Decision-making in Adolescent Females who Deliberately Self-Harm*

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Abstract

Self-harming behaviour most commonly begins in adolescence and is more frequent among adolescent females. We explored the hypothesis that adolescent females who deliberately self-harm were more likely to perform worse on a decision-making task. Previous research in adolescents who self-harm reported impaired decision-making. However, research put little emphasis on older adolescents and the emotional learning. In our research, we presented the Iowa Gambling Task to 35 adolescent females who self-harmed and were treated at a psychiatric clinic, and to 35 healthy female controls. Our results show that in comparison to the control group the adolescents who self-harm took more risky decisions and were less concerned about the outcome. In addition, the clinical group also focused more on immediate gains and showed a reduced ability to learn from poor decisions in the past. Further research is suggested to explore the potential neurological correlates of decision-making and self-harming behaviour.

Keywords: adolescence, self-harm, Iowa gambling task, decision-making

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Introduction

Self-harming behaviour is a phenomenon that typically begins in early adolescence (Favazza, 1998; Favazza & Rosenthal, 1993; Pattison & Kahan, 1983; van der Kolk, Perry, & Herman, 1991). Although definitions of self-harm (SH), non-suicidal self-injury and self-mutilation (henceforth self-harm) vary in literature (Klonsky, 2007) they share a common basic description of what self-harm is.

Self-harm is commonly defined as socially unacceptable, intentional, and direct injury to one's own body tissue without suicidal intent (Nock & Favazza, 2009). Research shows that the average age of SH behaviour onset is 14 to 15 years (Baetens, Claes, Muehlenkamp, Grietens, & Onghena, 2011; Heath, Ross, Toste, Charlebois & Nedecheva, 2009) with females being more likely to harm themselves than males (Ross & Heath, 2002; Laye-Gindhu & Schonert-Reichl, 2005; De Leo & Heller, 2004; Madge, Hewitt, & Hawton, 2008; Hawton, Rodham, Evans, & Weatherall, 2002). While adolescent males are more prone to risk-taking behaviour, the most common form of self-injury in females is cutting of the skin, occurring between 70 and 97 percent of the cases (Pattison et al., 1983; Raine, 1982; Suyemoto & MacDonald, 1995; Lambert & de Man, 2007; Briere & Gil, 1998; Favazza & Conterio, 1988; Langbehn & Pfohl, 1993; Nijman et al., 1999; Wilkins & Coid, 1991).

Self-harming behaviour has also been associated with certain clinical traits, for example, depression and anxiety (Favazza, 1998; Feldman, 1988; Andover, Pepper, Ryabchencko, Orrico, & Gibb, 2005; Laye-Gindhu & Schonert-Reichl, 2005; Lambert & de Man 2007; Mars et al., 2014) and borderline personality disorder (Gerson & Stanley, 2002; Haw, Hawton, Houston, & Townsend, 2001; Simeon et al., 1992; Zlotnick, Mattia, & Zimmerman, 1999). Other psychiatric diagnoses have also been linked to SH, but to a lesser extent (Suyemoto, 1998). In the past, SH was classified as a symptom of borderline personality disorder. However, in DSM-V (American Psychiatric Association, 2013) SH is classified as a separate symptom, but a unified model explaining this behaviour has not emerged to date. Klonsky (2007) has shown that the existing theoretical models contextualize self-injurious behaviour as a way to regulate affect and interpersonal boundaries, as a form of self-punishment, to reduce suicidal attempts, and as a form of sensation seeking. These models conceptualize SH in the context of psychology, as opposed to psychiatry or neurology.

