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Impairment in risk-sensitive decision-making in older suicide attempters with depression

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Abstract

Suicidal behavior is a potentially lethal complication of late-life depression. In younger adults, suicide has been linked to abnormal decision-making ability. Given that there are substantial age-related decreases in decision-making ability, and that older adults experience environmental stressors that require effective decision-making, we reasoned that impaired decision-making may be particularly relevant to suicidal behavior in the elderly. We thus compared performance on a probabilistic decision-making task that does not involve working memory ("Cambridge Gamble Task") in four groups of older adults: 1) individuals with major depression and a history of suicide attempt (n=25), 2) individuals with major depression with active suicidal ideation but no suicide attempt (n=13), 3) individuals with major depression without suicidality (n=35), and 4) non-depressed control subjects (n=22). There was a significant effect of group on quality of decision-making, whereby the suicide attempters exhibited poorer ability to choose the likely outcome, compared with the non-suicidal depressed and non-depressed comparison subjects. There were no group differences in betting behavior. The suicide attempters differed in several aspects of social problem-solving on a self-report scale. Quality of decision-making was negatively correlated with the score on the impulsive/careless problem-solving subscale. These data suggest that older suicide attempters have a deficit in risk-sensitive decision-making, extending observations in younger adults. More specifically, older suicide attempters seem to neglect outcome probability and make poor choices. These impairments may precipitate and perpetuate suicidal crisis in depressed elders. Identification of decision-making impairment in suicidal elders may help with designing effective interventions.

Keywords

suicidality; cognition; mood disorder; executive function; risk-taking

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Introduction

Suicidal behavior is a potentially lethal complication of late-life depression. Compared to the general population, suicide rates in older adults (aged over 65) are elevated, and associated with higher lethality (De Leo et al., 2001; Dombrovski, Szanto, et al., 2008) and higher hospitalization rates following suicidal behavior (Crosby, Ryan, & Logan, 2005). Psychiatric diagnoses are present in the vast majority of individuals who die from suicide, with mood disorders being the most common (Conwell, Duberstein, & Caine, 2002; Conwell et al., 1996). Suicidality is a not an invariant feature of mood disorder, and in older adults, its presence is not clearly linked to overall depressive severity (Szanto, Prigerson, & Reynolds, 2001). Thus, addressing the severe threats to public health that are associated with suicidal behavior will rely on identifying the mechanisms underlying suicidal features, which likely involve treating suicidality as a trait that does not simply overlap with the primary diagnosis (e.g. depression) (J. J. Mann, 2003).

Cognitive dysfunction is a particularly likely mechanistic precursor for suicidal behavior (Dombrovski, Butters, et al., 2008; Dombrovski et al., 2010). By this formulation, suicidal behavior may arise from the interaction between certain cognitive characteristics (e.g. impaired decision-making), depressed mood, and environmental stress. Age-related changes in cognitive function and specific stressors in old age (e.g. physical illness, bereavement) may contribute to the elevated rate of suicidal behavior in the elderly. In particular, there are disproportionate impairments in executive functions in younger and older adults with suicidal behavior (Dombrovski, Butters, et al., 2008; Keilp, Gorlyn, Oquendo, Burke, & Mann, 2008; Keilp et al., 2001; Marzuk, Hartwell, Leon, & Portera, 2005). Executive functions are a collection of higher-level processes associated with the prefrontal cortex (PFC), which support monitoring, flexibility and suppression of behavior (Stuss & Levine, 2002). Keilp and colleagues (2001) identified executive function deficits including inhibition and initiation (based on the Stroop and verbal fluency tasks) in mid-life, high-lethality suicide attempters compared to low-lethality attempters and psychiatric control subjects (Keilp, et al., 2008; see also Marzuk, et al., 2005). Preliminary studies have supported these observations in older adult attempters. A study by King et al (2000) found no overall difference between elderly attempters and non-attempters in flexibility (measured by the Trail Making Test), but there was a significant interaction between group and age, which the authors interpreted as evidence for accelerated executive decline with age in the group of attempters. Our own pilot data (Dombrovski, Butters, et al., 2008) suggest a significant impairment in overall executive function (based on the Executive Interview (EXIT25)) in older suicidal depressed individuals (over age 60) compared to non-suicidal depressed control subjects, and this deficit could not be explained by the presence of dementia, substance use, medication or possible brain injury arising as a result of the suicide attempt.

