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Internet addiction and its facets: The role of genetics and the relation to self-directedness

Elisabeth Hahn [a,*,1], Martin Reuter [b,c], Frank M. Spinath [a], Christian Montag [d,e,1]

[a] Department of Psychology, Saarland University, Saarbruecken, Germany
[b] Department of Psychology, University of Bonn, Bonn, Germany
[c] Center for Economics and Neuroscience, University of Bonn, Bonn, Germany
[d] Institute of Psychology and Education, University of Ulm, Ulm, Germany
[e] Key Laboratory for NeuroInformation/Center for Information in Medicine, School of Life Science and Technology, University of Electronic Science and Technology of China, Chengdu, China

HIGHLIGHTS

- We examined Internet addiction and its facets in a twin-sibling design.
- Focus on adults to explore the role of age and developmental processes
- Use of different measurements to capture Internet addiction components
- Results showed considerable variation in heritability estimates.
- Heritability of Internet addiction facets was partly shared with self-Directedness.

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ABSTRACT

A growing body of research focuses on problematic behavior patterns related to the use of the Internet to identify contextual as well as individual risk factors of this new phenomenon called Internet addiction (IA). IA can be described as a multidimensional syndrome comprising aspects such as craving, development of tolerance, loss of control and negative consequences. Given that previous research on other addictive behaviors showed substantial heritability, it can be expected that the vulnerability to IA may also be due to a person's genetic predisposition. However, it is questionable whether distinct components of IA have different etiologies. Using data from a sample of adult monozygotic and dizygotic twins and non-twin siblings ($N = 784$ individuals, $N = 355$ complete pairs, $M = 30.30$ years), we investigated the magnitude of genetic and environmental influences on generalized IA as well as on specific facets such as excessive use, self-regulation, preference for online social interaction or negative consequences. To explain the heritability in IA, we further examined the relation to Self-Directedness as potential mediating source. Results showed that relative contributions of genetic influences vary considerable for different components of IA. For generalized IA factors, individual differences could be explained by shared and non-shared environmental influences while genetic influences did not play a role. For specific facets of IA and private Internet use in hours per week, heritability estimates ranged between 21% and 44%. Bivariate analysis indicated that Self-Directedness accounted for 20% to 65% of the genetic variance in specific IA facets through overlapping genetic pathways. Implications for future research are discussed.

1. Introduction

Since their invention in the 80s and 90s, computers, mobile-phones, and the Internet itself have developed rapidly and nowadays they are inevitable information and communication vehicles in our daily lives. Despite the fact that the Internet offers many opportunities and makes our life more convenient some individuals have difficulties dealing with the omnipresence of these technologies. As a consequence, a variety of problems in different areas of life emerge.

Internet addiction (IA) is a relatively new phenomenon and an increasing problem worldwide (Ko, Yen, Yen, Chen, & Chen, 2012). A rising number of humans spend more and more time both for leisure and business activities on the Internet, whereas an overuse of the Internet could have potential bad outcomes for one's own personal health (e.g., Kim & Chun, 2005; Xiuqin et al., 2010), well-being (Lachmann,

* Corresponding author at: Department of Psychology, Saarland University, Campus A1 3, D-66123 Saarbruecken, Germany.
E-mail address: e.hahn@mx.uni-saarland.de (E. Hahn).
[1] Shared first authorship, these authors contributed equally.

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Sariyska, Kannen, Cooper, & Montag, 2016) as well as social and work life (e. g., Nalwa & Anand, 2003; Young, 2004). To identify individual and contextual causes, correlates and negative consequences of these behavioral problems, a growing body of research focuses on problematic or addictive behaviors related to the use of the Internet. Although IA is not an official diagnosis in DSM-V, a specific form – namely Internet Gaming Disorder - has been included as an emerging disorder in section III in the latest version of the manual to highlight the importance for further research in this area. In the present paper, the main research question is to what extent genetic and environmental differences between individuals can explain why some individuals have more problems caused by their Internet usage than others. We focused on generalized Internet addiction and its specific behavioral facets (but not on distinct forms such as Internet Gaming or Internet Pornography Addiction). Furthermore, we investigated the extent to which the personality trait Self-Directedness mediates the heritability of IA and its facets.

Of note, scientists still argue over the definition and how to best name IA (e.g., Yellowlees & Marks, 2007). There is a consensus about key components of IA such as excessive use, mostly represented in many (private) hours per day, preoccupation with the using behavior, unsuccessful attempts to stop or reduce time online, as well as negative consequences in different life domains. Thus, there is also an ongoing debate on how this phenomenon should be labeled, diagnosed accurately and if it is a unidimensional or multidimensional disorder differentiated through subdomains and specific behaviors. In detail, it is still not clear if IA is actually best represented by being an addiction or linked to an existing other psychopathology such as depression, impulsive-control disorder or ADHD (co-morbidities in these areas have been observed with IA; e. g. Yen, Ko, Yen, Wu, & Yang, 2007a; Young & Rogers, 1998; Treuer, Fábián, & Füredi, 2001, Sariyska, Reuter, Lachmann, & Montag, 2015). Although the use of the terms problematic, compulsive or excessive use of the Internet might be less critical, we use the term IA throughout this paper, because it is well established in the literature (see also a general overview by Montag & Reuter, 2015e).

Years after the first description of a IA patient by Kimberly Young (1996, 1998a, 1998b), Tao et al. (2010) recently proposed a so called "2 + 1" rule encompassing both preoccupation with the Internet and withdrawal symptoms as prerequisite for IA together with one out of a list of several symptoms such as development of tolerance to diagnose IA. Of note, as a course criterion they also ask for a minimum of 6 h of daily private use of IA for a minimum of three months. The prevalence of IA differs strongly around the globe (depending among others on cultural differences, different methodologies used to diagnose IA and different sociodemographic variables of the samples under investigation; e.g. Shaw & Black, 2008; Spada, 2014). In Germany, where the present study took place, recent evidence points to a prevalence of about 1% in the population for IA (Rumpf, Meyer, Kreuzer, John, & Merkeerk, 2011).

Towards a fuller understanding of IA, Brand et al. (2016) proposed an Interaction of Person-Affect-Cognition-Execution (I-PACE) model to capture the processes underlying the development and maintenance of an addictive use of the Internet and its applications. The model explicitly distinguishes between predisposing factors making individuals vulnerable to an excessive use, and factors serving as moderators and mediators in the processes to and maintenance of addiction. Within the core predisposing characteristics of the person, personality (e.g. impulsivity, low self-esteem) as well as genetic factors together with other psychopathologies are specified while dysfunctional coping strategies or expectancies about the use and affective and cognitive responses are proposed as mediators and moderators. Most previous studies have focused on different presumed risk factors associated to IA, such as poor family functioning, low socio-economic status, and negative life events (Ni, Yan, Chen, & Liu, 2009; Park, Kim, & Cho, 2008; Yen, Yen, Chen, Chen, & Ko, 2007) or personality correlates (e.g. Müller, Beutel, Egloff, & Wölfling, 2014; Sariyska et al., 2014). However, it remains uncertain whether these factors exert their effect through an 'environmental' pathway, such as context, situation or family climate, or through biological pathways such as genetic factors shared by family members. It is now well established that genes are somehow involved in all aspects of human behavior (Polderman et al., 2015) and that relationships, such as the relationship between certain personality measures and incidence of depression (Kendler & Myers, 2010), may also be due to shared genetic risk factors. Given that both, personality and IA have shown a heritable component and to be phenotypically linked, it is likely that personality traits represent a vulnerability factor for IA that could be mediated through genetic mechanisms (see Fig. 1).

