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Preliminary communication

Distinct alterations in value-based decision-making and cognitive control in suicide attempters: Toward a dual neurocognitive model

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ABSTRACT

Objective: The literature suggests that many suicide attempters show impairment in both decision-making and cognitive control. However, it is not clear if these deficits are linked to each other, and if they may be related to more basic alterations in attention. This is a relevant question in the perspective of future interventions targeting cognitive deficits to prevent suicidal acts.
Method: Two different populations of patients with histories of suicide attempts were assessed ($N=142$ and 119). The Iowa Gambling Task (IGT) was used to measure decision-making in both populations. We used a D2 cancellation task and a verbal working memory task in population 1; the Stroop test, the *N*-Back task, the Trail Making Test, and the Hayling Sentence Completion test in population 2.
Results: Regarding decision-making, we only found a small negative correlation between the Hayling test error score ($r=-0.24$; $p=0.01$), and the net score from the second half of the IGT. In contrast, working memory, cognitive flexibility and cognitive inhibition measures were largely inter-correlated.
Limitation: Most patients were medicated. Only patients with mood disorders.
Conclusion: These results add to previous findings suggesting that the neurocognitive vulnerability to suicidal behavior may rely on impairments in two distinct anatomical systems, one processing value-based decision-making (associated with ventral prefrontal cortex, among others) and one underlying cognitive control (associated with more dorsal prefrontal regions). This distinction may result in tailored-made cognitive interventions.

1. Introduction

Several publications have now revealed cognitive deficits in patients with a history of suicidal acts in comparison to non-suicidal patients and healthy controls (Jollant et al., 2011; Richard-Devantoy et al., 2012a). These neurocognitive deficits may represent vulnerability factors to suicidal behavior, as they may render these individuals more sensitive to their environment and/or less likely to respond advantageously to changes in this environment. Among these deficits, disadvantageous decision-making has been found in several independent populations (Jollant et al., 2005, 2007, 2010; Malloy-Diniz et al., 2009; Martino et al., 2010; Clark et al., 2011). This was recently confirmed by a meta-analysis of nine positive and negative studies, showing a significant effect size in the comparison between suicide attempters and patient controls (Richard-Devantoy et al., submitted). In addition, several studies have now reported impairment in other cognitive domains, most notably cognitive control (Keilp et al., 2001, 2012, 2013; Richard-Devantoy et al., 2012b), a generic name for a set of functions including task switching, response inhibition, error detection, response conflict and working memory (Glascher et al., 2012). These deficits may become the target of future interventions aiming at reducing the risk of suicidal acts in some at-risk individuals.

One frequently raised question relates to the possibility that impaired decision-making and cognitive control may be largely linked to each other, or may stem from deficits in more basic cognitive processes, notably attention. For instance, previous studies in patients with brain lesions have found that alterations in working memory (through dorsolateral prefrontal cortex lesions, for instance) may negatively impact decision-making performance (Bechara et al., 1998). However, recent reviews

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suggest that Iowa Gambling Task (IGT) performance is usually not correlated with other cognitive domains in different non-clinical and clinical populations (Toplak et al., 2010), and that value-based decision-making (as measured by the IGT) and cognitive control may rely on different brain systems (Glascher et al., 2012). Few studies to date have examined correlations between neurocognitive measures in suicidal patients, with largely inconclusive results (Martino et al., 2010; Legris et al., 2012; Westheide et al., 2008). In the perspective to develop therapeutic interventions targeting cognitive abilities, it is necessary to shed light on the intimate mechanisms of neurocognitive vulnerability in suicide attempters.

The aim of this study was, therefore, to explore the link between decision-making and cognitive control (including flexibility, inhibition and working memory), and between these domains and attention, in two large populations of suicide attempters assessed with two different batteries of neuropsychological tests. We hypothesized that, in suicide attempters, decision-making and cognitive control would not be correlated to each other nor would they be related to attention, highlighting the distinction between deficits in two cognitive and brain systems.

2. Methods

2.1. Population and clinical assessment

Two populations of suicide attempters (Population 1, $n=142$; Population 2, $n=119$) were consecutively recruited from one outpatient and inpatient psychiatric setting at Montpellier University Hospital (CHU), France. The study has been approved by the local Ethics Committee (CPP Sud Méditerranée IV, CHU Montpellier). All participants were French natives, and written informed consent was obtained from all of them.

A suicide attempt was defined as a self-directed injurious act with a clear intent to end one's own life (Mann, 2003). All patients were in full or partial remission at the time of evaluation, with a 21-item Hamilton Depression Rating Scale score (Hamilton, 1960) below 12 and no current diagnosis of a major depressive episode according to DSM-IV criteria. Patients with neurological disorders, a history of brain injury or a history of electroconvulsive therapy in the last 2 years were not included.