Decision-making may be particularly pertinent to suicidal behavior. Impairments in decision-making may lead to unresolved problems that create an accumulation of stressors. Everyday decisions frequently require the careful evaluation of anticipated positive and negative outcomes, and the selection of a response option that maximizes expected value. We refer to this type of decision-making as risk-sensitive decision-making, because deficits at either the evaluation or selection stage may give rise to risky choices. Decision-making may be especially relevant for suicidal behavior because it is subserved by the ventromedial PFC (Bechara, Tranel, & Damasio, 2000; Clark et al., 2008; Hampton, Bossaerts, & O'Doherty, 2006; Hare, O'Doherty, Camerer, Schultz, & Rangel, 2008), a region where structural and functional abnormalities have been described in mid-life suicidal individuals (Jollant et al., 2008; Monkul et al., 2007; Oquendo et al., 2003).

The Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994) was devised as a neuropsychological probe of risk-sensitive decision-making. In this task, the subject makes a series of card choices between four decks, where two decks are risky (offering large wins but overall loss) and two decks are safe (offering smaller wins but overall profit). While healthy individuals develop a gradual preference for the safe decks, patients with focal lesions to the ventromedial PFC maintain risky choice throughout the task. A seminal study by Jollant and colleagues (Jollant et al., 2005) used this task in euthymic, mid-life adults with mood disorders, and reported performance deficits in the subjects with a history of suicide attempts compared with non-suicidal depressed and healthy control subjects. This finding has been replicated in adolescent self-harmers (Oldershaw et al., 2009) and mid-age suicide attempters with a primary diagnoses of major depression (Westheide et al., 2008) and bipolar disorder (Malloy-Diniz, Neves, Abrantes, Fuentes, & Correa, 2009), and converges with a cognitive literature describing impaired problem solving in younger (Beck, Steer, Beck, & Newman, 1993; Pollock & Williams, 1998) and older (Gibbs et al., 2009) suicide attempters. Age-related performance decline has been described on the Iowa Gambling Task (Denburg et al., 2007; Lamar & Resnick, 2004), and the ventromedial PFC substrates of decision-making also undergo age-related decline (Gunning-Dixon, Brickman, Cheng, & Alexopoulos, 2009; Resnick, Lamar, & Driscoll, 2007). As such, age-related decreases in decision-making ability may contribute to the high suicide rates in older adults.

The aim of the present study was to extend the findings of an association between impaired decision-making and suicidal behavior in late life. To better parse some important components of decision-making that may be compromised in elderly suicide attempters, we used an alternative probe of decision-making, given that successful performance on the Iowa Gambling Task involves multiple cognitive demands in addition to decision-making, including working memory, reinforcement learning and reversal learning (Dunn, Dalgleish, & Lawrence, 2006; Fellows & Farah, 2005). The Cambridge Gamble Task (Rogers et al., 1999) was devised to minimize these additional demands by removing the need to learn a strategy across trials. Participants make decisions between two color options (red or blue) that are associated with explicit risks of winning or losing, signaled by the ratio of red to blue boxes (e.g. 8 red: 2 blue). The proportion of trials where subjects select the color in the majority (henceforth 'Quality of Decision-Making') provides an index of probability processing. Decision latencies to make the red/blue decision are recorded as a measure of deliberation time and psychomotor function. After making their color decision, subjects are asked to bet on that decision, and the Betting variable constitutes a measure of risk preference. Group differences in both the Quality of Decision-Making (i.e. the red/blue color choice) and Betting parameters have been described previously in individuals with focal damage to the orbitofrontal and ventromedial PFC (Clark, et al., 2008; Rogers, et al., 1999).

We compared performance in four groups of elders: 1) individuals with major depression and a history of suicide attempt, 2) individuals with major depression with active suicidal ideation but no suicide attempt, 3) individuals with major depression without suicidality, and 4) non-depressed control subjects. Based on previous studies that used this task in mid-life major depression (Murphy et al., 2001; Taylor Tavares et al., 2007), we hypothesized that the three depressed groups would display longer Decision Latencies, reflecting psychomotor slowing, compared to non-depressed control subjects. Given data linking the Quality of Decision-Making and Betting variables to the ventromedial PFC, an area implicated in suicidality, we hypothesized that these measures would discriminate suicidal individuals from non-suicidal depressed individuals, and that these changes would be of greater severity in the attempters compared to the ideators.