However, several researchers (Suyemoto, 1998; Klonsky, 2007; LeGris & Van Reekum, 2006; Oldershaw et al., 2009) have commented on the relative lack of research on the neuropsychological basis of self-harming behaviour. In recent years, cognitive psychology and neuropsychology were strongly influenced by research from neurobiological sciences, where, for example Weinberger, Elvevag, and Giedd (2005) put forward one of convincing explanations of how the adolescent brain is developed. Yakovlev and Lecours (1967) have shown that frontal lobe regions are still in development during adolescence. This claim has received strong support from Huttenlocher (1983), Huttenlocher, De Courten, Garey, and Van Der Loos (1983), Casey, Giedd, and Thomas (2000), Paus (2005), and many others. Behavioural phenomena like risk-taking, novelty seeking, poor planning and impulsive decision-making are frequent in the adolescent population (Spear, 2000). Among these are also health-damaging behaviours (Arnett, 1992; Moffitt, 1993; Igra & Irwin, 1996). It is proposed that these behaviours are connected to prefrontal cortex immaturity, showing that executive functions are still in development (Ernst, Pine, & Hardin, 2006).

Adolescents who deliberately self-harm commonly describe a strong urge to damage their own body in order to regulate their negative affect (Klonsky, 2007). Although these individuals later commonly regret having harmed themselves, they are usually unable to

prevent themselves from doing so. Therefore we can define self-harm as consequence of poor decision-making, with an emphasis on immediate gain and little concern for the long-term outcome. This is also supported by Oldershaw et al. (2009), who define self-harm as a risky and reward-driven behaviour. From the neuroanatomical viewpoint, this can be better understood within the triadic model of motivated behaviour (TMMB), which was first proposed by Ernst et al. (2006). TMMB proposes that decision-making processes are determined by the medial and ventral prefrontal cortices, which balance input from reward-seeking and harm-avoidant regions. The implication is that greater prefrontal cortex immaturity may lead to greater risk–taking in adolescence. Consequently, adolescents are more likely to choose riskier options that carry higher rewards, when they face classic decision-making tasks in the lab (i.e. gambles). In terms of SH, to harm one's body represents a short-term reward, with a high risk of damage and long-term consequences.

In order to assess these decision-making processes in laboratory conditions, Bechara, Damasio, Damasio, and Anderson (1994) introduced the Iowa Gambling Task (IGT). IGT has been widely used within clinical and healthy populations to assess decision-making processes (Bechara, Tranel & Damasio, 2002; Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Damasio, Tranel, & Damasio, 1997; Ernst et al., 2003; Bridge et al., 2012), with Bechara, Damasio, Damasio, and Anderson (1994) claiming that it is a close approximation of real-life decision-making. The IGT was constructed to measure decision-making deficits in individuals of average intelligence, whose sub-optimal poor decision-making cannot be explained away by impairments in language, working memory, or attention (Bechara, 2004). In order to complete IGT successfully (i.e., finish with gain), participants must choose the cards from decks with lower risk and lower gains (Bechara et al., 1997). While completing the task healthy control participants usually adopt such a strategy. In contrast, patients with damage centred on the ventromedial prefrontal cortex (vmPFC) show impaired performance, resulting in a high-risk strategy and long-term losses (Bechara et al., 1994; Bechara et al., 1997; Clark et al., 2008). Li, Lu, D'Argembeau, Ng, & Bechara (2010) confirmed the activation of vmPFC. In addition, they have shown that many brain regions are activated during the IGT performance, for example the dorsolateral prefrontal cortex, the insula, posterior cingulate cortex, the mesial orbitofrontal (OFC) and ventromedial prefrontal cortex (vmPFC), the ventral striatum and anterior cingulate. Dysfunction within any of the other neural systems that feed into the OFC/vmPFC system could lead to the decision-making impairments. Furthermore, Hooper, Luciana, Conklin, and Yarger (2004) have shown that compared to healthy adults adolescents also perform more poorly on the IGT, which they interpreted that vmPFC or its connections are functionally maturing during adolescence. Younger adolescents showed greater tendency for poor decision-making. Considering the process of maturation, older adolescents are expected to perform better on a decision-making task like the IGT.

