	0.019
CLT_NAD	19.43	5.40	20.70	6.97	−0.090	0.72	0.399	0.007
CLT_EV	2453.98	2319.43	3126.00	2230.91	0.137	0.69	0.410	0.007

Notes. Covariate: age; sIAT-SNS = short Internet Addiction Test specified for social-networking sites; BIS = Barratt Impulsiveness Scale; MCST = Modified Card Sorting Test; CLT = Cards and Lottery Task; NAD = Number of advantageous decisions; EV = Expected value. * Standardized canonical discriminant function coefficients.

gaming, shopping, gambling, and pornography use, we identified individuals with zero, one, two, as well as three other potentially problematic online behaviors. A Mann-Whitney-*U* test comparing problematic and non-problematic social-network users regarding the number of additional problematic Internet-use behaviors revealed a significant difference, $U = 617.50$, $Z = 5.97$, $p < .001$. While non-problematic social-network users tended to no other problematic Internet-use behavior ($Mdn = 0$), more than half of the problematic social-network users scored problematic on the screening instrument of at least one other online behavior ($Mdn = 1$; see Fig. 2 A). Regarding the type of behavior, most of the problematic social-network users (39.29%) scored additionally problematic on shopping and more than one quarter (26.8%) indicated problematic gaming (see Fig. 2 B).

Regarding substance use, a chi-square test was used to compare problematic and non-problematic social-network users regarding cases of problematic alcohol and nicotine use respectively. None of the expected cell frequencies were below 5. Results show that problematic social-network use is associated neither with problem drinking, $\chi^2(1) = 0.38$, $p = .537$, nor with nicotine dependence, $\chi^2(1) = 1.13$, $p = .288$.

4. Discussion

This study investigated the relevance of impulsivity, executive functions and decision making under objective risk in problematic social-network use as well as the co-occurrence of other problematic behaviors. The results of extreme-group comparisons indicate that individuals with problematic social-network use (compared to those without) show heightened attentional impulsivity and lower executive functions but, contrary to our hypothesis, no reductions of decision-making performance under objective risk.

The findings indicate associations between problematic social-network use and facets of trait impulsivity, which is consistent with previous findings [30–32,62] as well as with those on other problematic Internet-use behaviors (e.g., [25,63]) and substance-use disorders [64]. Applied to dual-system theories (e.g., [10,65,66]), trait impulsivity represents the manifestation of a hyperactive impulsive neural system that processes immediate affective responses towards (anticipated) rewards. Neuroscientific studies underline that activation and morphology of brain areas associated with diminished impulse control are associated with problematic social-network-use severity [46,49]. The current results let assume that especially the ability to control and focus attention is diminished in individuals with problematic social-network use, while other facets of impulsivity are not affected, which is in line with previously reported associations [5,62].

Individuals with problematic social-network use, as compared to those without, showed less accurate performance in the MCST but equally superior performance in the CLT. These results indicate that some aspects of executive functions – probably those related to attention – may be reduced in problematic social-network use, but without impairments in general decision-making competence which involves a weighing of conflicting immediate and long-term consequences. The assumption of attention-related dysfunctions is consistent with models assuming that, in individuals with problematic addiction-like behaviors, inhibitory control is especially reduced in case specific behavior-related stimuli are present which drag additional attention [13]. The result of reduced executive functions in individuals with problematic social-network use contradicts with previous findings [49,67], but, it draws similarities with other problematic (online) behaviors as respective