Methods

Participants

All participants provided written informed consent as required by the University of Pittsburgh Institutional Review Board. A total of 98 older adults (aged 60 and over) participated. We recruited 25 depressed suicide attempters, 14 depressed individuals with suicidal ideation with a specific plan, 37 non-suicidal depressed participants, and 22 non-psychiatric control subjects. Depressed participants were recruited from an inpatient psychogeriatric unit and a late-life depression research clinic, and all met Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition Axis I (DSM-IV) criteria for unipolar, non-psychotic major depression, assessed using the Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbon, & Williams, 1996). Non-psychiatric control participants were recruited from university and community primary care practices.

Participants in the attempter group had made a self-injurious act with the intent to die. Suicide attempt history was verified by a study psychiatrist, using the interview, medical records, information from the treatment team, and information from family or friends (obtained through separate consent). We excluded participants with significant discrepancies between these sources. In 13/25 cases, the attempt was made within the past year. All attempters had current suicidal ideation and an active plan. Seven of 25 attempters had made more than one attempt: 4/25 made two attempts; 2/25, three attempts; and 1/25, four attempts. Participants in the ideator group had suicidal ideation with a specific plan of sufficient severity to warrant inpatient admission or an increase in the level of outpatient care. Our sampling strategy aimed to capture participants as close to a suicidal crisis as practically and ethically possible, and all neuropsychological testing was performed within 2 weeks of study entry. Participants in the non-suicidal depressed group had no life-time history of suicide attempt or suicial ideation defined by the Scale for Suicidal Ideation (SSI) (Beck, Kovacs, & Weissman, 1979). Participants in the non-psychiatric control group did not meet criteria for any DSM-IV diagnosis (including history of mood disorder), and had no life-time history of suicidal attempt and no current ideation.

Individuals were excluded from the study if they met a diagnosis of bipolar disorder, schizophrenia or schizoaffective disorder or frank dementia, but mild cognitive impairment was not an exclusion criterion. In addition, neurological disorders, and electroconvulsive therapy in the past six months, were further exclusion criteria.

In order to clinically characterize our sample and to assess other factors that may influence cognitive performance, we administered measures of several further domains. Burden of physical illness was assessed with the Cumulative Illness Rating Scale Modified for Geriatrics (CIRS-G) (Miller et al., 1992), and care was taken to recruit non-depressed control participants will some level of physical illness burden. CIRS-G was completed by study psychiatrists (KSz or AYD), and inter-rater reliability was assessed using tapes and measured with intra-class correlation coefficients, yielding inter-rater reliability of 0.97). Current depressive symptoms were assessed using the Hamilton Rating Scale for Depression (HRSD) (Hamilton, 1960), administered by trained bachelor- or masters-level clinicians (inter-rated reliability 0.95). We screened for dementia using the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). Current suicidal ideation was assessed by the SSI (Beck, et al., 1979), and suicide intent and medical seriousness of attempt were assessed by the Suicidal Intent and Lethality Scale (Beck, Beck, & Kovacs, 1975). Medical lethality of the suicide attempt was rated based on the clinical interview, medical records, and collateral information; scores were reviewed with a study psychiatrist (KSz or AD). We have also conducted additional chart review to identify attempters (n=3) who had a lethality score of 4 or higher, a history of systemic hypotension >5 minutes, or

asphyxia or neurotoxic ingestion, as cognitive deficits in these cases may be secondary to brain injury related to the attempt. We measured the intensity of pharmacotherapy for the current episode of depression with the cumulative strength score from the Antidepressant Treatment History Form (ATHF) (Sackeim, 2001), based on antidepressant trial duration, the dose, and the use of augmenting agents. Finally, to assess the relationship between our behavioral measures of decision-making and self-reported problem solving abilities we used the Social Problem Solving Inventory-Revised (SPSI) (D'Zurilla, Nezu, & Maydeu-Olivares, 2002), which measures participants' perceptions of their social problem solving ability. This scale yields two subscales relevant to adaptive (functional) aspects of problem-solving (positive problem orientation and rational problem solving) and three dysfunctional dimensions (negative problem orientation, impulsivity/carelessness, and avoidance). A small proportion of missing cases arose on the self-report scales and clinical measures due to time constraints (SPSI n=5 missing, CIRS-G n=4, HRSD n=1, SSI n=7, ATHF n=14), and these cases were excluded from the analyses of that variable (i.e. listwise deletion).