Psychiatric diagnoses were carried out according to the DSM-IV criteria. The MINI 5.0.0 (Sheehan et al., 1998) was used together with any other available information.

2.2. Neuropsychological assessment

In both populations, the cognitive battery included measures of *verbal IQ* with the French version of the National Adult Reading Test (NART) (Mackinnon et al., 1999) and *decision-making* with the computerized version of the Iowa Gambling Task (IGT) described elsewhere (Bechara et al., 1999). For the IGT, a net score (total number of safe minus risky choices, so the higher the score the better the performance) was calculated for the whole task but also for the first 50 choices (roughly corresponding to *decision-making under ambiguity* during which participants have to gain experience; IGT1-50) and the last 50 choices (corresponding to *decision-making under risk* when many participants have acquired a certain understanding of the underlying contingencies; IGT51-100).

In population 1 only, *attention* was evaluated with a letter-cancellation task, the D2 test (Uttl and Pilkenton-Taylor, 2001). Participants were required to cancel “as fast as possible and with the minimum errors” a maximum number of “d” letters with two dots in lines with “d” and “p” letters with one or two dots. *Verbal working memory* was assessed with a specific task (Huguelet et al., 2000) during which participants listened to a list of one hundred numbers read at a pace of one number per second. They had to tap with their finger on the table when they heard a number identical to the previous two numbers. For both tests, the higher the score, the more errors (both omission and commission) relative to responses they did.

In population 2 only, the cognitive battery included classical measures of *cognitive flexibility* with the Trail Making Test (TMT) (Godefroy et al., 2008), *working memory* and *attention* with a *N*-Back task, and *cognitive inhibition* with the Stroop Color test (Godefroy et al., 2008) and the Hayling Sentence Completion test (Burgess and Shallice, 1996). The ratio TMT B/A, the *N*-Back total score (as a measure of working memory) and 1-Back total score (used here as a measure of attention), the interference Stroop score (errors and time), and the time and number of penalties at the Hayling were used. Besides, TMT A was used as a measure of *cognitive processing speed*.

Subjects were not allowed to smoke during the neuropsychological session.

2.3. Statistical analysis

The characteristics of the two populations were described by using the mean and the standard deviation for quantitative variables, and proportions for categorical one. For continuous variables (age, level of education and tests scores), distributions were tested with Shapiro-Wilk's test and showed a normal distribution for most of the scores. Parametric tests were therefore used. The relation between the test scores was first tested for linearity. Then, Pearson's correlation tests were used. Significance was set *a piori* at a *p*-value below 0.05. Significant associations were additionally tested for potentially confounding factors

Table 1
Socio-demographic, clinical and cognitive description of the 2 populations of suicide attempters.

	Population 1 ($n=142$)	Population 2 ($n=119$)
Demographic variables		
Women, *n* (%)	108 (76.1)	91 (76.5)
Age (years), mean (SD)	36.4 (11.9)	40.1 (12.2)
Years of education, mean (SD)	12.4 (3.1)	13.2 (2.9)
Clinical variables		
Unipolar disorders, *n* (%)	94 (66.2)	66 (55.5)
Bipolar disorders, *n* (%)	43 (33.3)	35 (29.4)
Anxiety disorders, *n* (%)	80 (56.3)	66 (55.5)
Eating disorders, *n* (%)	30 (21.1)	21 (17.6)
Substance/alcohol abuse, *n* (%)	45 (31.7)	29 (24.4)
Benzodiazepines use, *n* (%)	87 (61.3)	16 (12.9)
Cognitive variables		
NART score, mean (SD)	23.7 (4.9)	22.7 (4.6)
IGT Net score, mean (SD)	−0.9 (23.9)	11.9 (28.7)
IGT 1–50 score, mean (SD)	−2.2 (9.89)	1.5 (12.3)
IGT 51–100 score, mean (SD)	1.5 (16.9)	10.4 (21.2)
D2 attention test total score, mean (SD)	22.8 (23.8)	–
Verbal working memory score, mean (SD)	86.4 (75.8)	–
N-Back total score, mean (SD)	–	114.3 (15.6)
TMT A score (ms), mean (SD)	–	41.6 (11.5)
TMT B/A score, mean (SD)	–	40.6 (28.6)
Hayling B Time (ms), mean (SD)	–	302.4 (165.9)
Hayling penalties, mean (SD)	–	4.8 (3.6)
Stroop interference time score (ms), mean (SD)	–	1.3 (9.6)
Stroop interference errors score, mean (SD)	–	2.8 (2.5)

SD=standard deviation; ms=milliseconds; NART=National Adult Reading Test; IGT=Iowa Gambling Task; TMT=Trail Making Test.