In addition, some researches show that emotions play an important role in complex decision-making (Bechara et al., 1994; Damasio, Everitt, & Bishop, 1996; Rolls, Hornak, Wade, & McGrath, 1994; Rogers et al., 1999; Manes et al., 2002). The IGT has been initially designed to engage emotional cues, which are thought to help humans in an ambiguous decision-making situation (Bechara et al. 1997). Damasio et al. (1996) propose that emotion drives emotion-based learning (EBL) during a complex decision-making task. Based on prior experience of the emotional consequences of actions, the EBL systems facilitate insights into the possible outcomes of complex decisions (Tranel & Damasio, 1993; Bechara et al., 1994; Damasio et al., 1996; Rogers et al., 1999; LeDoux, 2000). It has been proposed that EBL is compromised in individuals, who fail to learn from their past mistakes and focus on immediate outcome of decisions, with an apparent indifference to the long-term

consequences of their actions. This behaviour is a part of the definition of self-harming behaviour by Oldershaw et al. (2009).

Previous research on the topic of adolescents' decision-making (Hooper et al., 2004) and self-harming behaviour (Oldershaw et al., 2009) has mainly focused on younger adolescents with less emphasis on older adolescents. Overman et al. (2004) showed that IGT performance improves with age and with research showing that adolescent brain continues to mature into ages 20 and more (Johnson, Blum, & Giedd, 2009), we focused on specific measures of risk-taking on the IGT in older adolescent females who deliberately self-harm. Our study aims to add and expand on the existing research. We expect older adolescents to perform better on IGT, considering that decision-making process is linked to prefrontal maturation. We hypothesized that adolescent females who deliberately self-harm were more likely to perform worse on the IGT, compared with adolescent females, who do not deliberately harm themselves.

Method

Participants

Our study involved 70 participants allocated to two groups. The self-harm group consisted of 35 adolescent females in age range 15 to 20 years who were admitted to adolescent psychiatry unit in psychiatric hospital because of their self-mutilating behaviour. Primary ICD-10 diagnoses of self-harm group were: F90-F98 Behavioural and emotional disorders with onset usually occurring in childhood and adolescence (46%), F40-F48 Neurotic, stress-related and somatoform disorders (28%), F60-F69 Disorders of adult personality and behaviour (17%), F30-F39 Mood [affective] disorders (6%), and F50-F59 Behavioural syndromes associated with physiological disturbances and physical factors (3%). Secondary diagnosis of all participants was X78 Intentional self-harm by sharp object. At the time of examination some participants from the self-harm group were prescribed mood stabilizers, which had little or no affect on cognitive functions. This is in line with research by Gualtieri, and Johnson (2006); and Hessen, Lossius, Reinvang, and Gjerstad (2006) who have all shown that mood stabilisers comparable to those in our study had little or no effect on cognitive functions. The control group was composed of adolescent females between ages 14 and 20 (n=35). Participants from the control group did not engage in self-harming behaviour and were recruited from educational institutions (an elementary school, two high-schools and a university). They were interviewed by an examiner and they filled a self-report form stating that they had no history of self-mutilating behaviour and no history of mental illness or disorders. The participants in the Control group were age and sex matched to those in the self-harm group.

We calculated the number of required participants based on the findings from Oldershaw et al. (2009). Using the Gpower statistical software (Faul, Erdfelder, Lang, & Buchner, 2007) we calculated that in order to replicate an effect size of 0.25 on the last IGT trial block using a repeated measures ANOVA at an α-error rate of .05 and β-error rate of .20, we would require a total sample size of a least 60 participants.

Participants in the self-harm group (SH) had at least a 6-month history of continuous self-mutilating behaviour, which persisted at least until the time of the study. We defined self-harm as intentional behaviour designed to inflict damage on one's skin in order to reduce negative or intolerable feelings, but without suicidal intent. All included females participants in the SH used various sharp objects to intentionally cut their skin. We excluded individuals who engaged in self-harm with suicidal intent. This information was gathered through interviews and chart reviews. Our additional exclusion criteria were IQ scores below the 25th percentile, a history of head injury, a history of psychotic episodes, or current use of medication, which could impair attention (e.g. antipsychotics, anxiolitics). All participants

were screened with Raven's Progressive Matrices (Raven, Raven, & Court, 2003) in order to assess their IQ.