Procedure

Participants were administered the Cambridge Gamble Task by a trained psychology assistant, as part of a larger neuropsychological assessment. The task was run on a Paceblade tablet PC within the CANTAB Eclipse software (www.camcog.com), using touchscreen control. On each trial of the task, the participant was presented with an array of 10 boxes at the top of the screen, with each colored either red or blue. The ratio of red to blue boxes varied from 1:9 to 9:1, in a pseudo-random order. The participant was instructed that the computer had hidden a token in one of the boxes, and to guess whether the token was hidden under a red box or a blue box, by selecting one of the two colored panels ('RED' or 'BLUE') at the foot of the screen. After this probability decision, the participant was required to place a bet on their Red/Blue decision. Available bets were offered in a sequence, as a proportion of the participant's points total on that trial (Ascending condition: 5%, 25%, 50%, 75%, 95%; Descending condition: 95%, 75%, 50%, 25%, 5%), presented in 5s increments. On each trial, after the bet was selected, the hidden token was revealed, and the amount bet was either added to (on wins), or subtracted from (on losses), the current total.

Participants performed 4 practice trials, followed by a main task of 72 trials, administered in 8 blocks (4 Ascend, 4 Descend, counter-balanced for order across subjects). Trials with a 5:5 ratio of red-blue boxes were included in the task design to create an impression of randomness, but these trials were excluded from statistical analysis. The participant began each block with a total of 100 points, and they were instructed that "the idea is to build up as many points as you can. Try not to let your score get as low as one point, because then you will lose the game." In cases where this happened (henceforth 'bankruptcies'), that block of trials was terminated and the participant moved directly to the next block. 'Quality of Decision-Making' was assessed on the probability (Red/Blue) decisions, in terms of the proportion of choices to the color in the majority. Decision Latency was the response time to make the Red/Blue decision. Betting data were analysed in terms of the percentage of points staked. Decision Latency and Betting analyses were restricted to those trials where the participant selected the color in the majority, to maintain independence from choice behavior. To assess the change in Betting by the ratio of red:blue boxes, a Risk Adjustment score was calculated using the equation $(2a + b - c - 2d)/$ average bet, where a is the bet in the 9:1 ratio, b is the bet at the 8:2 ratio, etc (Deakin, Aitken, Robbins, & Sahakian, 2004). A greater value for this variable indicates a steeper slope for the betting function (see Figure 1c).

Statistical Analysis

Behavioral data on the Cambridge Gamble Task were analyzed using mixed-model analysis of variance models. For the dependent variables Quality of Decision-Making (i.e. proportion of choices to the box color in the majority) and Decision Latency (time to make color choice), the ANOVA model assessed the fixed factors of Ratio (within-subjects: 9:1, 8:2, 7:3, 6:4) and Group (between-subjects). For the dependent variable Betting (mean percentage of points bet), the ANOVA model assessed the fixed factor of Ratio, Condition (within-subjects: Ascending vs Descending bet sequence) and Group. The Greenhouse-Geisser correction was applied where sphericity was violated (Epsilon values are given to indicate where this correction was used). Statistical tests were thresholded at $p<.05$ two-tailed.

As our participants were elders and the Cambridge Gamble Task is relatively lengthy (approximately 20 minutes), we carefully screened the neuropsychological data for quality. We identified 13 subjects with extreme betting behavior, who uniformly placed the lowest available bet in the Ascend condition and the highest available bet in the Descend condition. In three of these individuals (one ideator, 2 non-suicidal depressed), the mean score for Quality of Decision-Making (red/blue color decisions) was close to chance (and approximately 2.5 standard deviations from the overall mean), and they additionally committed a large number of bankruptcies, which led to missing datapoints and other cell means based on single datapoints. We reasoned that these participants were either inattentive or unmotivated to perform the task, and these three subjects were excluded from the analysis. Findings were qualitatively unchanged with these participants included.

