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REWARD/PUNISHMENT REVERSAL LEARNING IN OLDER SUICIDE ATTEMPTERS

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Abstract

Objective—Suicide rates are very high in old age, and the contribution of cognitive risk factors remains poorly understood. Suicide may be viewed as an outcome of an altered decision process. We hypothesized that impairment in a component of affective decision-making – reward/punishment-based learning – is associated with attempted suicide in late-life depression. We expected that suicide attempters would discount past reward/punishment history, focusing excessively on the most recent rewards and punishments. Further, we hypothesized that this impairment could be dissociated from executive abilities such as forward planning.

Method—We assessed reward/punishment-based learning using the Probabilistic Reversal Learning task in 65 individuals aged 60 and older: suicide attempters, suicide ideators, non-suicidal depressed elderly, and non-depressed controls. We used a reinforcement learning computational model to decompose reward/punishment processing over time. The Stockings of Cambridge test served as a control measure of executive function.

Results—Suicide attempters but not suicide ideators showed impaired probabilistic reversal learning compared to both non-suicidal depressed elderly and to non-depressed controls, after controlling for effects of education, global cognitive function, and substance use. Model-based analyses revealed that suicide attempters discounted previous history to a higher degree, compared to controls, basing their choice largely on reward/punishment received on the last trial. Groups did not differ in their performance on the Stockings of Cambridge.

Conclusions—Older suicide attempters display impaired reward/punishment-based learning. We propose a hypothesis that older suicide attempters make overly present-focused decisions, ignoring past experiences. Modification of this 'myopia for the past' may have therapeutic potential.

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Keywords

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Worldwide, suicide is more common in the elderly than in any other age group (1). Suicide attempts in late life are more lethal than in mid-life (2), with up to one-half ending in death in older men (3). Though cognitive decline is prevalent in old age and may contribute to the heightened suicide risk, little is known about the role of cognitive factors. Initial evidence links late-life suicidal behavior to poor performance on screening measures of cognitive control (4,5).

Evidence from younger suicide attempters indicates impaired performance on tests of cognitive control (6–9) and poor problem-solving (10). To the extent that findings from younger adults generalize to late-life suicide, they suggest a deficit in cognitive abilities relevant to dealing with life's problems and making decisions. Yet, cognitive mechanisms that underpin these relationships remain unclear. In a pioneering study, Jollant and colleagues found impaired decision-making in otherwise cognitively-intact euthymic younger suicide attempters on the Iowa Gambling Task (11). Indeed, since a suicide attempt may be viewed as an outcome of a non-optimal decision process, it is plausible that impaired decision-making is a causal cognitive factor in suicidal behavior. However, the mechanisms of impairment on the Iowa Gambling Task are unknown, since the typically reported "net score" variable (total number of risky choices minus total number of safe choices) does not easily allow for dissection of underlying components. Suicide attempters may fail to represent the reinforcement contingencies on the task, or may be deficient in adapting a decision-making strategy, or may have a genuine preference for high-risk choices (12–14).

In this study, we sought to identify the components of decision-making that are associated with attempted suicide in old age. We selected a probabilistic reversal learning task, which requires one to 'map' an uncertain and changing environment by choosing between two stimuli variably associated with reward/punishment. Poor performance on this task can reflect a problem in mentally representing the environment, such as (1) a representation which is overly static in time (slow reinforcement learning) leading to perseverative responses, or (2) an unstable representation which changes too rapidly based on recent feedback and discounts past reinforcement history, leading to excessive switches in choice, or (3) abnormal sensitivity to rewards or punishments. Alternatively, it may result from a sub-optimal choice process, regardless of the nature of the representation. Previous research found that depressed people switch excessively in response to non-contingent punishment, suggesting that their representations are either unstable and/or overemphasize punishment (15,16). Behavioral and neural responses during decision-making on this task may be described by Bayesian computational models, which predict the activity of the ventromedial prefrontal cortex (20) and the striatum (21).

