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Decision-making in disinhibited adolescents and adults: insensitivity to future consequences or driven by immediate reward?

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Abstract

This study examined the effects of cognitive and behavioural disinhibition on real life decision-making in three different age groups (young adults, 15–16 year-olds and 12–13 year-olds). The Disinhibition-scale of Zuckerman's Sensation Seeking Scale was used to differentiate between low vs. high in cognitive disinhibition and the Matching Familiar Figures Test (Kagan et al., 1964) was used to obtain an index of behavioural inhibition. All participants completed two versions of an experimental analogue of the Iowa Card Gambling Task. In the standard version rewards were placed up front and punishments were delayed and this schedule was reversed in the other version. The results showed impaired performance of cognitively disinhibited individuals but only on the standard task, not on the reversed gambling task. Performance increased with age on both tasks. Behavioural inhibition failed to influence performance on both versions of the gambling task. These findings were interpreted to suggest that (1) real-life decision-making is intact in cognitively disinhibited individuals, and (2) the age-related increase in real life decision-making cannot be attributed to developmental changes in cognitive disinhibition.

Keywords: Decision-making; Sensation-seeking; Impulsivity; Inhibition; Development

1. Introduction

Suppose, you are planning a summer vacation: 2 weeks camping with the family in the south of France. Your children respond enthusiastically to this proposal and are already enjoying the

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prospect of hiking, rafting and swimming. But the response of your wife is considerable less positive. She reminds you that your mother in law is seriously ill so that it is impossible to leave. How to solve this difficult problem? Obviously, a decision cannot be reached by simply constructing a utility function including all relevant options. In real life, we rarely receive direct information about probable outcomes; instead, decisions are made under uncertainty, which requires the decision maker to learn and infer the event probabilities from past experience (Busemeyer & Townsend, 1993). During this process, one compares the obtained outcomes of a choice against beliefs about the likelihood of the obtained outcomes. Both experienced and anticipated emotions therefore influence the decision-making process.

A recent neuropsychological theory holds that bodily states may help to constrain the decision-making space (e.g. Damasio, 1994, 1995, 1996). Following this theory, people not only *experience* anticipated emotions during decision-making, but they also *rely* on these emotions to make favourable decisions when response outcomes cannot be easily predicted. More specifically, it is assumed that linkages are formed between a situation and affective states that are accompanied by the outcomes of the situation. These linkages lead to the development of somatic states, which are ‘‘musculoskeletal, visceral, and internal milieu components of the soma’’ (p. 1414, Damasio, 1996), and hold the potential to reactivate an emotion by acting on the appropriate cortical or sub-cortical structures. The somatic states provide value marks for similar future situations, thereby guiding the behaviour in the new situation towards options that are advantageous in the long run. However, in the absence of somatic markers, options and outcomes become virtually equalized and the process of choosing will depend entirely on logic operations over many option–outcome pairs. The somatic markers are therefore especially valuable in uncertain situations, in which the individual cannot easily make a fast cost–benefit analysis of the possible outcomes of their choices.

The somatic-marker hypothesis was derived from observations of patients with circumscribed damage to the ventromedial region of the prefrontal lobes. These patients have severe impairments in personal and social decision-making, in spite of otherwise largely preserved intellectual abilities. Damasio and co-workers designed a laboratory analogue of real-life decision-making, the Iowa Card Gambling Task (ICGT), to examine the apparent deficits of these patients in greater detail (Bechara, Damasio, Damasio, & Anderson, 1994). The ICGT simulates real-life decision-making in the way it factors uncertainty of premises and outcomes, as well as reward and punishment. The patients were given play money and had to make a series of card selections out of four decks, with the goal of the task to maximize profit. Two decks resulted in large gains, but were disadvantageous in the long run, because the costs were higher, while two other decks resulted in smaller gains, but were advantageous in the long run because the costs were lower. The performance of patients and controls on the ICGT was similar during the initial stages of the task. That is, all participants started sampling from all decks. During the later stages, however, patients selected from the decks with high gains that lead ultimately to higher costs (disadvantageous selections) whereas controls selected from the decks with smaller gains and lower costs.

Bechara et al. (1994) considered three explanations for this finding. Patients with ventromedial prefrontal damage are so sensitive to reward, that immediate gain outweighs the prospect of future punishment. Alternatively, patients are insensitive to punishment, and thus the prospect of reward will always prevail. Finally, patients are generally insensitive to future consequences, positive or negative, and thus their behaviour is always guided by immediate prospects, whatever they are. These alternative interpretations were addressed in a second experiment, in which the schedules of reward and punishment were reversed (Bechara, Tranel, & Damasio, 2000). In this task, punishment was placed up front and unpredictable reward schedules were used as unexpected variable. In this reversed task, patients were more influenced by immediate punishment than by delayed reward. This pattern of findings led the researchers to conclude that patients with ventromedial prefrontal damage are unresponsive to future consequences, whatever they are, and thus are more controlled by immediate prospects.