While previous family, adoption and twin studies revealed substantial genetic influences on a broad range of other addictions (e.g., substance use, pathological gambling; for a review see Agrawal et al., 2012), only a few studies investigated IA in a behavior genetic research design. So far, studies indicated that both genetics and environmental influences play a role, but the results between studies show pronounced variation. The first study by Li, Chen, Li, and Li (2014) reported heritability estimates for generalized IA of 58% for females and 66% for males. The remaining variance in the total addiction score was explained by unique environmental influences. In the second study, Deryakulu and Ursavaş (2014) investigated not only Internet addiction in general but also different components of problematic Internet use such as the excessive use, social benefit through the Internet compared to real life interactions and negative consequences associated with Internet use. They found extremely varying estimates for genetic influences from 19% to 86% but only for male participants while for the female participant heritability estimates were zero. With respect to the environment, 19%, respectively 17% of the variance were explained by shared environmental influences while the remaining variance was non-shared environmental in nature. Using a large population-based sample of adolescent twins, Vink, van Beijsterveldt, Huppertz, Bartels, and Boomsma (2016) reported a heritability of 48% for generalized compulsive Internet use which is comparable to a recent study by Long et al. (2016) showing that frequency of Internet use was explained by genetic factors accounting for 41% of the variance. Altogether, previous studies revealed inconsistent results with respect to the extent genetic influences are involved as well as whether sex differences occur in heritability estimates. All previous studies focused on adolescent participants. Given that also older generations suffer from being addicted to the Internet, it is important to further investigate the pattern of genetic and environmental influences on IA and its components in adults.

Moreover, only the study by Li et al. (2014) also investigated *how* to explain the heritability in IA in relation to personality by examining effortful control, an important aspect of self-regulation. Analysis indicated a significant overlap between genetic influences on IA and effortful control (larger in boys than in girls) which provides insights into possible genetic pathways. However, common genetic factors explained only a part of the heritability in IA leaving the rest of the genetic variance unexplained. Given that associations between IA and other personality traits, such as (low) Self-Directedness (Montag, Jurkiewicz, & Reuter, 2010; Montag et al., 2011; Sariyska et al., 2014), (high) impulsivity (Cao, Su, Liu, & Gao, 2007), (high) sensation-seeking (Lin & Tsai, 2002), (low) self-control (Kim, Namkoong, Ku, & Kim, 2008), and (high) neuroticism (Dong, Wang, Yang, & Zhou, 2013; Tsai et al.,

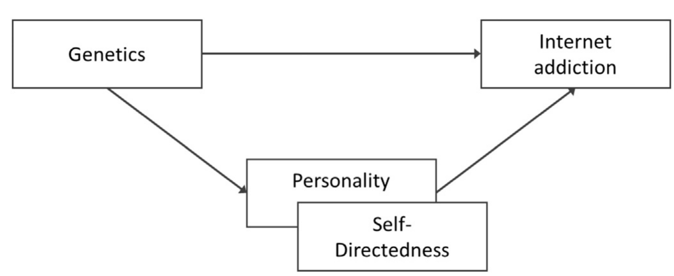

Fig. 1. Genetics could influence Internet addiction directly as well as mediated via personality characteristics such as Self-Directedness.

2009) have been identified, it can be hypothesized that these personality traits may also function as mediators to explain genetic influences on IA. For all these personality traits, a genetic basis has been demonstrated (see meta-analysis by Polderman et al., 2015).

In light of the recent findings, the present study aimed to revisit the question on the heritability of IA, but it clearly also goes beyond these studies in several ways. First of all, we investigated not only generalized tendencies for Internet overuse in terms of a total Internet addiction score, but also assessed specific components of IA such as loss of control, social interactions or negative outcomes. Because of the "definition problem" surrounding IA, two different questionnaires (i.e., Internet Addiction Test, Generalized Problematic Internet Use Scale 2) were applied to capture IA and its components. So far, despite the growing research on IA, findings are often not comparable because of the great diversity of theoretical approaches, varying diagnostic criteria and different instruments to capture IA (Huisman, Eijnden, & Garretsen, 2001). The majority of studies still investigates IA as unidimensional construct (for an overview see, Byun et al., 2009). However, an early theoretical study on the etiogenesis of IA by Davis (2001) proposed the distinction of generalized and specific forms of IA (here different activities such as pornography or online social network addiction), which has been empirically tested by Montag et al. (2015). Moreover, it has been shown that IA in general is associated with various psychiatric comorbidities such as depression (e.g., Caplan, 2002; Yen et al., 2007b; Sariyska et al., 2015), anxiety disorder (e.g., Bernardi & Pallanti, 2009; Sariyska et al., 2015), or attention deficit hyperactivity disorder (Bernardi & Pallanti, 2009; Yen et al., 2007b). However, less is known about which specific components, behavioral actions and problems of IA are important factors linking IA to a variety of mental health issue.

Other addictions, such as drug or alcohol abuse typically occur during adolescence, whereas disorders emerge during early adulthood. The process of addiction begins with early stages of initiation of use, followed by escalation to regular and chronic use, which can become problematic and develop into addiction. It has been shown that even within these stages there is considerable variation in etiology depending on whether adolescents or adults are being studied (Agrawal et al., 2012). Therefore, and in contrast to previous research, the present study focused on IA in a sample of adult twins and non-twin siblings to explore the relative contribution of genetic and environmental influences. According to Beard (2005), accessibility could play a role in the process of developing an addiction, specifically, the greater the availability of the Internet, the greater the probability that people will engage in Internet activities. In line, Prensky (2001) introduced the distinction of digital immigrants - those who were not born into the digital world but have, at some later point, become fascinated by it - and digital natives[2] in terms of ""native speakers" of the digital language of computers, video games and the Internet" (Prensky, 2001, p. 1). To evaluate the effect of accessibility at different developmental stages, *age* and *age at first contact* were investigated with respect to all components of IA in more detail in the present study.

Moreover, our earlier studies (Montag et al., 2010; Montag et al., 2011; Sariyska et al., 2014) give empirical evidence that the character dimension Self-Directedness of Cloninger's Temperament and Character Inventory (TCI, Cloninger, Svrakic, & Przybeck, 1993) is of great interest for a better understanding of IA. Low self-directed humans can be described by low self-esteem, low satisfaction with their own personalities and problems in handling everyday life. Low Self-Directedness is also linked to lower will-power and lower self-regulation abilities (Cloninger et al., 1993, p. 979). Low Self-Directedness was associated with higher IA in all of our earlier mentioned studies. Given the importance of Self-Directedness for IA, we also investigated in the present study if genetic factors exert their influence via Self-Directedness on IA to explain the heritability in IA. As low Self-Directedness is associated with low will power, this personality trait might predispose to loss of control over Internet usage.