To determine whether impaired reward/punishment-based learning is specifically related to attempted suicide, we attempted to dissociate the performance on the probabilistic learning task from executive abilities which do not involve reward or punishment. We hypothesized that suicide attempters would show impaired probabilistic reversal learning, reflecting unstable representations that discount past history and are overly focused on recent events. One may call such a view of one's past history 'myopic', akin to 'myopia for the future' linked by Bechara and colleagues to ventral prefrontal lesions (22). This 'myopia for the past' could be related to habitually decreased consideration of one's personal past in the face of recent events (23) during a suicidal crisis. We predicted that this 'myopia for the past' would be distinct from over-sensitivity to punishments. Further, we hypothesized that the suicide attempters' executive abilities would appear intact on a test of forward planning and working memory. Another limitation of the existing literature is that studies that contrast suicide attempters with non-suicidal individuals (7,11) cannot determine whether cognitive markers are specific for suicidal behavior or whether they also extend to suicidal ideation – a distinction of great clinical importance. To more strongly link decision-making with suicidal *behavior*, we included a comparison group of elderly with serious suicidal ideation but no history of attempt.

METHODS

Participants

Between May of 2006 and October of 2008, we recruited 65 participants aged 60 and older: 15 depressed suicide attempters, 12 depressed suicide ideators, 24 non-suicidal depressed elderly, and 14 non-depressed, non-suicidal elderly control subjects. Suicide attempters, suicide ideators, and non-suicidal depressed elderly were diagnosed with major depression without psychotic features by Structured Clinical Interview for *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* Axis I Disorders (24,25) (SCID/DSM-IV). To exclude individuals with clinical dementia and to ensure that participants could engage in computerized assessments, all were required to have a score of ≥24 on the Mini-Mental State Exam (26). We excluded elderly with sensory disorders that precluded cognitive testing, mental retardation, delirium, neurologic disorders, bipolar disorder, schizophrenia, schizoaffective disorder, and exposure to electroconvulsive therapy in the previous 6 months.

All participants provided written informed consent. The University of Pittsburgh Institutional Review Board approved the study.

Suicide attempters had made a suicide attempt; 9/15 made their first suicide attempt after age 60; all were inpatients. These participants displayed a high level of suicidal intent during their attempts and expressed severe suicidal ideation (Table 1); 5/15 made repeat attempts; 6/15 made an attempt within a month of assessment and 9/15, within a year. Suicide attempt history was verified by a psychiatrist, using the interview, medical records, information from the treatment team, and information from family or friends. We excluded participants with significant discrepancies between these sources. None of the suicide attempters had experienced head injuries directly related to attempt, however we assessed potential anoxic-ischemic or toxic brain injury, based on the Beck Lethality Scale (27), medical records and the clinical interview. A study psychiatrist (AYD) identified any attempts with a score of >4 on the Beck Lethality Scale and any history of systemic hypotension >5 minutes or asphyxia or neurotoxic ingestion, 1/15. For 2/15 participants it was impossible to rule out brain injury during past attempts Thus, we excluded these 3 participants from sensitivity analyses.

Suicide ideators had thoughts of suicide with specific plan, serious enough to precipitate an inpatient admission (10/12) or an increase in the level of outpatient care (2/12) and no lifetime history of suicide attempt. Suicidal ideation was also very severe in this group (Table 1).

Non-suicidal depressed elderly were included in the study to detect an association between decision-making and suicidal behavior above and beyond cognitive effects of depression. These participants had no current or lifetime history of suicide attempts or suicidal ideation as established by clinical interview, review of medical records, SCID/DSMIV, and Scale for Suicidal Ideation (lifetime); 2/22 were inpatients. Participants were excluded from this group if they had indirect self-destructive behaviors.

Non-depressed control subjects were included as the benchmark group. They had to have no lifetime history of any psychiatric disorder as determined by SCID/DSMIV.