When reviewing the findings that emerged from a series of gambling studies in ventromedial prefrontal patients, Bechara, Damasio, and Damasio (2000) considered but rejected the possibility that the ability to inhibit responses may have contributed to the performance deficits observed in these patients. It was noted that ventromedial patients performed well on the Wisconsin Card Sorting Test, a standard neuropsychological instrument for assessing disinhibition problems associated with prefrontal damage (e.g. Mountain & Snow, 1993; Stuss et al., 2000; Stuss & Levine, 2002). Furthermore, a detailed analysis of the patients' performance indicated that, like controls, patients switched decks following punishment indicating that their ability to withhold responses is still intact. On the other hand, it was noted that disinhibited individuals, such as substance abusers and low-anxious psychopaths, show performance deficits on the ICGT that are very similar to the failures observed for ventromedial prefrontal patients (Bechara, Dolan, Deinberg, Hindes, Anderson, & Nathan, 2001; Grant, Contoreggi, & London, 2000; Mazas, Finn, & Steinmetz, 2000; Petry, 2001; Petry, Bickel, & Arnett, 1998; Schmitt, Brinkley, & Newman, 1999). To reconcile these findings, Bechara, Damasio et al. (2000) made a distinction between behavioural inhibition and cognitive inhibition. The former refers to an important aspect of executive control; that is, the ability to inhibit responses. The latter applies to a personality or temperamental trait such as described by Zuckerman (Zuckerman, 1979; Zuckerman, Joireman, Kraft, & Kuhlman, 1999) and others (e.g. Newman, Schmitt, & Voss, 1997). The distinction between behavioural and cognitive inhibition is consistent with Nigg's (1999) review of the extant literature on inhibition showing that response inhibition and trait inhibition can be dissociated, both empirically and theoretically. Along these lines, Bechara, Damasio et al. (2000) concluded that (cognitively) disinhibited individuals share with ventromedial prefrontal patients 'the myopia for the future' while individual differences in the ability to inhibit responses (i.e. behavioural inhibition) does not seem to affect gambling performance.

The primary goal of the current study was to assess the conclusion derived from the analysis of Bechara, Damasio et al. (2000). While accepting their distinction between cognitive and behavioural inhibition, it remains to be demonstrated that cognitively disinhibited individuals are insensitive to future consequences of their decisions. So far, the supporting evidence is inconclusive and largely indirect. It is inconclusive because all studies available to date, at least to our knowledge, examined the performance of (presumably) disinhibited individuals using only the standard version of the ICGT, not the reversed version. Adopting the same reasoning employed by Bechara et al. (1994) when discussing the performance deficits of ventromedial prefrontal patients, performance deficits on the standard task do not preclude an interpretation in terms of reward sensitivity. Conclusive evidence for their alleged deficit in considering the future consequences of their decisions should be provided by an evaluation of their performance on the reversed task in which punishment is presented up front and reward is delayed. The supporting evidence is largely indirect because it is derived from studies examining individuals who are supposedly disinhibited (e.g.

substance abusers, psychopaths) but these individuals were not formally screened for cognitive disinhibition. Finally, the number of studies including a behavioural inhibition task is very limited (exceptions are Blair, Colledge, & Mitchell, 2001). The current study sought to remedy these apparent shortcomings by (1) examining performance on both the standard and reversed versions of the ICGT, (2) screening for individual differences in disinhibition, as assessed by Zuckerman's Sensation Seeking Scales (Zuckerman, 1979; Zuckerman et al., 1999), and by (3) including a behavioural inhibition task; the Matching Familiar Figures Task (Kagan, Rosman, Day, Albert, & Philips, 1964).

A secondary goal of the present study was to examine age-related changes in ICGT performance. Inhibition is an emerging theme in developmental psychology (Howe & Pasnak, 1993) emphasizing the relation between the protracted maturation of the frontal lobes and the pronounced developmental change in inhibitory control (e.g. Casey, Giedd, & Thomas, 2000; Dempster, 1993; Van der Molen & Ridderinkhof, 1998; Welsh, 2002). In a previous study, we observed that children failed on both versions of the ICGT presented in a developmentally appropriate format (Crone & Van der Molen, submitted for publication). This finding was interpreted to suggest that children fail to acknowledge the future consequences of their actions—an interpretation that seems to mesh nicely with daily observation. The current study sought to replicate this finding and its developmental focus provided the opportunity to extend the predicted adult pattern of findings (i.e. ICGT performance affected by cognitive but not behavioural inhibition) to younger age groups (i.e. 12–13 year-olds and 15–16 year-olds).

In sum, the goal of the current study was to examine the extent to which the performance on the ICGT is influenced by individual differences in cognitive inhibition and can be predicted on the basis of the performance on a behavioural inhibition task. The conclusion derived by Bechara, Damasio et al. (2000) led us to predict that individuals screened for disinhibition would fail on both standard and reversed versions of the ICGT. On the standard version, these individuals will select from the decks providing large gains although, ultimately, these choices are penalized by higher costs. Likewise, on the reversed version of the task, disinhibited individuals will avoid decks providing large punishments although, in the long run, these decks are associated with higher rewards. This pattern of findings is consistent with the Bechara, Damasio et al. (2000) conclusion stating that disinhibited individuals fail to consider future consequences when they are confronted with risky choices. Alternatively, the results may show that disinhibited persons fail on the standard version but not on the reversed version. In that case, it must be concluded that they are 'reward sensitive' rather than 'future insensitive'. In addition to the ICGT, all participants will perform the MFFT that should provide us with an index of behavioural inhibition. According to Bechara, Damasio et al. (2000), and based on the results reported by Blair et al. (2001), it was anticipated that ICGT performance cannot be predicted on the basis of MFFT performance. This finding would suggest that the ability to inhibit responses does not interact with sensitivity to future consequences. Finally, it was anticipated that the performance on both versions of the ICGT would increase with age, as observed in our previous study (Crone & van der Molen, submitted for publication). The performance on the MFFT should also reveal age-related change; that is, the correct alternative should be selected more frequently by older compared to younger age groups (Welsh, Pennington & Goisser, 1991). Finally, it was examined whether the independence of ICGT performance and MFFT performance predicted for adults applies also to the younger age groups.