Results

Demographic Characteristics

Demographic and clinical characteristics of the four groups are displayed in Table 1. After screening for data quality and outliers, the final groups of 25 suicide attempters, 13 ideators, 35 non-suicidal depressed and 22 non-depressed controls did not differ significantly on age ($F(3,94)=1.45$, $p=.235$), gender ($\chi^2=4.67$, $p=.197$), racial composition ($\chi^2=7.18$, $p=.305$) or MMSE scores ($F(3,86)=0.82$, $p=.489$). There was a significant group difference in years of education ($F(3,91)=4.80$, $p=.004$), with lower education in the group of attempters compared to the non-depressed control (Tukey's $p=.028$) and the ideator ($p=.005$) groups. There was also a significant group difference in the CIRS-G ($F(3,87)=5.91$, $p=.001$), due to a significantly higher physical illness burden in the non-suicidal depressed group compared to the non-depressed controls (Tukey's $p=.006$) and the ideators (Tukey's $p=.007$). The controls and the attempters did not differ significantly on this index, and this measure was not correlated with mean Quality of Decision-Making in the full sample. The intensity of pharmacotherapy for the current episode of depression was similar in the three depressed groups measured by the ATHF ($F(2,58)=1.42$, $p=.251$). In the three depressed groups, there was a significant difference in suicidal ideation ($F(2,63)=48.5$, $p<.001$), as expected, with elevated SSI scores in the attempters (Tukey's $p<.001$) and ideators (Tukey's $p<.001$) compared to the non-suicidal depressed, but no difference between the attempters and ideators (Tukey's $p=.426$). Current depressive symptom scores on the HRSD (after subtracting the suicidality item, #3) did not differ across the depressed groups ($F(2,69)=1.84$, $p=.166$). Within the group of attempters, the mean score on the Suicidal Intent Scale was 16.4 (sd = 5.1, range 8-29, max score 30) and the mean score on the Suicide Lethality Scale was 3.2 (sd = 2.1, range 0-7, max 8). While the lifetime prevalence of co-morbid anxiety disorders was similar among the depressed groups ($\chi^2=.167$, df=2, $p=.920$), lifetime substance use disorders were significantly more prevalent in the attempters than the ideators and non-suicidal depressed groups ($\chi^2=6.60$, df=2, $p=.037$) (see Table 1).

Cambridge Gamble Task

A mixed-model ANOVA on Quality of Decision-Making revealed a significant main effect of Ratio (F(3,273)=12.2, Epsilon = 0.82, p<.0001), as all groups were more likely to select the box color in the majority at the higher ratios (see Figure 1a), and a significant main effect of Group (F(3,91=4.41, p=.006). Between-group comparisons with Tukey's tests revealed significant reductions in Quality of Decision-Making in the attempters compared to the non-depressed controls (Tukey's p=.01, Cohen's d=0.79) and non-suicidal depressed (Tukey's p=.02, Cohen's d=0.67) groups. The difference between the attempters and ideators was not significant (Tukey's p=.081, Cohen's d=0.66), and there were no further between-group differences (all p>.10). The Ratio by Group interaction term was not significant (F(9,273)=0.45, p=.997), indicating that the groups did not differ in their adjustment of color choice as a function of odds.

Supplementary analyses were run to examine possible confounds. One consideration is whether the group differences in Quality of Decision-Making may have arisen from the differences in education across the groups. In the full sample, years of education was correlated significantly with mean Quality of Decision-Making (r95=.234, p=.022). However, in an ANCOVA model employing education as a covariate, the main effect of Group remained significant (F(3,90=3.05, p=.032). Three attempters with likely or possible brain damage arising from the suicide attempt were excluded; the main effect of Group in the ANOVA model remained significant (F(3,88)=5.97, p=.001), and notably, there were significant post-hoc comparisons of the suicide attempters against each of the other groups including the ideators (non-depressed controls: Tukey's p=.002; non-suicidal depressed: Tukey's p=.004; ideators: Tukey's p=.024). Finally, considering the higher rate of lifetime substance use disorders in the attempters compared to the other groups, we ran a post-hoc analysis comparing the Quality of Decision-Making variable in those attempters with (n=12, mean=0.80, sd=0.22) and without (n=13, mean=0.78, sd=0.22) substance use co-morbidity. Impaired decision-making in the attempters was not clearly attributable to the presence of substance use problems (t(23)=.263, p=.795).