Procedures

Our study was conducted at a university psychogeriatric inpatient unit and a specialty outpatient clinic for late-life depression. Since we aimed to capture decision-making in a state similar to a suicidal crisis, we assessed participants with major depression during an acute depressive episode. Participants were tested within two weeks of inpatient admission or at the beginning of outpatient treatment. Depressed participants continued to receive psychotropic medications as clinically indicated (Table 1). We ensured that none were intoxicated or had withdrawal symptoms at the time of testing. Neuropsychological testing took place in one to two sessions over 1–3 days. Assessors were blind to clinical history and ratings.

Assessments

Cognitive and clinical characterization—Current global cognitive function was assessed with the Dementia Rating Scale (DRS) (28). Depression severity was measured with the 17-item Hamilton Rating Scale for Depression (HRSD) (29). Burden of physical illness was assessed with the Cumulative Illness Rating Scale adapted for Geriatrics (CIRS-G) (30). We obtained medication lists from pharmacy records. We measured the intensity of pharmacotherapy for the current episode of depression with the cumulative strength score from the Antidepressant Treatment History Form (31), based on antidepressant trial duration, the dose, and the use of augmenting agents. In order to capture exposure to psychotropic medications not included in this score, we additionally assessed exposure to sedatives/hypnotics, anticholinergic drugs, and opioid analgesics. Intra-class correlation coefficients measuring interrater reliability among our assessors were 0.95 for HRSD, 0.97 for the Cumulative Illness Rating Scale, and 0.99 for the Dementia Rating Scale.

Probabilistic reversal learning—The probabilistic reversal learning task requires participants to learn to choose one of two colored rectangles in each of 80 trials. In an initial 40-trial acquisition stage, on 80% of the trials the subject is rewarded for selecting stimulus 1 and punished for selecting stimulus 2. On 20% of the trials, false feedback is delivered such that the subject is punished for selecting stimulus 1 (non-contingent or 'probabilistic' punishment), or rewarded for selecting stimulus 2. In the second 40-trial *reversal* stage, the probabilities are reversed (see Fig. 1). Our version of the task used symbolic reward (green frame around the stimulus, green 'CORRECT' display, high-frequency tone) and punishment (red frame around the stimulus, red 'WRONG' display, low-frequency tone). Prior studies of probabilistic reversal learning have found similar behavioral and neural responses to symbolic reward and punishment (19), monetary reward and loss (20), and angry and happy faces (32). Subjects were considered to 'pass' a stage if they reached a pre-determined learning criterion of eight consecutive correct trials. It is difficult to achieve this learning criterion by chance, without mastering the task, since at least one or two trials are likely to include non-contingent punishment. In addition, we used the number of trials before achieving the learning criterion in each stage as a parametric measure of performance.

To perform well on this task, one needs to trade off 'staying' (i.e. choosing the previously reinforced stimulus despite occasional non-contingent punishment) and 'switching' (i.e. reversing the preferred choice after punishment is received). One strategy is to integrate the reinforcement across a number of trials. The tendency to 'stay' while ignoring punishment feedback leads to *perseverative errors*, which result from selecting the previously correct stimulus after the reversal of probabilities. Conversely, the tendency to 'switch' too easily results in a large number of *probabilistic switch errors*, when one switches away from the preferentially reinforced stimulus in response to non-contingent punishment.

Control measures: forward planning and spatial working memory—To determine whether suicidal elderly demonstrate deficits that are specific to decision-making and can be dissociated from other aspects of cognition, we employed a test of forward planning and spatial working memory, the Stockings of Cambridge, a modification of the Tower of London task (33).