2. Method

2.1. Participants

Participants were undergraduate psychology students from the University of Amsterdam and adolescents from two age groups (12–13 year-olds and 15–16 year-olds) who were recruited from a local high school. All participants were screened for disinhibition using the Disinhibition subscale from Zuckerman's Sensation Seeking Scale (SSS) (Zuckerman, Eysenck, & Eysenck, 1978). This scale has previously been standardized for Dutch adults (Feij & Van Zuilen, 1984) and adolescents (Feij & Kuiper, 1984). All adults completed the SSS consisting of five subscales: General Sensation Seeking, Thrill and Adventure Seeking, Experience Seeking, Disinhibition, and Boredom Susceptibility. The Disinhibition subscale contains 12 items asking individuals to answer questions like "I like wild, uninhibited parties" on an anchored five-point scale (1 = never, 2 = rarely, 3 = sometimes, 4 = usually, 5 = always). The internal consistency of this scale is 0.78. Adolescents completed the adolescent version of the SSS containing a Disinhibition subscale consisting of 8 'true/false' items. The internal consistency of this subscale is 0.69.

In total, 257 psychology students were screened, 105 adolescents in the 12–13 years age range, and 74 adolescents in the 15–16 years age range. Individuals scoring in the top or bottom 20% of the norm distribution were selected for participation (e.g. Kagan, Reznick, & Gibbons, 1989). This amounted to 14 high-disinhibited and 21 low-disinhibited adults, aged between 18 and 25 years, 14 high-disinhibited and 13 low-disinhibited adolescents, aged between 12 and 13 years, and 13 high-disinhibited and 15 low-disinhibited adolescents, aged between 15 and 16 years. The disinhibition scores of the six groups of participants are presented in Table 1. The table provides also the *z*-transformed scores and the scores derived from a computerized Raven Standard Progressive Matrices task (Raven SPM). The *z*-transformed disinhibition scores discriminated significantly between the high- and low-disinhibited groups, $F\ (1,\ 89) = 808.01$, $P < 0.001$. There was also an interaction between age and disinhibition, $F\ (2,\ 89) = 5.06$, $P < 0.01$. Post-hoc analysis revealed that scores of the high-disinhibited adolescents in the 15–16 years age range was lower than the scores of the high-disinhibited individuals from the adult and youngest group. But the difference between high- and low-disinhibited individuals was significant for each of the three age groups. The Raven scores were significantly higher in the adult group compared to the younger

Table 1
Participant characteristics (Age, RAVEN, and Sensation Seeking subscale Disinhibition (SSS) in Raw and *z*-scores, *n* = number of participants)

Age range	12–13	15–16	18–25
M age	12.8	16.3	20.8
M RAVEN percentile	56	65	83
n low disinhibited (male)	13 (6)	15 (2)	21 (0)
n high disinhibited (male)	14 (8)	13 (3)	14 (7)
M (S.D.) SSS scores low disinhibited	0.77 (0.44)	1.07 (0.80)	26.12 (3.28)
M (S.D.) SSS scores high disinhibited	6.08 (0.76)	4.92 (0.90)	47.29 (3.69)
Z-scores for low disinhibited	−0.99	−0.87	−0.82
Z-scores for high disinhibited	+ 1.15	+ 0.74	+ 1.08

groups, $F(3, 234) = 11.06$, $P < 0.001$. However, the results reported later were not altered by group differences in Raven score, as indicated by co-variance analyses. Preliminary analyses revealed also that gender differences were absent.

2.2. Gambling tasks

The gambling tasks were developmentally appropriate experimental analogues of Bechara's original Iowa Card Gambling Task (Crone & Van der Molen, submitted for publication). Stimuli were presented on a 17-inch computer screen. Participants were presented four doors (*A–D*), equal in size and appearance and a donkey below the doors. They were told that the game consisted of door selections from any of the four choices using button *C*, *V*, *B* and *N* from a standard keyboard. The buttons corresponded with the choices on the screen. Each choice could result in a gain or loss of apples. The amount of gain was indicated by the amount of apples that were presented. The presentation of both apples and crossed apples informed the participants that they had earned, but also lost a certain amount of apples. The amount of wins and losses varied between choices.

The schedule of wins and losses was unknown to the participants. The participant was told that the goal was to maximize the amount of apples. The participant was informed about their status of gain by a horizontal bar presented at the bottom of the computer screen that was half red/half green at the beginning of the task. The green part of the bar increased with wins, and the red part with losses. The participants were told that they may turn any door, and they may switch doors at any time and as often as they liked. They were not told how many choice selections must be made, but the game stopped after 200 choice trials.

2.2.1. Standard gambling task

The relative gains and losses were derived from Bechara et al. (1994). After choice *A* or *B*, the participant received four apples. Choice *C* or *D* yielded two apples. The ultimate future yield of each choice varied, because the penalty amounts were higher at the high paying choices (*A* and *B*), and lower at the low paying choices (*C* and *D*). After 10 choices from *A*, the participant received 40 apples, but had also encountered five unpredicted punishments of either 8, 10, 10, 10 or 12 apples, bringing the total cost to 50 apples, thus incurring a net loss of 10 apples. After 10 choices from *B*, the participant received 40 apples but had encountered one unpredicted punishment of 50 apples, also incurring a net loss of 10 apples. On the other hand, after 10 choices from *C*, the participant received 20 apples, but had encountered five unpredicted punishments of 1, 2, 2, 2, or 3 apples, bringing their cost to 10 apples, incurring a net gain of 10 apples. The same happened at choice *D*, except that instead of encountering five punishments, there was one larger unpredicted punishment in the total amount of 10 apples. Therefore choice *D* also resulted in a net gain of 10 apples.