A mixed-model ANOVA on Decision Latency revealed a significant main effect of Ratio (F(3,723)=3.01, Epsilon = 0.85, p=.039), as subjects tended to deliberate for longer at the more uncertain, lower ratios (see Figure 1b), as well as a significant main effect of Group (F(3,91)=3.34, p=.023), but no significant Ratio by Group interaction (F(9,273)=1.38, p=.195). The post-hoc comparisons on the effect of Group revealed moderate slowing in the attempters relative to non-depressed controls that approached significance (Tukey's p=.071, Cohen's d=0.70), with no further between-group differences (all p>.10; Ideators vs non-psychiatric controls p=.137 Cohen's d=0.86; Attempters vs ideators p=.999, Cohen's d=0.04). There was no correlation between average Decision Latency (collapsed across box ratio) and years of education (r95=−.048, p=.646)

A mixed-model ANOVA of Betting data identified a significant main effect of Condition (F(1,91)=142.4, p<.001) as subjects placed higher bets in the Descend condition (mean 76%) compared to the Ascend condition (mean 40%). There was a significant main effect of Ratio (F(3,273)=63.0, Epsilon = 0.48, p<.001), as subjects reduced their bet at the more uncertain, lower ratios. There was a Condition by Ratio interaction (F(3,273)=4.60, Epsilon=0.87, p=.006), as subjects adjusted their bets by the box ratio more in the Ascend condition than in the Descend condition (see Table 2 for summary measures). There was no significant main effect of Group (F(3,91)=1.19, p=.319). The Group by Condition interaction term was not significant (F(3,91)=1.55, p=.206), indicating that the groups did not differ in their tendency to take an early bet, which provides an index of impulsivity or delay aversion. The Group by Ratio interaction term was non-significant (F(9,273=0.56, p=.832), indicating that the groups did not differ in their tendency to adjust their bets by the

level of uncertainty. The Group x Condition x Ratio interaction term was also non-significant (F(9,273)=.80, p=.616).

Two further measures were extracted from the task to assay more general performance levels. The total number of bankruptcies was compared between groups using a non-parametric Kruskal-Wallis test, with no significant effect (χ^2=2.76, df=3, p=.431). The total number of points accumulated over the 8 blocks was compared across groups using a one-way ANOVA, and was non-significant (F(3,91)=0.60, p=.615).

Correlations with self-reported problem-solving

There were significant differences between groups on the SPSI Total score (F(3,85)=11.8, p<.001) and on each of the five SPSI subscales (F(3,85)>5.13, p<.003). Post-hoc between-groups comparisons revealed significant differences between suicide attempters and non-suicidal depressed controls on the SPSI Total, the Negative Problem Orientation subscale, the Impulsive/Careless subscale, and the Avoidance subscale (see Table 3). In the overall sample, better Quality of Decision-Making was correlated with lower scores on the Impulsivity/Carelessness subscale of the SPSI (r90=−.22, p=.038; in the group of suicide attempters, r22=−.38, p=.078). Correlations against the SPSI total score (r90=.19, p=.09) and the other subscales (r90=−.20 to +.06, p>.05) did not reach statistical significance.

Discussion

This is the first study to explore risk-sensitive decision-making using a cognitive probe in elderly depressed suicide attempters. On the Cambridge Gamble Task, we found that older suicide attempters with major depression were less likely to predict the probable outcome. We included a group of non-suicidal depressed cases, and a group of depressed ideators with active suicidal intent but no history of attempt as well as a comparison group of non-depressed controls. The attempters had significantly impaired Quality of Decision-Making in direct comparisons to the non-suicidal depressed and the non-depressed controls. The direct comparison to the ideators was not significant, potentially as a result of low power (n=13 in the ideator group, p=.081) but yielded a moderate effect size (Cohen's *d*=0.66), suggesting that replication with larger groups would be likely to show an effect. While there was a significant effect of group on the time to make these probability decisions (Decision Latency), the between-group comparisons did not reveal any significant differences. There were no group differences in Betting, or in overall performance in terms of bankruptcy and net points won. Impaired Quality of Decision-Making was associated with impulsive/careless problem-solving on the SPSI, a self-report measure of perceived social problem-solving ability.