A total of 81 potential candidates were screened for participation, of which 11 were excluded as they met one or more exclusion criteria, or did not accept to participate in the study. A participant from SH group was excluded based on their intelligence score. In the same group, 4 participants opted out of the experiment. In addition, 6 participants from the control group also decided not to take part in the decision-making task.

Our initial experimental design included male participants, but there were no adolescent males available in the clinical sample. During the course of the present study (years 2011 to 2014), only one male patient with symptoms of self-harm behaviour was admitted to our psychiatric hospital. However, even that male participant was later excluded because he was acutely psychotic and was using medication that impacted his attention.

Ethics Statement. Written informed consent was obtained prior to the study from all adolescents older than 18, and from their legal guardians if they were younger. The present study was approved by National Medical Ethics Committee of Slovenia.

Measures

Measure of intelligence. Raven's Progressive Matrices (RPM) were applied in order to obtain quick and reliable assessment of participants' intelligence.

Clinical and personality measures. All participants were assessed using the Personality Assessment Measure for Adolescents (PAI-A) developed by Morey (2007). The PAI-A consists of 264 items, with 22 non-overlapping scales and is written at a fourth grade reading level. It features four validity scales, 11 clinical scales, five treatment consideration scales and two interpersonal scales. It is based on clinical constructs, which were selected on the basis of their importance within the nosology of mental disorder and their significance in contemporary diagnostic practice. It assesses experiences (e.g., depression, anxiety, borderline traits) that are also of relevance to the study of self-harming behaviour in adolescence. In our study, we only used the results from the depression, anxiety, and borderline scales, and the self-harm subscale. The PAI-A has been extensively tested and validated, showing an average internal consistency for the substantive scales .79 and .80 for the community standardization sample and the clinical sample, respectively. An average test-retest stability coefficient of .78 was found for the substantive scales.

Decision-making task. The Iowa Gambling Task was used, in order to assess decision-making processes of participants. During the IGT participants are presented with four virtual card decks on a computer screen. The participant selects a card from any of the four decks. After a card is selected, the computer generates a distinct sound and an image appears. A message is displayed indicating the amount of play money (we used the Euro currency) the participant has won or lost. If the participant gains money, a smiley face appears, if they lose it, a frowning face appears. A green bar at the top of the screen indicates the amount of money won or lost after each selection. The four decks are labelled A', B', C' and D'. In decks A' and B', immediate gains are large, but those are followed by large and hard to predict losses. In the long run, these two decks are disadvantageous. The decks C' and D' offer immediate gains, which are smaller; however the potential losses are also small. In the long run, these two decks produce higher gain, and are thus advantageous. The ratio of wins is set to yield 250 Euros in 10 trials on decks C' and D'. Similarly, the ratio of losses is set to -250 Euros in 10 trials on decks A' and B'. We used the default IGT setting with 100 trials. The trials are divided in five parts of 20 trials each, also called blocks. The total number of card selections on decks C' and D' represents the advantageous score sum and the total number of card selections on decks A' and B' represents the disadvantageous score sum. Results are calculated through net scores, which represents the values of the advantageous score sum, minus the disadvantageous score sum [(Deck C' + Deck D') – (Deck A' + Deck

B')]. A positive net score indicates that decision-making performance was advantageous and a negative net score shows a disadvantageous performance (Bechara, 2007). This method can reveal whether the participant developed a strategy during their participation or was just choosing randomly throughout the test. This helps to discriminate random performance, normal performance with a positive learning curve and abnormal performance, in which the participant shows a negative learning curve. In order to assess the strategy participants employed we also adopted a strategy of debriefing participants to control if participants approached the task intuitively (i.e. engaging emotions). Participants were asked which decks seemed better than the other, and were asked to assign a rank to each de

The IGT has been used in many studies examining decision-making capacity in a variety of populations, and has proven a valuable instrument in clinical populations (Guillaume et al., 2010; da Rocha, Alvarenga, Malloy-Diniz, & Corrêa, 2011; Sevy et al., 2007; LeGris, Toplak, & Links, 2014). However, the results in healthy populations showed variable results. The validity and reliability of the test also remains a subject of further research (Lin, Chiu, Lee, & Hsieh, 2007; Chiu & Ching-Hung, 2007; Buelow & Suhr, 2009; Ching-Hung et al., 2013).