Statistical analysis—We used SPSS 15.0 (SPSS Inc., Chicago, IL) and MATLAB 7.6 (The MathWorks Inc., Natick, MA). All tests were two-sided. We first compared groups on demographic and clinical characteristics using F-tests and chi-square tests. For these and all subsequent F-tests, we examined post-hoc contrasts using the Tukey HSD test. We then used the chi-square test to compare proportions of participants in each group passing acquisition and reversal stages of the probabilistic reversal learning task. In our follow-up contrasts, we compared each of the two suicidal groups to control subjects and to non-suicidal depressed subjects. We then examined the performance pattern in the reversal stage by group using multinomial regression with group as dependent variable and two alternative markers of poor performance – perseverative errors and probabilistic switch errors – as covariates. Our sensitivity analyses used binary logistic regression with passing/failing the reversal stage as the dependent variable. The predictors included group status (dummy-coded) and potential confounding factors: global cognitive functioning, years of education, lifetime or current substance use disorders, and gender.

Computational model—To test our hypothesis that poor decision-making in suicide attempters is explained by abnormally high discounting of past rewards and punishments, we employed a computational modeling procedure in which the degree to which subjects incorporate the past history into their decisions ('memory') is estimated based on their responses. We adapted a reinforcement learning model common in studies of reinforcement/punishment-based learning (e.g. (20,34,35)). The model, described in detail in the Data Supplement, used a Rescorla-Wagner learning rule to choose parameters that afforded the strongest match between choices produced by the model and subjects' actual choices, based on the reinforcement history experienced by each subject. The four free parameters were *memory, learning rate from rewards, learning rate from punishments*, and *exploration. Memory* reflected the effect of the prior reinforcement history on the choice. *Learning rate from rewards* and *learning rate from punishments* reflected the impact of reward or punishment on the last trial on the subject's subsequent choice. *Exploration* reflected whether choice was random vs. determined by feedback.

RESULTS

Group characteristics

The groups were similar in their demographic characteristics (Table 1). Global cognitive functioning measured by the Dementia Rating Scale was lower in the three depressed groups compared to non-depressed control subjects. Suicide attempters had a higher lifetime prevalence of substance use disorders, compared to non-suicidal depressed participants (Table 1; $\chi^2(1)=1615$, p=0.001); 6/15 suicide attempters and none of the participants in the other groups had current substance use disorders. Psychotropic exposure was similar across the three depressed groups.

Probabilistic reversal learning

Groups did not differ in their performance in the acquisition stage, suggesting similar overall learning ability. On the other hand, significant differences in performance emerged in the reversal stage (Fig. 2). After the reinforcement contingencies were reversed, suicide attempters were less likely to achieve a learning criterion than non-depressed control subjects ($\chi^2(1)=12.5$, $p<0.001$) and than non-suicidal depressed participants ($\chi^2(1)=6.5$, $p=0.011$). Suicide ideators did not differ from the two control groups ($\chi^2(1) \leq 1.2$, $p \leq 0.26$). These results were mirrored on trials needed to achieve the learning criterion in the acquisition ($F[3,61]=1.4$, $p=0.24$) and reversal stages ($F[3,61]=5.3$, $p=0.003$).

Measures of excessive switching (probabilistic switch errors) and perseveration in the reversal stage differentiated the groups (Table 2). Examination of suicide attempters' performance revealed two patterns: most attempters made multiple probabilistic switch errors, switching away from the newly reinforced stimulus after non-contingent punishment. Another, smaller, subgroup of suicide attempters made multiple perseverative errors. Suicide ideators did not differ from other groups.

Reinforcement learning model-based analyses

Suicide attempters displayed lower memory compared to non-depressed controls (omnibus ANOVA $F(3,61)=2.77$, $p=0.049$, Tukey HSD post-hoc: suicide attempters<controls, $p=0.039$; Figure 3a). That is, in their choice, attempters relied less on their previous reinforcement history and more on feedback on the last trial. As expected, participants with lower memory made more total switches in their choice (3b) and more probabilistic switches (3c). While the three depressed groups, particularly suicide ideators, tended to have a lower learning rate from punishments, group differences were not significant ($F(3,61)=2.52$, $p=0.066$, suicide ideators<controls, $p=0.087$; 3d.). This seemingly surprising trend was due to perseveration in the depressed groups (Table 2): participants who were less likely to switch their choice following punishment made more perseverative errors (3e). Learning rate from punishments was also positively correlated with the proportion of probabilistic switches among all switches (3f). Learning rate from rewards and exploration did not differ between groups (Data Supplement, Results, page s5).