Table 2
Inter-correlations between neurocognitive variables, and socio-demographic variables in suicide attempters.

Population 1 (*N*=144)	1	2	3	4	5	6	7	8
1. IGT net score	–							
2. IGT 1–50 score	0.75[a]	–						
3. IGT 51–100 score	0.92[a]	0.45[a]	–					
4. NART score	0.02	−0.05	0.21[b]	–				
5. Age	−0.001	0.03	−0.06	0.11	–			
6. Educational level	0.1	−0.02	0.15	0.37[a]	−0.18[b]	–		
7. D2 attention test total score	−0.016	0.09	−0.07	−0.2[b]	0.11	0.17[b]	–	
8. Verbal working memory score	−0.025	0.03	−0.06	−0.13	0.17[b]	−0.1	0.22[b]	–

Population 2 (*N*=119)	1	2	3	4	5	6	7	8	9	10	11	12	13
1. IGT net score	–												
2. IGT 1–50 score	0.74[a]	–											
3. IGT 51–100 score	0.92[a]	0.43[a]	–										
4. NART score	0.23[b]	0.18	0.21[b]	–									
5. Age	0.15	0.16	0.12	0.06	–								
6. Educational level	0.29[b]	0.19	0.29[b]	0.5[a]	0.15	–							
7. *N*-Back total score	0.1	0.04	0.11	0.16	0.27[b]	0.15	–						
8. TMT A score	0.02	0.08	−0.03	−0.06	0.15	–	−0.39	–					
9. TMT B/A score	−0.03	−0.04	−0.02	−0.05	0.29[b]	–	−0.10	0.14	–				
10. Hayling B time	−0.06	0.05	−0.12	−0.02	0.14	−0.14	−0.3[a]	0.13	0.02	–			
11. Hayling penalties	−0.2[a]	−0.02	−0.3[a]	−0.05	0.04	−0.05	−0.3[a]	0.06	0.3[b]	0.5[a]	–		
12. Stroop interference time score	−0.02	−0.13	−0.05	−0.2[a]	−0.2[a]	−0.16	0.06	0.03	−0.2	0.03	0.06	–	
13. Stroop interference Errors score	−0.2	0.03	−0.14	0.02	0.01	0.09	−0.22	−0.11	0.2	0.2	0.25[b]	0.25[b]	–

NART=National Adult Reading Test; IGT=Iowa Gambling Task; TMT=Trail Making Test.

[a] $p < 0.01$.
[b] $p < 0.05$.

including age, gender, diagnosis, benzodiazepine use, NART score, and level of education with a linear regression analysis. All analyses were performed using SPSS (version 20.0; SPSS, Inc., Chicago, IL).

3. Results

See Table 1 for a description of the patient samples, and Table 2 for correlation analyses.

In population 1, no correlation was found between the 3 IGT net scores (1–50, 51–100 and total) and working memory test score ($r=0.03$, $p=0.7$; $r=-0.06$, $p=0.5$; $r=-0.02$; $p=0.8$, respectively) or D2 score ($r=0.09$, $p=0.3$; $r=-0.07$, $p=0.4$; $r=-0.02$; $p=0.9$, respectively), nor were there any differences in relation to gender. The IGT net scores were not correlated with NART, age, or level of education. D2 score was slightly correlated with the educational level ($r=-0.2$; $p=0.04$), the NART score ($r=-0.2$; $p=0.02$), and the working memory test score ($r=0.2$; $p=0.01$). Moreover, working memory test score was positively correlated with age ($r=0.2$; $p=0.04$).

In population 2, no correlation was found between the 3 IGT net scores (1–50, 51–100 and total) and *N*-Back total score ($r=0.04$, $p=0.7$; $r=0.1$, $p=0.35$; $r=0.1$; $p=0.4$, respectively), TMT A time execution ($r=0.08$, $p=0.5$; $r=-0.03$, $p=0.8$; $r=0.015$; $p=0.9$, respectively), TMT B/A score ($r=-0.04$, $p=0.7$; $r=-0.02$, $p=0.9$; $r=-0.03$, $p=0.8$, respectively), attention score at the 1-Back total ($r=-0.001$, $p=0.9$; $r=-0.15$, $p=0.2$; $r=-0.1$, $p=0.3$, respectively), Stroop interference errors score ($r=0.03$, $p=0.7$; $r=-0.14$, $p=0.6$; $r=-0.2$, $p=0.8$, respectively), and Stroop interference time (r=-0.13, p=0.2; r=-0.05, p=0.15; r=-0.02, p=0.09, respectively). IGT total and 51–100 net scores were slightly associated with the NART score in this population ($r=0.2$, $p=0.5$; $r=0.21$, respectively).