Finally, our study differs in terms of the investigated cultural background. While the first twin studies on IA have been investigated in China (Li et al., 2014), Turkey (Deryakulu & Ursavaş, 2014), Netherlands (Vink et al., 2016), and Australia (Long et al., 2016), the present study has been conducted in Germany.

Altogether, the following hypotheses were observed:

Hypothesis 1. Age will correlate negatively with generalized Internet addiction as well as its specific components. Moreover, digital natives will show higher scores in Internet addiction than digital immigrants.

Hypothesis 2. Self-Directedness will correlate negatively with Internet addiction and its specific components (low Self-Directedness will be associated with higher tendencies towards Internet addiction).

Hypothesis 3. Different specific components of Internet addiction will be influenced by genetic factors to differing degrees.

Hypothesis 4. The relations between Self-Directedness and generalized Internet addiction and its specific components will be mediated by common genetic and specific environmental effects.

2. Methods

2.1. Sample

Data for the present study were drawn from the German Twin Study on Internet- and Online-Game Behavior (TwinGame), a study of adult twins and non-twin sibling pairs reared together. From 2013 to 2014, twins and non-twin siblings (with a maximum age difference of three years) were invited to complete an online or paper-pencil version of our questionnaire which encompasses questions on different areas such as Internet consumption behavior, first contact with the Internet, personality characteristics, health, subjective well-being, empathy and several attitudes. Participation was on a voluntary basis and was rewarded with 10 Euros per person. The present sample comprised 784 individuals, aged between 17 and 60 years ($M = 30.3$, $SD = 9.6$) including 528 twins ($N = 236$ complete pairs) and 256 non-twin siblings ($N = 119$ complete pairs). The sample covered a wide range of socioeconomic background including 7% lower middle and lower class, 60% middle class and 33% upper middle and upper class. In total, female participants were overrepresented in the sample, a fact that will be discussed with respect to the results. The twin sample included 113 monozygotic (MZ) female pairs, 33 MZ male pairs, 44 dizygotic (DZ) female pairs, 16 DZ male pairs and 30 opposite-sex pairs. The sibling sample consisted of 70 female pairs, 11 male pairs and 38 opposite-sex pairs. About 17% of the siblings showed an age difference of one year, 66% were two years apart and 17% were about three years apart. All participants filled in different questionnaires on IA and related behavior as well as certain personality questionnaires. Zygosity was determined by a valid self-report questionnaire assessing physical similarity (e.g., eye color, hair structure, skin color) as well as the frequency of twin confusion by different relatives, teachers, and peers across the life span.[3] The accuracy of the questionnaire method used in our sample was estimated to be 95% compared to DNA markers (Oniszczenko, Angleitner, Strelau, & Angert, 1993; Price et al., 2000). The study was approved by the research ethics' committee of the University of Bonn, Bonn, Germany.

[2] To distinguish between digital natives and digital immigrants, we divided the sample into individuals born before and after 1992. 1992 was chosen because of the growth of the Web since that time.

[3] For 53 individuals, zygosity could not be determined because of missing information.

2.2. Questionnaires on Internet addiction

First of all, participants filled in the German version of the Internet Addiction Test (IAT) by Young (1998b), which is based on diagnostic criteria for pathological gambling and has been tested for psychometric properties by Widyanto and McMurran (2004). The items comprise several facets of IA, such as loss of control, preoccupation and psychological dependence. Our self-translated German version has been used in several of our earlier works and is characterized by good psychometric properties (e.g., Montag et al., 2010; Montag et al., 2011; Sariyska et al., 2014). The present version consists of 20 items presented on a five point Likert scale ranging from 1 = never to 5 = always. In addition to an overall main factor of IA (Khazaal et al., 2008), several previous studies also revealed a two factor structure (Korkeila, Kaarlas, Jääskeläinen, Vahlberg, & Taiminen, 2010; Pawlikowski, Altstötter-Gleich, & Brand, 2013) incorporating the factors *loss of control* and *salient use*. Internal consistencies of the IAT scales in the present sample were excellent ($\alpha = 0.90$ main factor; between 0.84 and 0.86 for sub-factors).

Second, the Generalized Problematic Internet Use Scale 2 (GPIUS-2; Caplan, 2010) was used to assess tendencies in IA consisting of 15 items with an eight point-Likert scale ranging from totally disagree (1) to totally agree (8). The self-translated German version of this questionnaire has also been used in an earlier work of our group (Montag et al., 2015). In sum, the GPIUS-2 was constructed to tap four constructs: (1) *Preference for online social interaction*, (2) *mood regulation*, (3) *deficient self-regulation* and (4) *negative outcomes*. As with the IAT, an overall main factor of problematic usage behavior can be computed. In the present sample, internal consistencies of the GPIUS-2 scales were satisfying ($\alpha = 0.90$ main factor; between 0.73 and 0.90 for sub-factors).

In addition, participants were asked how many hours they spent online for leisure and business activities on a weekly basis. In our earlier studies (e. g. Montag et al., 2010), in particular leisure time (private Internet usage: USE) spent on the Internet was associated with Internet addiction tendencies. We also collected information about age at first contact with the Internet to explore the relation to problematic Internet usage.

2.3. Questionnaires on personality

We included 44 items from the TCI by Cloninger et al. (1993) to measure individual differences in Self-Directedness. The TCI originally consists of 240 items with a dichotomous answer format comprising yes (1) and no (0). For reasons of length and also with respect to our earlier work (Montag et al., 2010 Montag et al., 2011) we only included the items measuring Self-Directedness (SD). We administered the German version of the TCI by Cloninger, Przybeck, Svrakic, and Wetzel (1999) and computed SD as higher order dimension describing persons who have high self-esteem, follow their goals and are well-integrated. Higher scores represent higher SD. In the present sample, Cronbach's alpha of the SD scale was satisfying ($\alpha = 0.86$).

2.4. Statistical analyses

Factor analysis of the IAT items and also of the GPIUS-2 items using varimax rotation were conducted to examine the factor structure of the administered questionnaires in the current sample. Accordingly, sum scores were calculated for the resulting IAT and GPIUS-2 factors. With respect to the IAT main factor, we also categorized the sample using a cut-off value of >39 (Young, 1998b; Widyanto & McMurran, 2004) to analyze individuals with problematic Internet usage compared to average users. To evaluate differences between native and immigrant users (Prensky, 2001) with respect to the scores for IAT, GPIUS-2 as well as the USE scale we calculated one-way ANOVAs. *Age*, *age at first contact* and *sex* effects were investigated by inspection of correlations and T-tests for all factors. Also, prerequisites for structural equation modeling were inspected for each scale. Before conducting twin and sibling resemblances as well as model fitting analysis, all scores were residualized for age, age squared, sex and interaction effects between age and sex by multiple regression procedures, as the perfect correlation for age and sex in the same-sex twin pairs can inflate twin and sibling similarities (McGue & Bouchard, 1998).