In summary, choices *A* and *B* were equivalent in terms of overall net loss over the trials. The difference was that for choice *A*, the penalty was more frequent, but of smaller magnitude, whereas for choice *B*, the penalty was less frequent but of higher magnitude. Choices *C* and *D* were also equivalent in terms of overall net loss. For choice *C*, the penalty was more frequent and of smaller magnitude while for choice *D* the penalty was less frequent and of higher magnitude. Choices *A* and *B* were disadvantageous in the long run, because they resulted in high immediate reward but a net loss in the long run, while choices *C* and *D* were advantageous in the long run because they resulted in immediate low reward but an overall gain.

2.2.2. Reversed gambling task

The important difference between the standard gambling task and the reversed gambling task is that in the former reward is presented up front and punishment is introduced later whereas in the latter punishment is presented up front and reward is introduced later. In the reversed task, choice *A* or *B* resulted in a loss of four apples, whereas choice *C* or *D* resulted in a loss of two apples. Again, the ultimate future yield of each choice varied because the reward amounts were higher at high losing choices. After 10 choices from *A*, the participant lost 40 apples, but also encountered five unpredictable rewards of 8, 10, 10, 10 or 12 apples, resulting in a net gain of 10 apples. The same happened for choice *B*, except that there was one large unpredicted reward of 50 apples. However, after turning choice *C* 10 times, the participant was faced with a loss of 20 apples and five unpredictable rewards of 1, 2, 2, 2, or 3 apples, resulting in a net loss of 10 apples. After turning 10 times from choice *D*, the participant lost 20 apples, and had encountered one unpredictable reward of 10 apples, also resulting in a net loss of 10 apples. Therefore choices A and B were equivalent in terms of overall net gain over the trials. The difference was that choice A resulted in more frequent reward but smaller in magnitude, whereas choice *B* resulted in less frequent reward but higher in magnitude. Choices *C* and *D* were also equivalent in terms of overall net gain over the trials. Choice *C* resulted in reward that was more frequent but of smaller magnitude, and choice *D* resulted in reward that was less frequent but of higher magnitude. In the reversed task, choices *A* and *B* were advantageous in the long run, because they resulted in immediate high punishment but an overall gain due to high delayed rewards. Choices *C* and *D*, on the other hand, were disadvantageous in the long run, because they resulted in immediate low punishment but due to small delayed rewards, in larger losses in the long run. For both the standard and the reversed gambling task, the primary dependent variables were the number of advantageous choices and the number of disadvantageous choices.

After completion of the standard gambling task, the participant was asked which choice was preferred, and to provide a rationale for this strategy.[1] These scores were used to estimate the conceptual knowledge stage after completion of the task and the answers were scored by the conceptual knowledge stages as defined by Bechara, Damasio, Tranel, and Damasio (1997). These stages are: (1) prepunishment phase (preference for disadvantageous choices), (2) pre-hunch phase (no idea what the task is about), (3) hunch phase (hunch that disadvantageous choices are riskier) and (4) conceptual phase (knowledge why the disadvantageous choices are disadvantageous in the long run).

2.3. Matching Familiar Figures Test

Originally designed by Kagan and colleagues (1964), this test requires systematic visual search, hypothesis testing and impulse control.[2] The participant is instructed to select among six or eight

[1] Knowledge state was assessed only following the standard version of the ICGT. This was done to avoid the potential confound of test–retest effects.

[2] It has been argued that the MFFT requires several abilities in addition to response inhibition (e.g. visual search, hypothesis testing) (e.g. Logan, Schachar, & Tannock, 1997; Tiedemann, 1989). Thus, the MFFT does not provide a 'pure' index of response inhibition. Yet, the MMFT was included in the current study because this instrument has been, and still is, widely used as a measure of disinhibition or impulsivity within a developmental context (Kagan, Lapidus, & Moore, 1978; Welsh et al., 1991). Moreover, the MFFT was used previously to assess whether gambling performance is affected by behavioural disinhibition (Bechara, Damasio et al., 2000).

alternatives the one that exactly matched the standard picture. The internal consistency is 0.89 for response time and 0.62 for errors (Block, Block, & Harrington, 1974). The data were acquired by computer administration (Hummel-Schluger & Baer, 1996). A correct response is immediately followed by the disappearance of the stimulus display and the presentation of the next trial. If the initial response choice is incorrect, 'FOUT' (meaning "wrong" in Dutch) is presented on the top of the screen in red for 2000 ms and the participant is instructed to choose again. The participant proceeded to the next item if the correct response was given or if the participant made eight consecutive incorrect responses. Performance measures are average time-on-task and total number of choices across twelve items. Thus, disinhibition was indexed by shorter time-on-task and a higher number of trials.

2.4. Procedure

Students and adolescents filled out Zuckerman's Sensation Seeking Scale approximately 2 months before the experimental test session. (The test–retest reliability of the Disinhibition Scale is 0.89, Feij & Van Zuilen, 1984.) During the test session, all participants were tested individually in a quiet laboratory or classroom. The experimenter was blind to the participants' Disinhibition score or Raven score. The participants performed the standard and the reversed gambling tasks in counterbalanced sequence. The mapping of the reward/punishment schedules was also counterbalanced over keys *C*, *V*, *B* and *N*, to control for key preference. However, the disadvantageous and advantageous choices were always presented on one side together. Thus, the disadvantageous choices were either *C* and *V* (left keys), or *B* and *N* (right keys), and vice versa for the advantageous choices. The schedule of the frequency of the unpredictable penalty or reward was counterbalanced across the two options, for example, mapped to *C* or *V*, and to *B* or *N*.