Results

We used the non-parametric test (Mann-Whitney U test) to test the differences in PAI-A subscales between both groups and differences in debriefing information. Differences in age and RPM scores between groups were tested with t-test.

For the statistical analysis of the Iowa Gambling Test (IGT) we used generalized linear estimating equations (GEE) as implemented in the statistical software package SPSS 19.0. Research has shown (Ma, Mazumdar, & Memtsoudis, 2012) that compared to repeated-measures ANOVA, the GEE method is more efficient in that it is able to achieve higher power with smaller sample size or lower number of repeated measurements.

The dependent variables in our analysis were the IGT test results, defined as the total number of on decks C' and D' (sum of advantageous decks) minus the total number of cards selected on decks A' and B' (sum of the disadvantageous decks) calculated for the first and the last trial block. We tested for a significant interaction between trial blocks and group membership to examine if the SH group was more likely than the control group to continue on making disadvantageous choices later on in the test. We chose to focus on this interaction because the performance on the last block was shown to be a valid measure of risk-associated decision-making (Brand, Recknor, Grabenhorst, & Bechara, 2007).

Table 1. Sample description (n=70).

	Healthy controls	Self-harm group
Age, mean (S.D.)	17.4 (1.6)	17.2 (1.6)
RPM raw score, mean (S.D.)	52.5 (4.8)	50.3 (5.2)
Primary diagnosis (main ICD-10 categories)		
F90-F98	0	16
F40-F48	0	10
F60-F69	0	6
F30-F39	0	2
F50-F59	0	1
Medication	None	Mood stabilizers
PAI-A subscales, mean (S.D.)		
DEP	8.8 (6.0)	35.1 (10.1)**
ANX	14.5 (7.9)	35.0 (9.7)**
BOR	18.0 (9.5)	36.5 (6.2)**
BOR-S	2.5 (2.5)	6.4 (2.7)***

Note. * p<.05 ** p<.01 *** p<.001

Table 1 shows that adolescents from both groups were of comparable age and intelligence. Both groups did not differ in terms of age (t = 0.52, df = 68, p = .603). The results of the Raven's Progressive Matrices indicated that the clinical group tended to have slightly lower general cognitive ability (t = 1.87, df = 68, p = .066). Adolescents in the self-harm group scored significantly higher than those in the control group on the depression (DEP) (U = 22.5, p = .001), anxiety (ANX) (U = 69.5, p = .001) and borderline scales (BOR) (U = 76.5, p = .001). Both groups differed significantly in the Personality Assessment Measure for Adolescents subscale, which measures self-harm (BOR_S) (U = 166.5, p = .000). Furthermore, as expected the Personality Assessment Measure for Adolescents self-harm subscale was a strong predictor of belonging to the self-harm group.

The generalized linear estimating equations analysis showed that participants in the self-harm group were more likely to choose cards from the disadvantageous decks compared to the participants in the control group (Supplement 1). The group x trial block interaction was significant at p < .10 with $\chi^2 = 3.37$, df = 1, p = .053.