2.5. Behavior genetic analyses

To estimate the relative importance of genetic and environmental influences for individual differences in IA and its specific components, we performed univariate genetic modeling of the data collected in MZ and DZ twin pairs (Neale & Maes, 2004; Plomin, DeFries, Knopik, & Neiderheiser, 2013). The rationale behind behavior genetic research is simple: If genes are relevant for a specific trait, then biological relatives should resemble one another more than genetically unrelated individuals do. If the environment is important, family members sharing relevant environmental factors should be more alike than family members and unrelated individuals who don't share this environment. By comparing within-pair correlations for MZ twins (who are 100% genetically identical) and DZ twins (who on average share only 50% of their segregating genes), these different sources of variability in a measured trait (phenotype), i.e. IA, can be distinguished and estimated. Because MZ twins are genetically twice as similar as DZ twins, a greater correlation between MZ twin pairs than that of DZ twin pairs indicates genetic influences. A high correlation within both, MZ and DZ twin pairs suggests environmental influences shared between family members. In contrast, any differences between MZ twins growing up in one family (indicated by a correlation of < 1) can be attributed to unique, non-shared environmental effects and measurement error. Within the heritability component, additive genetic influences (commonly denoted as A; the sum of all allelic (i.e. different versions of a gene locus) effects within and across genes) and non-additive genetic influences (commonly denoted as D; interactions between genes at the same loci) can be distinguished. While MZ twins share 100% additive and non-additive genetic influences, DZ twins share on average only 50% additivity and 25% non-additivity. Therefore, if the MZ twin correlation goes beyond double of the DZ twin correlation, non-additive genetic influences can be suspected. With respect to the environment, shared environmental influences (commonly denoted as C) refer to experiences common to all members in a household covering nearly everything that causes members of the same family to become more similar to one another. Non-shared (unique) environmental influences (commonly denoted as E) refer to specific individual experiences and lead to differences between family members. Overall, it is important to note that genetic and shared environmental influences increase intra-pair twin similarity whereas the non-shared environment decreases it. In the classical twin design, however, shared environmental influences and non-additive genetic influences are confounded and therefore cannot be estimated simultaneously (Ozaki, Toyoda, Iwama, Kubo, & Ando, 2011; Plomin et al., 2013). Whether shared environment or non-additivity should be expected to be important sources of variation can be seen in the pattern of twin similarities.

The applied genetic model relies on a number of prerequisites (for details see Plomin et al., 2013) such as that twins are generalizable to the rest of the population.

To explicitly test whether being a twin compared to being raised in the same family as siblings had an influence on similarities among family members, we observed our third group of non-twin siblings. As described above, DZ twins as well as non-twin full siblings share on average 50% of the genes that differ among humans. While DZ twins grow up together at exactly the same time, siblings differ in time more or less depending on the age differences between them. Differences in DZ twin and non-twin sibling resemblances are indicative for twin specific environmental influences.

In addition to univariate behavior genetic models for each scale of the IAT and the GPIUS-2, USE as well as Self-Directedness, we further calculated bivariate Cholesky decomposition models (Loehlin, 1996; Neale & Maes, 2004) to investigate the relative contributions of genetic and environmental factors on the phenotypic relation between Self-Directedness and IA components. Based on the results of univariate model fitting as well as the phenotypic correlations, bivariate models were set up only on the relevant IA facets in relation to Self-Directedness.

All behavior genetic models were fitted using the OpenMx package (Neale et al., 2015). Path coefficients corresponding to the genetic and environmental factors were estimated using maximum likelihood, and the goodness of model fit was indicated by -2LL (log-likelihood). Model fit was assessed using the Root Mean Square Error of Approximation (RMSEA) and Akaike's Information Criterion (AIC). A detailed description of the model fitting approach and assessment of heritability can be found elsewhere (Neale & Cardon, 1992; Rijsdijk & Sham, 2002). Due to the limited sample size and hence power considerations, we focused on the results for the full models (ACE and ADE models), instead of reduced models (e.g. AE model without shared environmental influences), given that the exclusion of any genetic or environmental effect may result in biased estimates of the remaining factors in the model, even if the removed factor was not significant (Ozaki et al., 2011).

3. Results

Descriptive statistics for IAT scales, GPIUS-2 scales and USE for the total sample and separately for each group are depicted in Table 1. Exploratory factor analysis and varimax rotations on the IAT and GPIUS-2 were conducted to prove the dimensionality of the questionnaires in the current sample. A two-factor solution for the IAT and a four-factor solution for the GPIUS-2 revealed good results explaining between 45% and 74% of the total variance (see also Table 2 for correlations between IAT and GPIUS-2 scales as well as USE). As proposed by the authors and for better comparability with the literature, total scores of IAT and GPIUS-2 were also computed. In the total sample, the IAT scores ranged between 20 and 73 points (between 20 and 71 within the subsample of twins), with a mean of 33.8 ($SD = 10.3$). About 25% of the total sample ($N = 197$) has an IAT score above 39 (about 19% within the twin sample) and can therefore be considered as individuals with frequent problems due to Internet usage. 0.3% of the sample has a score higher than 69 points indicating severe problems due to Internet overusage. With respect to the GPIUS-2 total score, values ranged between 15 and 103 in the total sample and between 15 and 84 within the twins indicating sufficient variance in IA behavior in the current sample. The USE score showed a maximum of 70 h per week only for private use.

Table 1
Descriptive statistics on all scales: Means, standard deviations and reliabilities for the total sample and subsamples of twins and siblings.

	Total sample N = 784			MZ N = 295		DZ N = 180		SIB N = 256	
Age mean (SD)	30.3 (9.6)			33.5 (9.9)		32.9 (10.1)		23.8 (3.9)	
Sex % women	73%			66%		78%		75%	
Education % middle class	59%			63%		59%		52%	
	α	M	SD	M	SD	M	SD	M	SD
IAT									
IAT-total	0.90	33.8	10.3	32.0	9.7	31.6	9.9	37.8	10.6
Loss of control	0.84	14.8	5.2	13.9	4.9	13.4	4.9	16.9	5.1
Salient use	0.86	19.0	6.2	18.1	5.7	18.2	5.8	20.9	6.8
GPIUS-2									
GPIUS2-total	0.90	27.4	13.4	24.4	11.5	25.4	12.1	32.9	15.1
Social interaction	0.85	5.6	3.6	5.2	3.5	5.3	3.0	6.2	4.0
Mood regulation	0.87	7.7	5.1	6.7	4.8	7.1	5.0	9.6	5.3
Self regulation	0.85	10.2	5.9	8.9	4.7	9.2	4.9	12.6	7.1
Negative outcomes	0.90	3.9	2.5	3.6	1.9	3.7	2.7	4.5	3.0
Private Internet use		10.0	10.8	8.2	9.2	8.2	10.4	13.9	12.2
Self-Directedness	0.86	76.5	15.3	79.0	14.2	78.8	14.6	71.8	15.8

Notes. IAT = Internet Addiction Test; GPIUS-2 = Generalized Problematic Internet Use Scale 2; α = Cronbach's alpha; SD = standard deviation; MZ = monozygotic twins; DZ = dizygotic twins; and SIB = non-twin siblings.