Forward planning and spatial working memory

On the Stockings of Cambridge test, groups did not differ in the number of problems solved in minimum moves, the number of moves used to solve the problems, adjusting for the level of difficulty, or deliberation times (Data Supplement, Results, Forward Planning and Working Memory, Fig. s2).

Sensitivity analyses: global cognitive function, substance use, age of first attempt, possible brain injury, medication exposure, and gender

The groups still differed in achieving the learning criterion in the reversal stage (Wald(1)=5.8, $p=0.015$) after controlling for global cognitive functioning measured by the Dementia Rating Scale (Wald(1)=1.5, $p=0.22$), years of education (Wald(1)=5.8, $p=0.016$), and for the effects of lifetime history of substance use disorders (Wald(1)=2.4, $p=0.12$). After all participants with lifetime substance use disorders were excluded, suicide attempters were still least likely to pass the reversal stage ($\chi^2=11.6$, $p=0.009$, N=52; suicide attempters vs. non-suicidal depressed: $\chi^2=5.6$, $p=0.018$, N=29). The same was true after excluding participants with current substance use disorders and after limiting the attempter group to 9/15 with first attempt after age 60 (Data Supplement, p. s6). Similarly, the difference between suicide attempters and non-suicidal depressed remained after excluding 1/15 suicide attempter with potential anoxic brain injury from the suicide attempt and 2/15 for whom brain injury could not be ruled out (χ^2=10.2, p=0.001). Gender was not related to performance in the reversal stage (χ^2=1.85, p=0.17).

DISCUSSION

We found that in depressed elders, a deficit in a component of decision-making – probabilistic reversal learning – is associated with attempted suicide, but not with suicidal ideation. Suicide attempters discounted their reinforcement history to a high degree compared to controls, basing their choices largely on reward/punishment received on the last trial. Besides, some suicide attempters also made multiple perseverative errors. This impairment was not explained by lower global cognitive function, effects of lifetime substance use disorders, or possible brain injury from suicide attempts. Furthermore, it was dissociated from cognitive abilities engaged outside the context of punishment and reward – forward planning and working memory.

Time and decision-making in suicidal behavior

Our results extend earlier findings of impaired decision-making in younger suicide attempters with affective disorders (11,36) to a group of depressed elders with a history of suicide attempt. Suicide attempters in our study showed unstable decision-making, which has been described in mid-life depression (15,16), only to a more extreme degree. Further, decreased reliance on past history was dissociated from abnormal sensitivity to rewards or punishments. Thus, in counterpoint to the prevailing view that suicidal individuals' representations of reality are distorted in the *valence domain* (negative cognitive biases; e.g. (37)), our findings indicate distortions in the *time domain*. This notion is supported by early empirical findings of altered time perception (38–41) and by self-report evidence that future orientation is weakened in older suicide ideators and attempters (42). A similar process could have contributed to the decaying performance of suicide attempters on the Iowa Gambling Task (11); that is, they may have failed to integrate reinforcement history from a deck over a number of trials. Assuming that these laboratory observations are representative of individuals' lives, they suggest that people vulnerable to suicidal behavior, faced with change and uncertainty, fail to access their past experiences, making decisions based largely on their present state.