Participants in the clinical group chose an additional two to three cards more from the disadvantageous decks than participants in the control group (95% CI = 0.51 – 4.46). The additional generalized linear estimating equations analyses, which included age and general cognitive ability as covariates, showed that age (Wald $\chi^2 = 0.01$, df = 1, p = .954) and general cognitive ability (Wald $\chi^2 = 1.50$, df = 1, p = .221) were not significantly associated with Iowa Gambling Task scores.
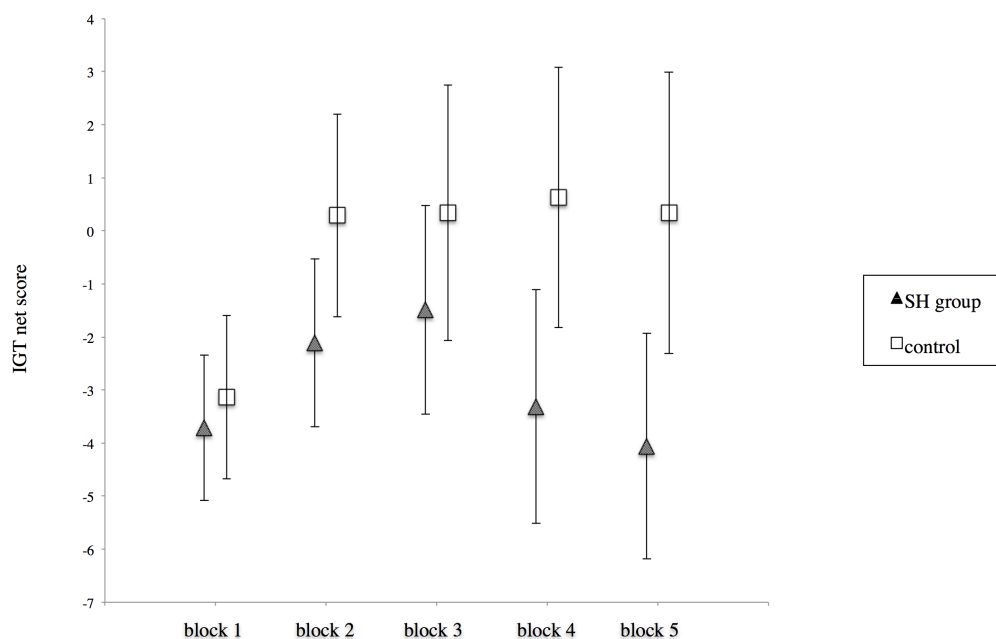
Figure 1. Iowa Gambling Task Results Across Trial Blocks and Participant Groups.

Figure 1 shows results of both groups across Iowa Gambling Task trial blocks. The net score above 0 indicates more advantageous card selections (Decks C' and D'), and the net score below 0 indicates more disadvantageous card selections (Decks A' and B'). Groups differed significantly in their decision-making performance, with control group reaching total net raw score -1.5 and SH group finishing with a total score of -14.63 (t-test = 2.44, df = 68, p = .017).

Furthermore, post-hoc tests indicated that compared to the first trial block adolescents from self-harm group continued choosing from disadvantageous decks, while the participants in the control group were more likely to switch towards the advantageous decks. In the learning phase (block 1) there were no significant differences between the two groups (Mean difference = -0.57, df = 1, p = .582). In the performance phase (block 5) the two groups differed significantly (Mean difference = -4.40, df=1, p = .010), with the control group showing better performance. The control group showed improvement across trials (Mean difference = -3.49, df = 1, p = .032), in contrast to the self-harm group, which demonstrated no improvement in decision-making across trials (Mean difference = 0.34, df = 1, p = .763). While the control group shows gains from block 2 on, the self-harm group shows improvement only up to block 3. On block 4 and 5, the self-harm group shows substantial losses. Error bars show the Wald 95% confidence interval.

Debriefing of the participants showed no differences between groups in assigned ranks for each IGT deck: A' (Mann-Whitney U = 397.0, p = .513), B' (Mann-Whitney U = 355.0, p = .172), C' (Mann-Whitney U = 382.5, p = .389), D' (Mann-Whitney U = 345.0, p = .126).

Discussion

The present study examined decision-making in adolescent females who deliberately self-harm. In our clinical group of older adolescents, who showed the typical clinical symptoms of depression, anxiety and borderline traits associated with SH behaviour, we found impairment in decision-making thereby confirming our hypothesis.