As proposed in Hypothesis 1, correlations between age and the different IA scales ranged between −0.17 ($p < 0.01$; for *preference for online social interaction*, GPIUS-2) and −0.40 ($p < 0.01$; for *mood regulation*, GPIUS-2) showing that problematic behavior associated with Internet use decreased with age (see Table 2). The pattern of correlations between *age at first contact* and all scales was highly comparable to the associations found with age (see Table 2). Following the classification by Prensky (2001), Fig. 2 shows that digital natives ($N = 185$) score on average significantly higher than digital immigrants ($N = 599$) with respect to the main factors of IAT ($F(1782) = 47.7$, $p < 0.01$) and GPIUS-2 ($F(1782) = 38.5$, $p < 0.01$) as well as the USE score ($F(1770) = 7.8$, $p = 0.01$).

Significant sex differences were observed for all IA scales, except the *mood regulation* factor from GPIUS-2 ($t\ (782) = 0.9$; $p = 0.36$). As expected, male participants scored significantly higher than females for all remaining scales. As can be seen in the Table 1, non-twin siblings were on average about 10 years younger than the twin groups. As a consequence, siblings also differ in the IAT and GPIUS-2 dimensions as well as USE. After correction for age and sex effects, there were still statistically significant differences between the twin and the non-twin sibling group means and variances as determined by one-way ANOVAs and Levene's tests for the residual scores of most IAT and GPIUS-2 dimensions as well as USE. Therefore, non-twin siblings could not be considered as highly comparable to the DZ twin siblings and were investigated separately.

In line with Hypothesis 2, phenotypic correlations for the IAT scales and Self-Directedness ranged between −0.31 (IAT *loss of control*) and −0.36 (IAT main factor). For the GPIUS-2 scales, the lowest correlation was found for the *social interaction* subscale (−0.29) and the highest for the GPIUS-2 total scores (−0.41). In addition, SD also showed a modest correlation of −0.24 with USE.

Table 3 shows twin and non-twin sibling resemblances (intra-class correlations, ICCs) as well as *p*-value differences for ICCs between DZ twins and non-twin siblings. For all scales, ICCs were higher in the twin groups than in the non-twin sibling group. The comparison of the DZ twins' resemblance with the resemblance of the non-twin siblings revealed significant differences for most of the scales suggesting that non-twin siblings differ from twin siblings. Within the non-twin sibling group, the majority ($N = 59$ pairs) showed an age difference of two years, 20 pairs were one year apart and 40 pairs were born three years apart. Inspecting these different subgroups of non-twin siblings, ICCs for the IAT main factor decreased with each additional year between the siblings from 0.29 (age difference of one year) to 0.01 (age difference of three years). The same pattern was observed for the GPIUS main factor (from 0.40 to −0.03) and other subscales indicating that growing up in the same family at exactly the same time (as it is the case for twins) seems to be an important factor contributing to similarity between family members. In other words, with an increase in age difference, siblings showed increased dissimilarity suggesting that differences in resemblances between DZ twins and non-twin siblings were not a direct effect of 'being a twin' vs. 'being a sibling'. However, given the differences between siblings and twins, behavior genetic models were performed using data from MZ and DZ twins only.[4]

For the IAT, MZ twin resemblances only exceeded those of the DZ twins for the sub-factor *loss of control* indicating genetic influences as a source of variation. Regarding the IAT main factor as well as the *salient use* scale, the MZ correlations were smaller than the DZ correlations, showing that genetic factors did not play a role in explaining individual differences. Rather, correlations between family members seem to be

[4] Given the skewness of some GPIUS-2 scores, all residual scores were log transformed for behavior genetic analysis.

Table 2
Correlations between all scales (IAT, GPIUS-2, USE and SD) with age and age at first contact as well as among each other.

	Age	Age contact	IAT			GPIUS-2					Use
			I.	II.	III.	I.	II.	III.	IV.	V.	
IAT											
I. IAT-total	−0.38**	−0.34**	1.0								
II. Loss of control	−0.38**	−0.36**	0.89**	1.0							
III. Salient use	−0.31**	−0.27**	0.93**	0.66**	1.0						
GPIUS-2											
I. GPIUS2-total	−0.37**	−0.34**	0.75**	0.62**	0.74**	1.0					
II. Social interaction	−0.17**	−0.17*	0.39**	0.26**	0.44**	0.69**	1.0				
III. Mood regulation	−0.40**	−0.36**	0.55**	0.46**	0.54**	0.78**	0.40**	1.0			
IV. Self regulation	−0.31**	−0.28**	0.74**	0.64**	0.71**	0.89**	0.46**	0.53**	1.0		
V. Negative outcomes	−0.18**	−0.17**	0.57**	0.48**	0.56**	0.68**	0.34**	0.32**	0.65**	1.0	
Private Internet use	−0.30**	−0.31**	0.55**	0.49**	0.50**	0.52**	0.31**	0.38**	0.49**	0.40**	1.0
Self-Directedness	0.27**	0.22**	−0.36**	−0.31**	−0.34**	−0.41**	−0.28**	−0.32**	−0.38**	−0.29**	−0.24**

Notes. IAT = Internet Addiction Test; GPIUS-2 = Generalized Problematic Internet Use Scale 2; USE = private Internet use (hours per week); SD = Self-Directedness; Age contact = Age at first contact with the Internet; ** = $p < 0.01$.

due to shared environmental influences among them. For the GPIUS-2 scales, different patterns of resemblances were found. For the subscales *mood regulation*, *self-regulation* and *negative outcomes*, the MZ correlations were higher than the DZ correlation suggesting a genetic impact. For *negative outcomes*, MZ twins were even more than twice as similar as the DZs which could be indicative for non-additive genetic influences, i.e. genetic interaction effects. For the GPIUS-2 main factor and the *social interaction* scale, twin similarities rather suggest genetic influences to be negligible but shared environmental influences to be important given the comparable high correlations in MZ and DZ twins. For USE, MZ twins showed higher ICCs than DZ twins suggesting a heritable component. The same pattern of similarities was found for the personality scale Self-Directedness.