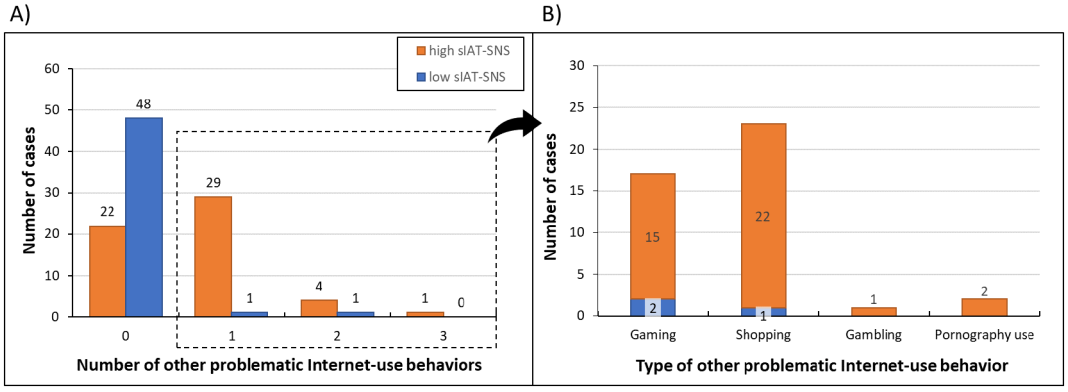

Fig. 2. Distribution of individuals with problematic and non-problematic social-network use regarding A) number and B) type of other potentially problematic Internet-use behaviors. *Note.* sIAT-SNS = short Internet Addiction Test specified for social-networking sites with high values (1SD above mean) indicating problematic and low values (1SD below mean) indicating non-problematic social-network use.

reductions have also been demonstrated in individuals with gambling disorder or gaming disorder [68–72], problematic online pornography use [73,74], and unspecified problematic Internet-use [35]. In the context of problematic social-network use, Wegmann, Müller [62] reported that general executive functions (measured by the MCST) and attentional impulsivity interact in the prediction of problematic social-network-use severity. Accordingly, — and in accordance with dual-process theories – especially the combination of high attentional impulsivity and weak executive control may potentially contribute to an uncontrolled use of social networking sites.

Previous reports of decision-making deficits in individuals with problematic social-network use were mainly based on performance in the Iowa Gambling Task and Balloon Analogue Risk Task [e.g., 41, 43]. These tasks, in contrast to the CLT, depict decisions under ambiguity in which the potential outcomes and risks of decision options are not given but have to be derived from the given feedback. Accordingly, feedback processing is more important in decisions under ambiguity than in decisions under objective risk [75]. On this basis, it might be assumed that problematic social-network use is related to attentional deficits which especially affect learning from feedback, and which in turn affects higher cognitive and decision-making processes particularly depending on an adequate integration of feedback from previous decisions, i.e., decisions under ambiguity. The current results showed no impairments in CLT performance, which may indicate that social-network users' decision making is not impaired in situations that do not necessarily require previous experience to make advantageous choices. To prove this assumption, future studies should test associations between problematic social-network use and decision-making performance in different types of risky choice tasks.

The results of the screeners for other problematic behaviors suggests that problematic social-network use is likely to co-occur with other problematic Internet-use behaviors, especially gaming and shopping. The co-occurrence of disordered gaming and social networking has also been demonstrated in a recent review by Burleigh, Griffiths [29]. Against their findings regarding gaming disorder, our findings indicate no associations between problematic social-network use and alcohol or nicotine dependence, which adds to assumed differences in the proximity of individuals with addictive behaviors to those with substance-use disorders (e.g., [28]).

To note, we cannot infer causal relationships from the results of this study. The investigated sample is not representative of the general population and we did not control for state anxiety which might have increased during the assessment due to the restricted access to the smartphone. Furthermore, we examined a non-clinical sample, for which typically no significant correlations are reported between disordered social-network-use severity and impairments in prefrontal cortex regions associated with executive functions [46–49,76]. However, with the building of extreme groups we were able to identify potentially clinically relevant cases of problematic social-network use for which, notably, there is still missing consensus about appropriate diagnostic tools and criteria. We would like to note that the "problematic" group consisted of individuals with sIAT scores ≥35, which is clearly above the previously defined cut-off of 31 for problematic use, and a mean score of 38 which even exceeds the proposed cut-off of 37 for pathological use [52]. Future longitudinal studies should examine cause-effect relationships between reduced executive functions (including prefrontal cortex impairment) and problematic social-network use to help identify when and why behavior shifts from excessive but non-problematic to clinically relevant problematic social-network use causing substantial impairment of everyday functioning.

Data availability statement

Data will be made available for research use purposes, upon request.

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Declaration of Competing Interest

none.

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