Impaired performance on IGT in our clinical group concurs with previous studies, which compared IGT performance in adolescents with psychiatric diagnoses and healthy adolescents (Ernst et al., 2003; Bridge et al., 2012). In comparison with the control group,

female adolescents who deliberately self-harm demonstrated decision-making that was more geared towards short-term rewards, with less regard for long-term loss. The comparison of the learning phase (block 1) and performance phase (block 5) shows that in contrast to the control group, the SH group showed no evidence of learning based on negative feedback. The analysis of block by block performance shows that the SH group developed a negative learning curve, while healthy controls developed a positive learning curve. These findings can be understood in the context of research by Rolls et al. (1994), and Damasio et al. (1996), who proposed that emotions play a significant role in the learning processes as part of EBL. Based on their findings, we can infer that in the SH group a deficit in EBL leads to a failure in learning from past mistakes and focusing solely on immediate outcomes. In our case this was reflected in adolescents in the SH group learning less from punishing stimuli. Furthermore, the SH group shows peak learning curve in the middle of the task (figure 1). At the third block the SH group reached highest gains, but gains fall significantly after that. We speculate that the SH group learned the strategy of gaining in the decision-making task, but later demonstrated a preference for higher risk choices. This suggests that the SH group was more prone to risky, short-term gains, despite the long-term consequences. In contrast, results from the control group show that these participants approached the ambiguous decision-making task by relying more on their emotions, which enabled them to finish the task with gains. The control group showed gains (net score > 0) on block 2 and continued to finish every block with gain. They also reached the performance phase early in the first half of the test and thus learned the optimum strategy earlier than the SH group. SH group did not reach a gain within blocks (net score < 0) and continued making more disadvantageous selections. Considering there were no differences in debriefing across groups, we speculate that participants approached the task intuitively, thus relying more on their "hunches" and less on cognitive strategies. This claim has some limited support in the literature, for example Damasio (1994). Furthermore, IQ scores did not have a significant impact on the results of the IGT performance in our measured population. This is in line with a review by Toplak, Sorge, Benoit, West, and Stanovich (2010) who showed that performance on the IGT and intelligence seem to be relatively dissociated.

Our experiment shows that risk-taking and focus on immediate reward with little concern about the outcome plays a significant role in self-harming behaviour. This also suggests that adolescent females, who self-harm, show deficits in EBL. That also explains their failure to learn from their past sub-optimal choices (e.g. health-damaging behaviours, consequences of impulsive actions). We propose that adolescent females who deliberately self-harm tend to receive less emotional input on average and that this deficit plays a crucial role in complex decision-making processes. The existence of hindered emotional processing in decision-making process of this type has been supported by studies of patients with vmPFC lesions (Bechara et al., 1997; Bechara et al., 1999; Clark et al., 2008). Therefore, OFC/vmPFC region might be underdeveloped or projections from other brain regions otherwise impaired in adolescent females that intentionally self-harm. Further research is clearly required to explore the role of this potential neuroanatomical correlate.

Differences between the two groups confirm previous research findings (Oldershaw et al., 2009), showing that younger adolescent females who deliberately self-harmed, showed poor real-life decision-making performance. We showed that impaired decision-making persists well into later adolescence. In addition to confirming previous research findings, we also showed that female adolescents who deliberately self-harm develop a negative learning curve, with the opposite being true for control. Since previous research did not explore the learning process, we cannot directly compare our results to their findings. However, the comparison with IGT total net scores reported by Oldershaw et al. (2009) shows that younger adolescents in both of tested groups performed significantly better on IGT than older

adolescents. This could suggest that decision-making is not directly related to brain maturation, as proposed by Overman et al. (2004). This is also supported by our findings, which show that there is no significant effect of age in IGT performance. Direct comparison of these results has limitations - there are many other factors like sample differences, cultural differences, and others that would impact the raw data. However, the differences between results could show that brain maturation is still under development in later adolescence, probably expanding into young adulthood. Further research in differences in decision-making process between younger and older adolescents is suggested.