Both the standard and the reversed task took approximately 10–15 min each to complete. After the participants had finished the two gambling tasks, the Raven SPM and MFFT were administered in counterbalanced order. After completion, the participants were thanked for participation and students were given credit points. Including instructions and breaks, the participants spent approximately one hour in the laboratory or classroom.

3. Results

The results will be presented in two sections. First, the results that emerged from the gambling tasks will be presented. These results relate to the number of advantageous choices made in the standard and reversed gambling tasks, the speed of decision-making, and the individuals' knowledge state associated with the performance of the standard task. The primary question addressed in this section is whether gambling performance is systematically influenced by group differences in cognitive disinhibition. Second, the results of the MFFT will be presented focusing on the number of trials that were needed to complete the task as well as total test time. The primary question examined in this section is whether gambling performance is influenced by individual differences in behavioural inhibition as indexed by the MFFT scores. Differences between age groups are assessed in both sections.

3.1. Gambling and cognitive disinhibition

To examine group differences in gambling performance, we submitted the net score differences (advantageous choices−disadvantageous choices) to a 2 (task) × 3 (age) × 2 (cognitive disinhibition) × 10 (block) ANOVA, where block represents the division of the task in segments of 20 trials. Participants made more advantageous choices in the reversed task compared to the standard task, $F\,(1, 83)=42.15$, $P<0.001$. These main effects were qualified by an interaction between task and block, $F\,(9, 747)=3.42$, $P<0.001$. In Fig. 1, it can be seen that the learning rate was faster in the reversed than in the standard task.

There was no main effect of cognitive disinhibition, $F\,(1, 82)=0.01$, $P=0.98$, but cognitive disinhibition was included in an interaction with task, $F\,(1, 83)=4.25$, $P<0.05$, and a higher-order interaction with task and block, $F\,(9, 747)=2.03$, $P<0.025$. Follow-up analyses were then done for each task separately. As anticipated, the cognitive disinhibition by block interaction was significant for the standard task, $F\,(9, 738)=2.67$, $P<0.01$. Both groups sampled initially from all decks but, as the task progressed, the low-disinhibited individuals learned to make advantageous choices whereas the disinhibited individuals started to select from disadvantageous desks. Importantly, the cognitive disinhibition by block effect failed to reach significance for the reversed task, $F\,(9, 738)=0.34$, $P=0.96$. If anything, the disinhibited individuals made more advantageous choices than their inhibited counterparts on the reversed task. Finally, it is important to note that the cognitive disinhibition effects did not differ between age groups, $F\text{s}<1$.

The interaction between age group and block failed to reach an acceptable significance level, $F\,(18, 747)=1.28$, $P=0.19$. The data of the two youngest age groups were then collapsed and submitted to an analysis including an Age factor with two levels. This analysis yielded a significant interaction between age group and block, $F\,(9, 765)=1.77$, $P<0.05$, that was not altered by task. In Fig. 2 it can be seen that adults, but not the younger age groups learned to make advantageous choices.

An additional analysis focused on strategy change following gain and loss on the next trial. A 3 (age) × 2 (cognitive disinhibition) × 2 (previous feedback: gain vs loss) × 2 (switch: switch vs non-switch) ANOVA resulted in a main effect of Switch, $F\,(1, 82)=150.58$, $P<0001$, that was qualified by an interaction between Switch and Previous Feedback, $F\,(1, 82)=156.71$, $P<0.001$. Individuals more often made similar choices than switching between options, but this effect was much larger following gain (52.59 vs. 20.58 choices) than following loss (15.19 vs. 9.37 choices). Most important, this effect was not qualified by cognitive disinhibition, $F\,(1, 82)=0.69$, $P=0.41$, or age, $F\,(2, 82)=1.87$, $P=0.16$.

The computerized administration of the gambling tasks also permitted an assessment of the speed of decision-making. Analysis of median response times in a 3 (age) × 2 (cognitive disinhibition) × 2 (task) × 2 (block within task) × 2 (gain) × 2 (frequency) ANOVA yielded a main effect of age, $F(2, 70)=4.51$, $P<0.015$, showing that the 13-year olds responded faster ($M=529$ ms, S.D. = 39.6) compared with the 16-year olds ($M=683$ ms, S.D. = 35.7) and the young adults ($M=653$ ms, S.D. = 38.5). The main effect of cognitive disinhibition was also significant, $F\,(1, 70)=4.67$, $P<0.035$, showing that the disinhibited groups responded faster ($M=574$ ms, S.D. = 33.0) than the inhibited groups ($M=669$ ms, S.D. = 28.8). There were no other main or interaction effects.