These findings support the relevance of decision processes to our understanding of suicidal behavior in the context of depressive illnesses. Attempted suicide has been previously associated with impaired performance on the Iowa Gambling Task, in adolescents (Oldershaw, et al., 2009) and younger adults (Jollant, et al., 2005; Malloy-Diniz, et al., 2009). Our findings extend these observations to elderly depressed subjects, who are known to be most at risk of death by suicide. Our study used an alternative task (Cambridge Gamble Task), which was not confounded by information processing demands that can be impaired in the elderly, to probe risk-sensitive decision-making. This task also enables us to dissect several components of decision-making cognition. The Iowa Gambling Task assesses decision-making based on the prior experience of rewarding and punishing outcomes with the four card decks. The subject is given no explicit information about the chances of winning and losing on each deck. Thus, the Iowa Gambling Task measures decision-making *under uncertainty and risk,* in a learning context. Using the Cambridge Gamble Task, we are able to show an impairment in decision-making in elderly attempters on a task with minimal

learning requirements, where the outcome probabilities are provided explicitly by the ratio of red to blue boxes in the array (i.e. decision-making *under risk* only). In fact, each of the four groups, including the attempters, used the box ratio information about outcome probability to adjust their color decision and bet (the main effects of Ratio), and there were no significant differences in these adjustment slopes across groups (the Group by Ratio interaction terms). Thus, the ability to derive decision weights from probabilities appears unimpaired in the attempters, while their deficit was in the ability to consistently apply this knowledge of probability in selecting the probable outcome.

Why did suicide attempters ignore outcome probabilities, even when they are explicitly presented and correctly understood? One can formulate a few testable hypotheses about biases in their decision-making. Suicide attempters' behavior could be explained by a belief in spurious contingencies, such as the gambler's fallacy (e.g. red is more likely to win after several successive blue outcomes). Probability matching is a related phenomenon: instead of always selecting the highest-probability option, humans often match the estimated probability (e.g. 80:20) by selecting the lower-probability option on some trials. Assessment of these facets of judgment and numerical reasoning in suicidal individuals represents one line of future enquiry. Also, if the subject believed that the computer provided inaccurate or misleading probability information, he or she may approach the task as an uncertain environment and engage in sampling from both colors to learn the underlying probability distribution. In light of our previous findings using a Probabilistic Reversal Learning task (Dombrovski, et al., 2010), which showed that suicide attempters neglected to integrate prior experiences into their decisions, our current findings indicate that elderly suicide attempters appear to also neglect basic probability information, thus ignoring the broader context in which decisions are made. This tendency can clearly undermine deterrents to suicide in someone who fails to consider prior experiences and the probable consequences of their choices.

The observed changes on a neuropsychological probe of decision-making are broadly consistent with dysfunction in the ventromedial PFC in suicide attempters (J. J. Mann, 2003; J. J. Mann et al., 2000). Quality of Decision-Making on the Cambridge Gamble Task was previously reported to be impaired in patients with orbitofrontal cortex damage, who were also slowed in their decision latencies (Rogers, et al., 1999). However, subsequent studies have shown that ventral PFC pathology preferentially changes the Betting parameter (Clark, et al., 2008; Mavaddat, Kirkpatrick, Rogers, & Sahakian, 2000; Rahman, Sahakian, Hodges, Rogers, & Robbins, 1999). It is, of course, possible that these measures are related. In groups where the basic probability judgment is intact, Betting may represent the more sensitive marker of risky decision-making. However, in cases where basic probability processing is disrupted, the amount bet may be less meaningful. Thus, we are cautious about inferring strong evidence for ventromedial PFC dysregulation. It should also be noted that deficits on the Quality of Decision-Making variable are not unique to suicidality: previous studies have described deficits on this parameter in patients with bipolar mania (Murphy, et al., 2001), chronic schizophrenia (Hutton et al., 2002), and as a predictor of treatment outcomes in opiate users (Passetti, Clark, Mehta, Joyce, & King, 2008). Some previous studies of cognition in suicide have tested heterogeneous groups with a variety of primary diagnoses (Jollant, et al., 2005; Raust et al., 2007). A strength of the present study is that we focused on major depression, as the single most common antecedent of elderly suicide (Conwell, et al., 1996). Individuals with primary diagnoses of schizophrenia or bipolar disorder were excluded. The three mood disorder groups did not differ on lifetime anxiety co-morbidity, and whilst the attempters were more likely to have lifetime substance use problems, those attempters with substance use co-morbidity did not display worse decision-making than those without, so this seems unlikely to confound our effects. Inclusion of these co-morbidities increases the generalizability of these findings.