Table 4 displays the results of behavior genetic model fitting. As expected based on the pattern of MZ and DZ twin similarities, heritability estimates for the IAT and GPIUS-2 main factors as well as for the sub-dimensions *salient use* (IAT) and *social interaction* (GPIUS-2) were zero. For these factors, shared environmental influences accounted for 33% (IAT total) up to 41% (GPIUS-2-total) showing that resemblances between members of the same family could be explained mainly by shared environmental influences rather than common genetic influences. The remaining part of the variation could be explained by the non-shared environment ranging between 59% and 67%. For the IAT subscale *loss of control* and the three GPIUS-2 scales *mood regulation*, *self-regulation* and *negative outcomes*, heritability estimates varied between 0.21 and 0.33 while non-shared environmental influences explained between 58% and 76% of the variance. The shared environment explained only a small proportion of the variation (between 6% and 16%). With respect to the USE scale, 44% could be

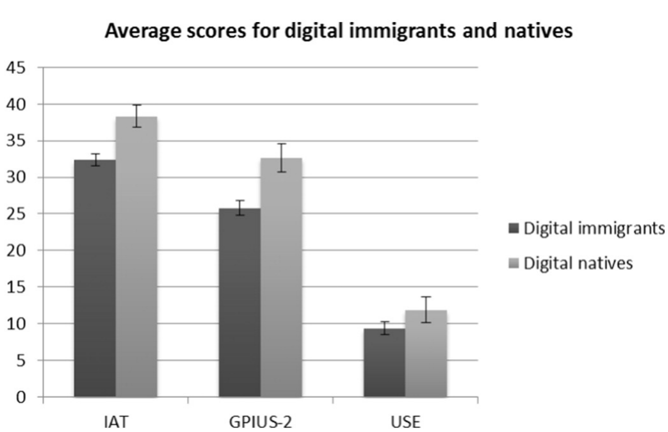

Fig. 2. Average scores for individuals classified as digital immigrants ($N = 599$) or digital natives ($N = 185$).

accounted to additive genetic influences while 14% were attributed to the shared environment and 42% to the non-shared environment. Highest heritability estimates were found for Self-Directedness (59%) while the remaining variance of 41% could be accounted to non-shared environmental variation. In sum, different specific components of Internet addiction were influenced by genetic factors to differing degrees as expected in Hypothesis 3.

Based on the results of the univariate analyses, bivariate Cholesky decomposition models were conducted for the IA facets *loss of control* (IAT), *mood regulation*, *self-regulation* and *negative outcomes* (GPIUS-2) as well as USE, each in relation to the personality factor Self-Directedness. Standardized estimates and fit statistics of all models are presented in Table 5.[5] In the bivariate model, *loss of control* showed a heritability of 20% while 9% of the total variance (45% of the genetic variance) were common genetic influences with Self-Directedness and 11% (55% of the genetic variance) were specific genetic influences on *loss of control* independent of the relation to Self-Directedness. The model revealed no common shared and non-shared environmental influences between Self-Directedness and *loss of control* suggesting that genetic influences instead of environmental factors contribute to the co-occurrence of Self-Directedness and the IA facet *loss of control*. For the GPIUS-2 facets, bivariate models showed a similar pattern. For *mood regulation*, 48% of all genetic influences (in sum 27%) on the total variance were mediated by Self-Directedness which was reflected in a high negative genetic correlation of −0.71. With respect to the environment, shared (16%) and non-shared environmental influences (57%) were completely specific to *mood regulation* and did not contribute to the association with Self-directedness. For the sub-factor *self-regulation*, the majority of genetic influences (11% in total; 65% of the genetic variance) were common genetic influences affecting Self-Directedness as well as *self-regulation*, albeit in different directions as can be seen in the negative genetic correlation between them ($rA = -0.79$). In addition, a small part of the relationship between Self-Directedness and the *self-regulation* facet could be explained by 7% common shared environmental influences while non-shared environmental factors were completely specific to *self-regulation* explaining 76% of the total variation. For the GPIUS-2 factor *negative outcomes*, the co-occurrence with Self-Directedness could mainly be attributed to common genetic influences (8% in total, 36% of all genetic influences) instead of environmental influences (4% in total, 5% of all environmental influences). Controlled for the common variance between Self-Directedness and *negative outcomes*, the remaining part of the variation could be explained by 14% specific genetic influences and 74% non-shared environmental influences. Finally, the association between USE and Self-Directedness was fully mediated by common genetic influences that explained 8% of the total variance in

[5] To reconstruct genetic and environmental influences on IA facets, all estimates (specific and common) must be summed.

Table 3
Twin and non-twin sibling similarities.

	Twin and sibling ICCs (95% CI)			
	MZ (N = 146 pairs)	DZ (N = 90 pairs)	SIB (N = 119 pairs)	p-value difference between DZ and SIB[a]
IAT				
IAT-total	0.30* (0.15; 0.44)	0.37* (0.17; 0.53)	0.02 (−0.16; 0.20)	0.01
Loss of control	0.37* (0.22; 0.50)	0.26* (0.05; 0.44)	0.02 (−0.16; 0.20)	0.04
Salient use	0.32* (0.16; 0.46)	0.38* (0.19; 0.55)	0.06 (−0.12; 0.23)	0.01
GPIUS-2				
GPIUS2-total	0.35* (0.20; 0.49)	0.47* (0.30; 0.62)	0.06 (−0.12; 0.24)	0.00
Social interaction	0.31* (0.16; 0.45)	0.37* (0.18; 0.53)	0.10 (−0.09; 0.27)	0.02
Mood regulation	0.41* (0.26; 0.53)	0.28* (0.08; 0.46)	0.09 (−0.09; 0.27)	0.08
Self regulation	0.26* (0.10; 0.41)	0.18 (−0.02; 0.38)	0.05 (−0.13; 0.23)	0.18
Negative outcomes	0.29* (0.13; 0.43)	0.09 (−0.12; 0.29)	-0.03 (−0.21; 0.15)	0.20
Private Internet use	0.60* (0.49; 0.70)	0.37* (0.17; 0.54)	0.25* (0.07; 0.41)	0.17
Self-Directedness	0.59* (0.47; 0.69)	0.16 (−0.05; 0.35)	0.14 (−0.04; 0.31)	0.44

Notes. IAT = Internet Addiction Test; GPIUS-2 = Generalized Problematic Internet Use Scale 2; ICC = Intra-class-correlation; CI = confidence interval; MZ = monozygotic twins; DZ = dizygotic twins; and SIB = non-twin siblings; [a] correlations between DZ twins and siblings were tested for significant differences, two-tailed testing; numbers in brackets refer to the confidence intervals; scores were corrected for age and sex effects; * = $p < 0.05$.

USE (20% of all genetic influences) while shared (18%) and non-shared environmental influences were specific to private Internet usage and did not overlap with environmental factors influencing Self-Directedness. Altogether, genetic correlations between IA facets and Self-Directedness varied between −0.44 and −0.79 indicating a genetic overlap confirming Hypothesis 4.