After participants finished the standard gambling task, their knowledge of the task was categorized into one of four conceptual knowledge stages (Bechara et al., 1997). Increase in knowledge

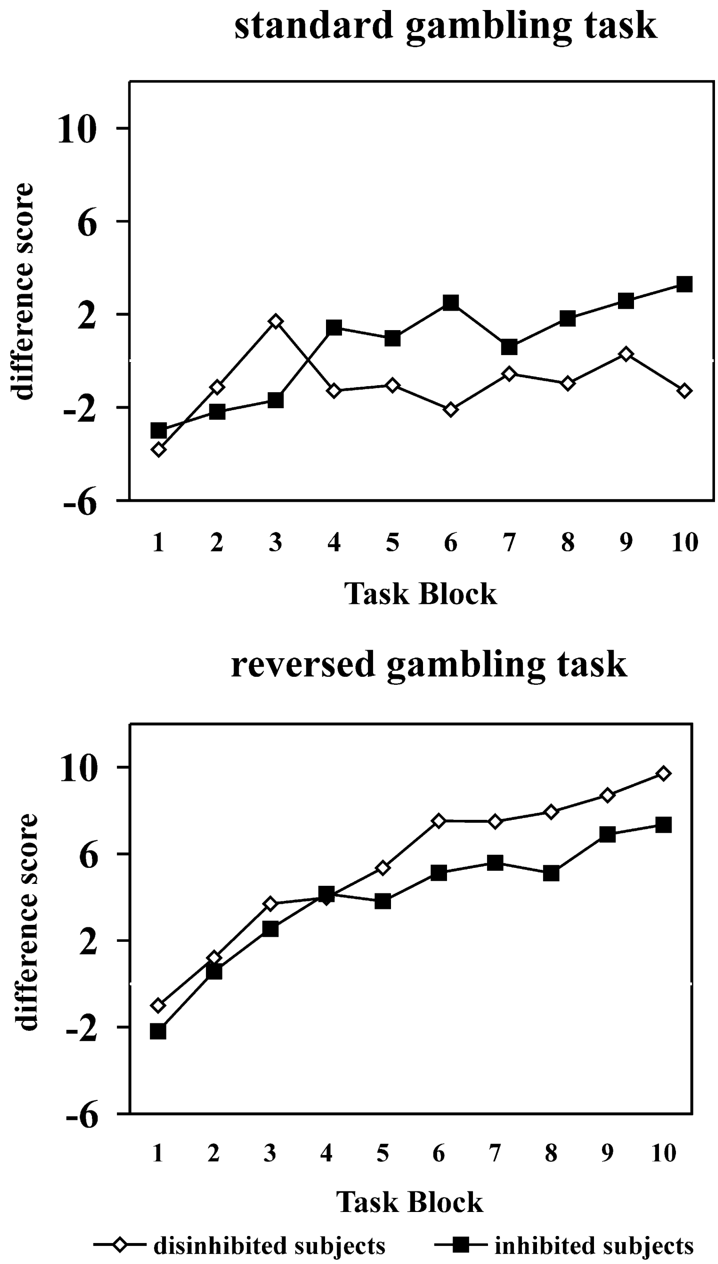

Fig. 1. Mean difference score (advantageous choices − disadvantageous choices) for cognitively disinhibited and inhibited participants on the standard and reversed gambling tasks as a function of task block.

stage was associated with an increase in the total number of advantageous choices in the standard task (pre-punishment $M = -2.17$, pre-hunch $M = 0.14$, hunch $M = 2.14$, conceptual knowledge $M = 3.00$), $F\,(1, 85) = 7.07$, $P < 0.001$. Chi-square analyses examining group differences in age and cognitive disinhibition revealed a significant difference between age groups, χ^2 $(6) = 19.08$, $P < 0.001$, but not between cognitive disinhibition groups, χ^2 $(3) = 1.78$, $P = 0.61$. The differences

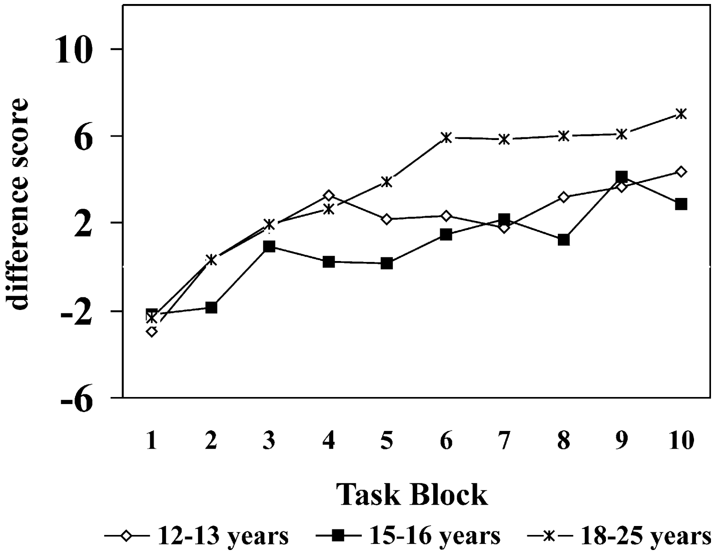

Fig. 2. Mean difference score (advantageous choices − disadvantageous choices) for each age group.

between age groups are presented in Table 2. Post-hoc analysis revealed that young adults reached more often the 'hunch' and 'conceptual knowledge' stages compared to the 12–13 and 15–16 year-old participants, χ^2 (3) = 14.05, $P < 0.001$, who did not differ from each other, χ^2 (4) = 4.81, $P = 0.19$.