Decision-making and possible neural substrates of suicidal behavior

Human lesion (13,17,18,43) and imaging (19,20) studies implicate the ventral prefrontal cortex in reward/punishment-based learning. Thus, our findings converge with evidence of ventral prefrontal pathology from post-mortem [reviewed in (44)] and imaging studies of attempted suicide in younger persons (45–47). Further, the suicide attempters' intact performance on the Stockings of Cambridge test could indicate that forward planning and working memory associated with the dorsolateral prefrontal cortex (48) are relatively preserved.

Strengths, limitations, and future directions

Detailed clinical characterization, the inclusion of suicide ideators, and the use of a control task add confidence in our findings. Many cognitive studies of suicide are difficult to interpret, since they often combine individuals with major depression, bipolar disorder (11), and schizophrenia (9). Unipolar depression is the most common antecedent of late-life suicide (49–51), and thus our study focused on elders with major depression. It is unclear whether our findings can be generalized to other psychiatric disorders, although in mid-life the association between impaired decision-making and attempted suicide appears to transcend diagnostic boundaries (36). Further, we cannot assume that impaired reward/punishment-based probabilistic learning is unique to attempted suicide. While in our small

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sample it was not related to substance use, similar impairments have been described in pathological states characterized by impulsivity, such as pathological gambling (52) and behavioral toxicity of dopamine agonists (53,54). Small group sizes and case-control design comprise the main limitations of this study. The lack of effect of depression on forward planning and working memory test raises questions about the sensitivity of the Stockings of Cambridge as a control test – a concern partly mitigated by the presence of robust test difficulty effects. Further, suicide attempters paid less attention to their reinforcement history than controls, but did not differ significantly from depressed elders. This observation cannot rule out an alternative hypothesis that distortions in the time domain are associated with depression and not specifically with suicidal behavior. Finally, our reinforcement learning model is limited in the extent to which it captures human decision-making. More complex formalisms, such as hidden Markov models (20) or models based on production rule learning (55), may be needed to characterize decision-making in suicidal behavior.

In summary, our study presents preliminary case-control evidence of dissociable deficits in older suicide attempters' ability to learn from the experience of rewards and punishments under uncertainty. We propose a hypothesis that older suicide attempters make overly present-focused decisions, ignoring past experiences.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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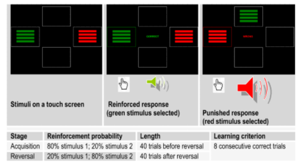

Figure 1.
Probabilistic reversal learning task

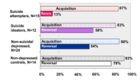

Figure 2. Overall probabilistic reversal learning performance: proportion of participants reaching the learning criterion in each stage

The bars display the proportion of participants in each group who reached a pre-defined 8-trial learning criterion. All groups demonstrated similar probabilistic learning ability in the acquisition stage (chi-square test: $\chi^2(3)=0.57$, $p=0.90$), but performance in the reversal stage differed considerably between groups ($\chi^2(3)=13.1$, $p=0.004$)

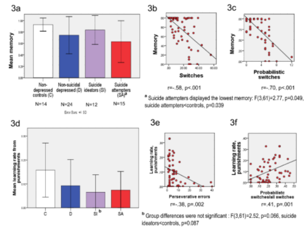

Figure 3. Model-based analyses of probabilistic reversal learning: reliance on past reinforcement history (decay) and learning from punishments

3a, 3d: model-derived meta-learning parameters by group. 3b, 3c, 3e, 3f: correlations with behavioral indices illustrate the meaning of meta-learning parameters. **Memory**: attention to prior reinforcement history vs. last trial. **Learning rate from punishments**: impact of punishment on the last trial on subsequent choice.