Research by Hooper et al.(2004) proposed that female adolescents are more averse to punishment, regardless of its severity. Results in our study further suggest that female adolescents who self-harm are even less sensitive to punisher stimuli in comparison with adolescent females, who do not self-harm. This insensitivity and poor decision-making is one of the possible explanations of why these adolescent females self-harm.

Given that poor IGT performance has been shown to be linked with prefrontal cortex immaturity (Hooper et al., 2004; Overman et al., 2004) we suggest that an alternation in the development of the prefrontal cortex in adolescent who self-harm may, at least in part, be responsible for the poor decision-making of our SH group. Further neuroscientific research is still needed to confirm this hypothesis. This hypothesis also seems attractive, as prefrontal cortex immaturity in this population would also partially explain why it is more prone towards risk-taking behaviours and impulsive actions. It would also explain why these individuals are less able to learn from past experiences and why they show little regard for long-term outcomes (according to our study). Further research is clearly required to elucidate the specific neuroanatomical underpinnings relevant to his issue.

Limitations

We found the expected differences between the groups on the self-reported clinical scales. However, due to the number of participants and lack of a clinical comparison group without SH, we were only partially successful in examining the potential clinical predictors, and the impact of depression and anxiety on decision-making in adolescents with self-harming behaviour. A follow-up study with a larger number of patients would strengthen our findings.

In addition, to extend the conclusions regarding the connections between vmPFC, decision-making and self-harming behaviour, further studies should incorporate established neuroimaging research methods and neurophysiological methods, such as the galvanic skin response. There is strong evidence that the galvanic skin response is an indicator of the decision-making process (Bechara et al., 1999). The somatic marker hypothesis put forward by Damasio (1994) proposes that individuals with bad decision-making abilities lack the emotional and physiological response in the decision-making process. Research focused on measurements of skin conductance during decision-making process should show further differences in brain functioning in adolescents who deliberately self-harm. Furthermore, research based on functional magnetic resonance imaging could provide valuable information on role of vmPFC in self-harming behaviour.

Advantages

The behavioural measures of decision-making of self-harm in adolescents remain a relatively poorly studied field of research in clinical psychology. Our study adds to this relatively small body of work by extending the findings of Oldershaw et al. (2009). It shows that decision-making deficits in female adolescents who self-harm persist well beyond middle adolescence and extend well into late adolescence.

By looking at decision-making in the context of emotion-based learning (EBL) our study also offers an interesting avenue of understanding self-harming behaviour as a form maladaptive decision-making. This has clinical implications. It provides preliminary support

for the development of cognitive behavioural therapy and other intervention approaches aimed at reducing self-harming behaviour by means of improving adolescent's decision-making. This type of approach, focusing on the development of meta-cognitive skills and expertise in decision-making, has already found recognition in the treatment of addiction disorders in adolescents (Bartholomew, Dansereau, Knight, Becan, & Flynn, 2011; Dansereau, Knight, & Flynn, 2013). Based on our research findings we feel it is worthwhile pursuing the development of such treatment programs for self-harming behaviour.

Conclusion

Our research shows that adolescent females, who deliberately self-harm show poor performance in the decision-making process. We speculate that the frontal lobe regions are impaired or still under development in the population of older female adolescents, who engage in self-harming behaviour. The greater immaturity of this area could be connected with the self-harming behaviour, but further research is suggested. Decision-making tasks represent a valuable addition to existing diagnostic tools for identifying individuals, who are at risk for self-harm. Furthermore, future therapeutic approaches could focus on the role of decision-making in the rehabilitation of self-harming adolescents. Results from the present study also add to our growing knowledge on the role of cognitive and emotional processes in decision-making and psychopathology.

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Supplement 1. Predictors of Iowa Gambling Task Results Based on Generalized Linear Estimating Equations Analysis.

	Wald χ^2	df	P
Intercept	27.47	1	.000
Trial block	2.51	1	.113
Group	6.08	1	.014
Group x Trial block	3.73	1	.053