3.2. Behavioural disinhibition and gambling

A 3 (age) × 2 (cognitive disinhibition) ANOVA analysis was done on the two performance measures of the MFFT; 'number of trials needed' and 'total time on task'. The scores for all

Table 2
Conceptual knowledge stages for three age groups, n = number of participants

Age group	12–13 years	15–16 years	18–25 years	Total
Pre-punishment	13 48.1%	19 67.9%	7 20.0%	39 43.3%
Pre-hunch	6 22.2%	2 7.1%	12 34.3%	20 22.2%
Hunch	3 11.1%	4 14.3%	3 8.6%	10 11.1%
Conceptual knowledge	5 18.5%	3 10.7%	13 37.1%	21 23.3%
Total	27 100%	28 100%	35 100%	90 100%

Table 3
MFFT scores for each age group and Disinhibition subgroup

	Age group			Total
Cognitive inhibition	12–13 years	15–16 years	18–25 years	
Inhibited participants				
Number of trials	36.0	25.2	23.9	28.4
Time on task (minutes)	8.78	13.13	10.56	10.82
Disinhibited participants				
Number of trials	37.5	28.0	22.6	29.4
Time on task (minutes)	9.00	11.04	11.95	10.78
Total				
Number of trials	36.8	26.6	23.2	
Time on task (minutes)	8.89	12.26	11.25	

groups are presented in Table 3. For the analysis of 'number of trials' there was a significant effect of age, $F\,(2, 87) = 12.94$, $P < 0.001$, showing that the 13-year old participants needed significantly more trials than the 16-year old participants to complete the task, and these participants again needed more trials than the young adults. The number of trials needed to complete the task did not discriminate between low- and high-disinhibited participants, $F\,(1, 87) = 0.08$, $P = 0.83$, nor did the interaction between age group and cognitive disinhibition groups reach significance, $F\,(2, 87) = 0.27$, $P = 0.77$. A similar analysis was performed on 'total time on task', and this analysis yielded a similar pattern of results; a significant main effect of age, $F\,(1, 87) = 4.24$, $P < 0.02$, showing that 13-year olds used less time than 16-year olds and adults, and no effects of cognitive disinhibition.

To examine whether gambling performance was systematically affected by behavioural disinhibition, a stepwise regression analysis was performed with 'total number of advantageous choices' as dependent variable and the MFFT measures as predictors. This analysis was done for both the standard and reversed task. Both analyses failed to show a systematic influence of behavioural disinhibition on gambling performance.

4. Discussion

The current study set out (1) to examine the thesis that performance on the Iowa Card Gambling Task (ICGT) is systematically affected by individual differences in cognitive disinhibition but not behavioural disinhibition (Bechara, Damasio et al., 2000) and (2) to replicate age-related differences in gambling performance observed in a previous study (Crone & van der Molen, submitted for publication). The results that emerged from the current study were straightforward in showing first that cognitively disinhibited individuals performed worse on the standard ICGT. Secondly, gambling performance was not systematically related to individual differences as indexed by the Matching Familiar Figures Test (MFFT). Thirdly, adults performed significantly better on both ICGT versions compared to adolescents.

The finding that cognitively disinhibited individuals perform worse on the standard ICGT is consistent with the results reported previously in studies examining individuals who are arguably cognitively disinhibited, such as Grant et al. (2000) and Bechara et al. (2001). These findings have been taken to suggest that cognitively disinhibited individuals are impaired in 'real-life decision-making'. More specifically, it is assumed that the sensitivity for the future consequences of their decisions is compromised in these individuals (Bechara, Damasio et al., 2000). The current findings, however, present an important challenge to this interpretation by showing that cognitively high-disinhibited individuals performed equal or even better than low-disinhibited individuals on the reversed version of the ICGT. The implication of this finding seems to be that the decision-making of high-disinhibited individuals is reward-driven rather than future-insensitive.

The 'response-modulation hypothesis' advanced by Newman and colleagues may provide a unified account for the current gambling findings (Patterson & Newman, 1993). Response modulation entails brief and relatively automatic shifts of attention from the implementation of goal-directed behaviour to its evaluation allowing for the initiation of controlled processes associated with self-regulation (see also Arnett & Newman, 2000). The response-modulation hypothesis relies primarily on a series of studies examining the impoverished performance of psychopaths (Newman et al., 1997). The important point made by these investigations is that the performance deficit of psychopathic individuals is situation specific. These individuals are less likely than controls to adjust their performance to changes occurring in the experimental contingencies and they are less able to inhibit punished responses. But psychopathic individuals have no difficulty avoiding punishment in the absence of a strong approach set or when punishment is made a salient characteristic from the outset of the task. Framed in general terms, the response modulation hypothesis predicts that the processing of potentially relevant information that is peripheral to a dominant response set occurs less readily in disinhibited individuals. Applying this view to the current data would suggest that the response contingencies in the standard ICGT version (i.e. reward is presented up front and punishment is delayed) induced a dominant approach set that, in high-disinhibited individuals, interfered with the processing of the future consequences of their decisions and prevented them to adjust their performance accordingly. They persisted in making risky choices. Most importantly, the high-disinhibited individuals performed equally well or even better than low-disinhibited individuals on the reversed ICGT version (i.e. punishment is presented up front and reward is delayed). This latter finding is consistent with the response-modulation hypothesis predicting adequate performance in high-disinhibited individuals when punishment is a salient task characteristic. The implication of this pattern of findings is that the apparent failure of high-disinhibited individuals to process the future outcomes of their decisions is secondary to their inability to suspend a dominant approach set induced by rewarded choices.

In passing, it should be noted that two findings are not readily explained within the framework provided by the response-modulation hypothesis. One finding refers to the speed of decision-making showing that high-disinhibited respond faster than low-disinhibited individuals. Fast responding of high-disinhibited individuals on the standard version of the ICGT is consistent with their more active dominant response set as predicted by the response-modulation hypothesis. On the reversed version of the task, however, the decision-making of high-disinhibited individuals did not differ from the performance of the low-disinhibited individuals. Within the context of the response-modulation hypothesis, this finding suggests that, at times, a more passive, information gathering set acquired dominance over the active approach set slowing down the speed of decision-making.