4. Discussion

To the best of our knowledge this is the first study to examine genetic and environmental influences on IA and its specific facets in a sample of adult twins and non-twin siblings. The present study utilized a direct approach to estimate not only the heritability of Internet addiction behaviors but also the role of the personality factor Self-Directedness as a potential mediator. Compared to the results found in previous studies for adolescents (Vink et al., 2016; Li et al., 2014; Deryakulu & Ursavaş, 2014), heritability estimates for adults were lower and for some scales we even found genetic influences to be negligible. The pattern of lower heritability estimates for adults compared to adolescents has also been found for substance addictions (Kendler, Schmitt, Aggen, & Prescott, 2008) indicating that the relative contribution of genetics and the environment on individual differences in addictive behavior such as IA changes over the life span.

Our results showed that it is important to distinguish different facets of IA when studying genetic and environmental sources underlying these different components. Likewise, Deryakulu and Ursavaş (2014) found considerable variation in the magnitude of genetic influences on Internet addiction subscales indicating different etiologies for specific behavioral components involved in Internet addiction. The results of the present study revealed that those IA facets linked to behavior regulation (i.e., mood regulation, self-regulation and loss of control) showed the highest heritability estimates. Furthermore, Self-Directedness accounted for about 50% of the genetic variance in these IA components. In line, Li et al. (2014) found a significant overlap between genetic influences on Internet addiction and effortful control (larger in boys than in girls) which provides insights into possible genetic pathways. In general, we expect that personality traits linked to will-power and self-regulation will be of higher importance for a better understanding of Internet addiction than traits linked to negative emotionality. Earlier, Montag et al. (2010) demonstrated that low Self-Directedness excels high neuroticism in predicting high IAT scores. Although neuroticism was not assessed in the present study, we would have expected the same to be true here. Besides Self-Directedness of the TCI, another scale clearly is of interest for future twin studies – namely Barrett's Impulsivity Scale. Several studies reveal that impulsivity plays an important role for Internet addiction (inversely linked to Self-Directedness; Cao et al., 2007; Zhang et al., 2015) and therefore a purer impulsivity measure would have been of interest also for a twin study like the present one.

Finally, we would like to further discuss the finding of only small to negligible genetic contributions in the study of individual differences of IA. In line with other studies, early stages (of addiction) were less heritable and under a stronger influence of familial environmental factors, whereas later stages, such as problem use and dependence were more strongly influenced by heritable factors (Agrawal et al., 2012). Even within these stages there is considerable variation in etiology

Table 4
Univariate model fitting results and standardized parameter estimates for A, C and E influences.

	Fit statistics				Estimates (95% CI)		
	χ^2 (df)	p	AIC	RMSEA	A	C	E
IAT							
IAT-total	5.92 (6)	0.43	−1265.88	0.00	0.00 (0.00; 0.42)	0.33 (0.00; 0.44)	0.67 (0.53; 0.78)
Loss of control	4.01 (6)	0.68	−1902.58	0.00	0.21 (0.00; 0.50)	0.16 (0.00; 0.43)	0.63 (0.50; 0.77)
Salient use	1.53 (6)	0.96	−1846.73	0.00	0.00 (0.00; 0.37)	0.34 (0.02; 0.45)	0.66 (0.54; 0.77)
GPIUS-2							
GPIUS-total	7.77 (6)	0.26	−1081.50	0.04	0.00 (0.00; 0.36)	0.41 (0.10; 0.51)	0.59 (0.47; 0.70)
Social interaction	3.49 (6)	0.75	−2313.68	0.00	0.00 (0.00; 0.31)	0.33 (0.04; 0.44)	0.67 (0.56; 0.79)
Mood regulation	3.78 (6)	0.71	−1979.38	0.00	0.33 (0.00; 0.54)	0.09 (0.00; 0.42)	0.58 (0.46; 0.73)
Self-regulation	5.38 (6)	0.50	−1981.42	0.00	0.21 (0.00; 0.41)	0.06 (0.00; 0.33)	0.73 (0.59; 0.88)
Negative outcomes	5.03 (6)	0.53	−1005.14	0.00	0.22 (0.00; 0.38)	0.02 (0.00; 0.30)	0.76 (0.62; 0.92)
Private Internet use	12.86 (6)	0.05	641.65	0.07	0.44 (0.08; 0.67)	0.14 (0.00; 0.46)	0.42 (0.32; 0.53)
Self-Directedness	4.67 (6)	0.59	2801.15	0.00	0.59 (0.40; 0.68)	0.00 (0.00; 0.15)	0.41 (0.32; 0.53)

Notes. Model fitting based on data from MZ and DZ twin pairs; IAT = Internet Addiction Test; GPIUS-2 = Generalized Problematic Internet Use Scale 2; df = degrees of freedom; AIC = Akaike's information criterion; RMSEA = Root Mean Square Error of Approximation; A = additive genetic influences; C = shared environmental influences; E = non-shared environmental influences; and CI = confidence interval; for the GPIUS-2 sub-scale negative outcomes, an ADE model was also fitted to the data but the ACE model was preferred based on the model fit.

Table 5
Bivariate model fitting results and standardized parameter estimates for A, C and E influences.

	Fit statistics			Estimates of variance common with Self-Directedness (95% CI)			Estimates of variance unique to IA scales (95% CI)			Genetic and environmental correlations		
	χ^2 (df)	p	AIC	A	C	E	A	C	E	r_A	r_C	r_E
IAT												
Loss of control	12.65 (17)	0.76	638.33	0.09 (0.00; 0.30)	0.00 (0.00; 0.40)	0.00 (0.00; 0.02)	0.11 (0.00; 0.41)	0.17 (0.00; 0.37)	0.63 (0.50; 0.76)	−0.68	−0.26	−0.03
GPIUS-2												
Mood regulation	16.67 (17)	0.48	546.28	0.13 (0.03; 0.41)	0.00 (0.00; 0.39)	0.00 (0.00; 0.03)	0.14 (0.00; 0.42)	0.16 (0.00; 0.37)	0.57 (0.45; 0.71)	−0.71	−0.12	−0.07
Self-regulation	27.97 (17)	0.05	579.15	0.11 (0.00; 0.26)	0.07 (0.00; 0.28)	0.00 (0.00; 0.02)	0.06 (0.00; 0.27)	0.00 (0.00; 0.23)	0.76 (0.62; 0.90)	−0.79	−1.0	−0.01
Negative outcomes	15.00 (17)	0.60	776.91	0.08 (0.00; 0.26)	0.03 (0.00; 0.27)	0.01 (0.00; 0.52)	0.14 (0.00; 0.32)	0.00 (0.00; 0.26)	0.74 (0.60; 0.89)	−0.58	−0.93	−0.12
Private Internet use	22.14 (17)	0.18	488.67	0.08 (0.00; 0.34)	0.00 (0.00; 0.48)	0.00 (0.00; 0.02)	0.33(0.00; 0.60)	0.18 (0.00; 0.48)	0.41 (0.32; 0.53)	−0.44	−0.06	−0.07

Notes. Model fitting based on data from MZ and DZ twin pairs; IAT = Internet Addiction Test; GPIUS-2 = Generalized Problematic Internet Use Scale 2; df = degrees of freedom; AIC = Akaike's information criterion; RMSEA = Root Mean Square Error of Approximation; A = additive genetic influences; C = shared environmental influences; E = non-shared environmental influences; CI = confidence interval; r_A = additive genetic correlation; r_C = shared environmental correlation; and r_E = non-shared environmental correlation.

depending on whether adolescents or adults are being studied. For the history of any alcohol use, heritability declines rapidly during emerging adulthood, likely due to the ubiquity of normative alcohol consumption. It is noteworthy that only parts of the sample in the present study reached a problematic area of Internet usage, whereas severe "Internet addicts" were not included. Therefore, one could characterize some of our participants as being in a transitional area to a more severe form of IA – hence they probably are in an earlier stage - but this is just speculation.