We found a negative correlation between the IGT total net score and the penalty score of the Hayling test ($r=-0.21$; $p=0.02$), but not with the time to execute the Hayling test. This positive result remained significant after taking into account age, gender, NART score, benzodiazepine use, and diagnoses. The correlation was only significant during the last 50 choices of the IGT ($r=-0.28$; $p=0.003$), with higher scores in men ($r=-0.49$; $p=0.009$) compared to women ($r=-0.25$; $p=0.02$), but not during the first 50 choices ($r=-0.18$; $p=0.8$).

Hayling penalties score was correlated with the *N*-Back total score ($r=-0.31$; $p=0.009$), TMT B/A score ($r=0.30$; $p=0.01$), Hayling time score ($r=0.5$; $p<0.001$), and Interference Stroop errors score ($r=0.25$; $p=0.005$). The NART score was correlated with the educational level ($r=0.5$; $p<0.001$), TMT B/A score ($r=-0.26$; $p=0.03$) and Interference Stroop errors score ($r=-0.23$; $p=0.01$).

4. Discussion

Previous studies have shown neurocognitive deficits in patients with histories of suicide attempt compared to patients with no suicidal history. These deficits may be the focus of future interventions specifically targeting the neurocognitive vulnerability to suicidal behavior, i.e. independently of co-morbid disorders such as depression. However, this first finding necessitates uncovering the mechanisms that underlie such impairment. Findings from the current study suggest that alterations in decision-making are largely independent of cognitive control (including cognitive flexibility, cognitive control and working memory) and are not related to attention deficits. Though we found a weak negative correlation between the IGT net score and the penalty score of the Hayling test (a test of verbal initiation and inhibition), no association was found between performances on the Stroop test (another test of inhibition), and IGT. In contrast, the different domains of cognitive controls were for a large part inter-correlated.

Previous small scale studies examining decision making and cognitive inhibition in suicide attempters using the Go/No–Go commission errors (Westheide et al., 2008) or the Stroop task (Legris et al., 2012) show a significant correlation, while another study found no correlation between the IGT net score and attention, working memory, or cognitive flexibility (Martino et al., 2010), providing inconclusive data. Overall, our findings support the conclusions from a review paper of clinical and non-clinical populations on “the separability between decision-making on the IGT and cognitive abilities” (Toplak et al., 2010)

Moreover, it also give arguments to the possible anatomical discrimination between regions mostly implicated in the IGT (notably ventral prefrontal cortex) and regions mostly implicated in cognitive control (notably dorsal prefrontal cortex) (Glascher et al., 2012). Indeed, we previously found decision-making impairment in suicide attempters to be associated with lateral orbitofrontal cortex (Brodman area 47) dysfunction (Jollant et al., 2010), a region also reported in post-mortem studies of suicide completers (Mann et al., 2000). Interestingly, this region appears to be implicated in both the initiation and suppression phases of the Hayling test (Volle et al., 2012; Collette et al., 2001), whereas Stroop performances were mainly associated with the dorsolateral prefrontal and anterior cingulate cortices (Glascher et al., 2012), highlighting the diversity of inhibitory processes. Dysfunction of the lateral orbitofrontal cortex in suicide attempters may therefore explain the reported relationship between IGT and Hayling performances.

Our study has several limitations. First, most patients were under medication, although patients were assessed when the medication was reduced to the lowest possible dose. This may have impaired some cognitive functions more than others and, consequently, altered the strength of some associations. Moreover, our patients mainly suffered from affective disorders but never from psychotic disorders, which has to be taken into account when generalizing the results. In addition, one has to note that population 2 did not show the same level of decision-making impairment as population 1. Although this may have very little effect on the correlation analyses, it also emphasizes the variability of decision-making performance among suicide attempters, which is hardly surprising in the face of the heterogeneity of suicidal behavior. Of note, the lower rate of benzodiazepine use and overall of all major psychiatric diagnoses in population 2 may suggest the inclusion of a less severe population in this second wave of recruitment.

In summary, our study supports the hypothesis that suicidal behavior may rely on a combination of deficits affecting value-based processes (as revealed by disadvantageous decision-making) and related to the ventral prefontal cortex among other regions, on one side; and deficits affecting cognitive control, related to more dorsal prefrontal cortex, on the other side. We may expect that patients show a variable combination of these deficits, leading to the perspective of potential tailored-made treatments.

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Conflict of interest

All authors declare no conflict of interest.

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