The other finding concerns the individuals' knowledge state assessed following the performance of the standard ICGT version. The questionnaire results showed that both groups reached the hunch and conceptual knowledge state, suggesting that even if high-disinhibited individuals have the knowledge of what options are good or bad, they fail to act on this knowledge. Given the response-modulation hypothesis, one would be led to assume that the more prominent information gathering strategy adopted by low-inhibited individuals translates in a higher knowledge state compared to the dominant response set entertained by the high-disinhibited individuals. Both issues will be addressed in future work.

The MFFT was used to provide an index of behavioural inhibition. The pattern of findings that emerged from this task is consistent with the claim that behavioural and cognitive disinhibition are empirically separable (e.g. Blair et al., 2001) and must be theoretically distinguished (see Nigg, 1999). With advancing age individuals took more time to complete the test but they took fewer trials. This finding is consistent with the mounting literature showing that as children grow older they are better able to inhibit responses (e.g. Casey et al., 1995; Diamond, 2002; Welsh, 2002; Welsh et al., 1991). In contrast, MFFT performance did not discriminate between cognitively high vs. low individuals. Most importantly, the current findings support the claim of Bechara, Damasio et al. (2000) that individual differences in behavioural inhibition do not contribute to gambling performance. The regression analyses with advantageous choices on the ICGT as dependent variable and the MFFT measures (i.e. total test time and total number of trials) as predictors failed to reveal any effect, for both the standard and reversed versions of the ICGT. In failing to do so, the current findings provided yet another instance of the separability of cognitive and behavioural disinhibition. An additional finding that supports this conclusion comes from the performance analysis on strategy switching. Similarly as the patients in Bechara et al.'s studies, cognitively disinhibited individuals switched strategy following punishment as often as inhibited subjects, indicating that their ability to withhold responses is intact. The current findings bear some resemblance with the results reported previously by Blair et al. (2001). These investigators compared the performance of psychopathic and comparison children on two tasks, a computerised version of the ICGT and a dimensional shift task. One of the abilities required by this task is to inhibit responding to a previously rewarded stimulus. The investigators observed that, relative to the comparison children, the performance of psychopathic children was impaired on the standard version of the ICGT but not on the dimensional shift task. This pattern of results makes at least two important points. First, regarding the somatic-marker hypothesis, it provides another demonstration of impaired decision-making in high-disinhibited individuals in spite of their intact ability to inhibit responses. Secondly, regarding the response-modulation hypothesis, it suggests that high-disinhibited individuals are able to shift set provided that the response contingencies are easy to detect (cf. Blair et al., 2001). It would be of considerable interest to examine whether the high-disinhibited individuals would develop risk aversion on the ICGT task when the response contingencies were spelled out to them at the beginning of the task (see also the discussion in Schmitt et al., 1999).

Finally, the current results replicated the age-related trend in the performance of the ICGT observed in a previous developmental study (Crone & van der Molen, submitted for publication). In this study it was observed that adolescents performed better than children in middle childhood but were less risk aversive than adult individuals. The current results are in accord with this pattern by showing that adolescents were less sensitive to the future outcomes of their decisions than were adults. The previous study included several conditions designed to manipulate the uncertainty of response contingencies. In one condition, individuals performed computerised versions of the ICGT and had to infer the response contingencies while engaged on the task. In other conditions, ‘money-meters’ kept tally of the gains and losses associated with each deck thus allowing individuals to make effective use of the response contingencies when deciding between decks. The response-contingency information slowed down the speed of decision-making, as predicted from the response-modulation hypothesis, but it did not alter risk aversion, as predicted by the somatic-marker hypothesis. Children persisted in making risky choices and did not turn faster to the advantageous decks. This finding was taken to suggest that approach set induced by the response contingencies during the initial phase of the ICGT is so potent that individuals fail to implement the detailed information on response contingencies in their decision-making. The observation that failures in risk aversion occur also when punishment is placed up front and reward is delayed (i.e. on the reversed version of the ICGT) indicates that avoiding punishment induces in children a response set that is almost as dominant as the response set elicited by collecting reward.

In conclusion, the current finding, that high-disinhibited individuals failed on the standard version of the ICGT but not on the reversed version, provides strong evidence against general notions emphasising that these individuals must be characterized by low sensitivity to future consequences. Instead the current findings indicate that they are reward-prone rather than future-insensitive. From a neuropsychological perspective, the reward-proneness of cognitively high-disinhibited individuals could result from abnormal activity of the mesolimbic dopamine system. Dysfunction within this system is related to exaggerated processing of incentive values (Depue & Collins, 1999). Depue, Collins, and Luciana (1996) proposed that dopamine-projecting systems, projecting from the ventral tegmental area of the midbrain to limbic structures such as the amygdala, hippocampus, and nucleus accumbens, facilitate emotional and cognitive processes that support goal-directed behaviour, and dopamine is found essential for associative stimulus-reward learning (Di Chiara, 1999). Cognitively disinhibited individuals’ behaviour might be guided by stronger dopamine firing, given that high levels of dopamine projecting activity are proposed to emerge in behaviour that motivates and guides emotional responses to signals of reward (Depue et al., 1996). Previously, it has been argued that behaviour of substance abusers, purportedly disinhibited individuals, might also be related to higher levels of dopamine firing (Bechara et al., 2001; Depue et al., 1996; Di Chiara, 1999). Although the present findings indicate reward-proneness in disinhibited groups, data from this study were collected in a normal population. Future research is necessary to examine if these results can be generalized to psychopathological groups.

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