As a consequence, heritability estimates could be different for "normal range Internet usage" compared to "abnormal range of behavior/problematic use". This is mirrored in the fact that the hours of private usage each week (which is not pathological per se) shows higher heritability estimates than the psychopathological variables in the present research endeavor. Therefore, studies on normal Internet usage, moderate problems due to Internet usage and clinical patients with Internet addiction should further be investigated to find out if genetic and environmental influences vary over the (wide) range of possible Internet addiction behavior or healthy usage. Also, it seems to be of importance to understand our result of small to no genetic influences on IA in such a way that genetic differences could not explain differences in overall IA, but in specific IA related behaviors. This is not the same as saying that genetic factors do not play a role. Only few children and adolescents who show problematic Internet usage behavior continue to have symptoms that persist into adulthood. Within these developmental stages, genetic differences on IA related behavior in early adolescence could also interact with specific environmental factors in the form of gene-environment interaction effects. Over time, these effects could lead to a relatively large contribution of environmental influences explaining individual differences in IA in adulthood. It is also conceivable that some genetic risk factors for IA exert their negative influence only later in life.

Besides quantitative genetic studies, also evidence from molecular genetics point towards an influence of genetics on IA. Here studies revealed that genetic markers associated with dopaminergic (Han et al., 2007), serotonergic (Lee et al., 2008) and acetylcholinergic pathways (Montag, Kirsch, Sauer, Markett, & Reuter, 2012) were associated with IA. For an overview see Montag & Reuter (2015e). These candidate genes investigated in previous studies described above (DRD2, COMT, SLC6A4, CHRNA4) were also shown to be associated with substance use and substance addiction (Breitling et al., 2009; Han et al., 2011; Le Foll, Gallo, Le Strat, Lu, & Gorwood, 2009; Tammimäki & Männistö, 2010), suggesting that behavioral addiction such as Internet addiction might be linked to substances addiction by chairing the same risk genes (e. g. genes related to neural reward/SEEKING circuits; see also Alcaro & Panksepp, 2011).

Despite genetics, non-shared as well as shared environmental influences explained a remarkable part of the variation in general IA and its facets. This strengthens not only the importance of individual experiences of family members (e.g. individual life events, peers) but also of the family environment per se. If we are able to identify these effects, we might learn what environmental factors inside and outside of families make people more or less vulnerable or resilient to IA by taking into account genetic factors and possible interactions of genes and environments. In turn, this information could also be used in the development of IA prevention programs. According to Morahan-Martin (2008), learning processes such as learned adaptive or functional behavior could be part of these environmental effects influencing the development or vulnerability to IA. Further factors of importance could be family functioning and parent–adolescent conflicts (Yen et al., 2007a), social support (Tsai et al., 2009), family violence exposure (Park et al., 2008) or family organization and cohesion (Li et al., 2014). Given our finding of higher similarities within sibling pairs with a smaller age difference, further research should also investigate the effect of sibling relationships and sibling interaction behavior as potential etiological sources.

4.1. Research outlines for the future

It is argued that comorbidity of two disorders may indicate the causal relationship and/or common etiology shared by them (e.g., Mueser, Drake, & Wallach, 1998). Therefore, the investigation of whether preexisting psychosocial problems or psychopathologies linked to IA (e.g. ADHD, depression, social anxiety) have an impact on the relative contribution of genetic influences on IA, is another research avenue that needs to be explored. Given that low Self-Directedness has also been associated with ADHD (Barkley, 1997; Salgado et al., 2009), further examinations of co-morbidities by taking common related personality traits into consideration could help to unravel the role of previous conditions and personal characteristics for the development of IA.

Further research should be conducted on the question whether specific forms of Internet addiction (e.g., pathological online gaming, Ferguson, Coulson, & Barnett, 2011; social network addiction, Korkeila et al., 2010; or online pornography addiction, Brand et al., 2011) should be distinguished from generalized IA also on the etiological level (see also Montag et al., 2015). According to Davis (2001), these two pathologies (generalized vs. specific) should not only be distinguished from one another, they also differ in their ontogenesis. According to his model, generalized IA could be seen as an individual "solution" to compensate for social deficits, social isolation or social anxiety. The origins, e.g. increased anxiety or higher sensitivity may be genetically influenced as well as the tendency to compulsive behavior, but the solution of combining these issues in form of an IA could be related to unique environmental influences.

4.2. Limitations

Because of the relatively small sample size and the restricted number of male same-sex MZ and DZ pairs, sex-effects with respect to the etiology of IA components could not be investigated in our models. Consistent with previous studies, we found significant sex differences in generalized Internet addiction as well as its components on a phenotypic level: males presented more symptoms of IA than females in the present study (see also the studies by Cao & Su, 2007; Li et al., 2014). Despite mean differences between males and females, it is of interest if individual differences within males and within females are due to varying degrees of genetic and environmental differences. In a sample of adolescents, Deryakulu and Ursavaş (2014) found strong sex effects regarding the etiology of Internet addiction. Heritability estimates were zero for female participants and ranged from 19% up to 86% for male participants. In contrast, Li et al. (2014) reported only small sex differences with slightly lower heritability estimates for females while Vink et al. (2016) found sex differences on a phenotypic level, but no impact of sex on the relative importance of genetic and environmental influences. In the light of the findings so far, it is possible that different genes and/or different environments might influence differences in IA in the two sexes (Boomsma, Busjahn, & Peltonen, 2002). Molecular genetic studies showing that a genetic predisposition to IA may exist especially in males (Han et al., 2007; Kim et al., 2006; Lee et al., 2008; in contrast the study by Montag et al., 2011 found the strongest effect in females, which might be explained by problematic usage of social networks). Furthermore, age effects should be investigated in more detail in combination with the stage of addiction to enrich the current understanding of developmental pathways related to problematic Internet usage behavior.

5. Conclusion

The present study aimed to revisit the question if and how individual differences in IA are influenced by genetic and environmental factors. Compared to the already published studies we investigated an older sample, included information on specific facets of IA as well as on the role of the personality trait of Self-Directedness. Overall, genetic influences ranged between being negligible up to explaining 44% of the variation. Moreover, the personality trait Self-Directedness accounted for a part of the genetic variance in IA components. In light of the previous findings in the literature, our study provides evidence that age plays an important role for the quantification of genetic and environmental parts of IA.

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