3a. Analyses based on the fit-parameters of the computational model revealed a lower **memory** among suicide attempters, compared to non-depressed controls (omnibus ANOVA F(3,61)=2.77, p=0.049, Tukey HSD post-hoc: suicide attempters<controls, p=0.039). That is, attempters relied less on their previous reinforcement history in making their decisions and more on feedback on the last trial, compared to non-depressed controls. As expected, memory was negatively correlated with the total number of switches in subjects' choice **(3b)** and with the number of probabilistic switches (switches following non-contingent negative feedback, **3c**). **3d.** While the three depressed groups, particularly suicide ideators, tended to have a lower **learning rate from punishments**, group differences were not significant: F(3,61)=2.52, p=0.066, suicide ideators<controls, p=0.087. This seemingly surprising trend was due to perseverative errors in the three depressed groups (means shown in Table 2): learning rate from punishments was negatively correlated with the number of perseverative errors **(3e),** i.e. subjects who did not switch their choice in response to punishment made multiple perseverative errors. Learning rate from punishments was positively correlated with the proportion of switches in response to non-contingent punishment (probabilistic switches) among all switches **(3f)**.

Table 1

Demographic, clinical, and cognitive group characteristics

	Non-Depressed Controls (C) N=14				Non-Suicidal Depressed (D) N=24				Suicidal Ideators (I) N=12				Suicide Attempters (A) N=15				P	Post-hoc, Tukey HSD
	N	%	SD	M	N	%	SD	M	N	%	SD	M	N	%	SD	M		
Age			4.9	65.6			7.4	70	12		5.6	68.8	15		7.8	66.8	0.22	NS
% Men	12	86			11	46			7	58			6	40			0.06	-
% White	13	93			20	83			11	83			11	73			0.67	
% Married	10	71			11	46			9	75			4	27			0.2	
Years of Education (N=59)			2.6	15.7			2.7	14.3			2.6	15.7			2.8	12.9	0.06	NS
Burden of physical illness (Cumulative Illness Rating Scale adapted for Geriatrics) (N=60)			2.5	6.9			3.5	9.5			0	6.6			3.4	9.3	0.022	NS
Mini-mental status examination (N=56)			1.8	29			1.6	28.3			2.1	28.3			1.8	28.7	0.76	NS
Dementia rating scale (N=58)			3.4	138.4			3.9	133.7			6	133.5			5.7	132.3	0.011	A, I, D<C
Depressive Severity (HRS16) (N=64)			1.7	3			3.7	18.5			4.7	20.2			4.7	19.2	<.01	A, I, D<C
Lifetime substance use disorders	0	0			2	9			3	25		25	8	53		53	<.01	-
Current substance use disorders	0	0			0	0			0	0			6	40				
Intensity of Antidepressant Pharmacotherapy During Current Episode, Antidepressent Treatment History Form Score (N=41)				-			1.4	1.4			2.1	2			1.2	1.9	0.5	NS
% Receiving Sedatives/ Hynotics (N=48)				-	9	39			8	67			7	54			0.29	-
& Receiving Anticholinergic Agents (N=48)				-	6	26			4	33			6	46			0.47	-
% Receiving Opioid Analgesics (N=48)				-	6	26			4	33			2	15			0.58	-
Scale for Suicidal Ideation				-				-			6.9	15.3			8.7	19.6	0.24	-
Suicidal Intent Scale				-				-				-			5.3	17	-	-

Table 2

Decision-making performance: behavioral indices and meta-learning parameters

	Non-depressed controls (C) N=14		Non-suicidal depressed (D) N=24		Suicide ideators (I) N=12		Suicide Attempters (A) N=15		X^2	p	Group Contrasts
	SD	M	SD	M	SD	M	SD	M			
Excessive switching in response to non-contingent negative feedback: probabilistic switch errors (lose-switch errors)	0.8	1	1.5	1.9	1.5	1.5	2.3	2.5	12.6*	0.006	A>C p=0.004
Perseveration: perseverative errors	3.1	3.4	7.5	6.7	10.2	9.2	14.1	11.1	13.2†	0.004	A>C p=0.023

*Multinomial logistic regression with group as dependent variable, covarying for perseverative errors.

†Multinomial logistic regression with group as dependent variable, covarying for probabilistic switch errors.