In adolescents and young adults, suicide is often regarded as an impulsive act (McGirr et al., 2008), and neuropsychological correlates of impulsivity have been reported in young adult samples (Horesh, 2001; Raust, et al., 2007; Swann et al., 2005). Our clinical experience suggests that suicide attempts in older adults are more premeditated, and indeed, this may account for the higher lethality of attempts in the elderly (Dombrovski, Szanto, et al., 2008). To what extent can a deficit in risk-sensitive decision-making be related to impulsivity? Prior work has shown that impulsivity did not predict the degree of impairment in suicide attempters on the Iowa Gambling Task (Jollant, et al., 2005) or on a test of decision-making under risk, similar to the Cambridge Gamble Task, in healthy volunteers (Franken, van Strien, Nijs, & Muris, 2008). In the Cambridge Gamble Task, the discrepancy between the level of betting in the Ascend and Descend conditions provides a direct index of delay aversion and impulsivity, and this parameter was not associated with attempted suicide in the present study. Rather, having processed the probability information, the suicide attempters made a decision that neglected knowledge of probability. We observed no significant differences between groups on the Decision Latency measure, which mitigates against an explanation in terms of speed-accuracy trade-offs or 'reflection impulsivity' (see Clark, Robbins, Ersche, & Sahakian, 2006). Poor Quality of Decision-Making was significantly associated with the impulsivity/carelessness subscale of the SPSI, and scores on this subscale were significantly higher in the attempters compared to the other three groups (see also Gibbs, et al., 2009). However, other facets of the SPSI were also linked to suicidality (Total score, and Negative Problem Orientation and Avoidance subscales), and although the only significant correlation was with the impulsivity/ carelessness subscale against the decision-making parameter, this association may not be selective. We infer that the profile observed in suicidal depressed elders is not readily explained in terms of impulsivity. Specifying any age-related change in impulsive versus deliberative, premeditated decisions in suicidal behavior would seem to represent an important target for future research, comparing younger and older groups.

The similar performance of the non-suicidal depressed and non-depressed controls on the Cambridge Gamble Task is also notable. Previous studies have reported some decision-making abnormalities in mid-life depressed populations. For example, on the Iowa Gambling Task, patients with major depression made fewer selections from the safe decks (Must et al., 2006), and on the Cambridge Gamble Task, one study reported slower deliberation times and some attenuation of risk adjustment (the variation in betting across box ratios) (Murphy, et al., 2001) while a later study reported no effects (Taylor Tavares, et al., 2007). The history of suicidal behavior and ideation was not described in these earlier reports, and it is possible that the depressed individuals whose decision-making was impaired had prior suicide attempts or ideation. If our findings are replicated, decision-making impairments may differentiate those who contemplate suicide from those who act on these thoughts. Another clinical implication of our findings is that decision-making impairment may be a useful target for treatment in suicidal depressed elders. Further, impaired decision-making may contribute to inability to adhere to treatment, manage one's finances, or remain in independent housing – these problems are associated with prefrontal dysfunction (Fan, Royall, Chiodo, Polk, & Mouton, 2003; L. S. Mann et al., 1999; Royall, Chiodo, & Polk, 2005) and often encountered in depressed elders, and may also be amenable to targeted interventions.

Several limitations of the current study should be noted. We used a cross-sectional design, and it is possible that the psychological profile of suicide completers may differ from the suicide attempters that we have characterized here. Sample sizes were modest, particularly in the ideator group, and the lack of significant direct comparisons against the ideators may be due to a lack of statistical power. It is notable that a significant difference between attempters and ideators was revealed on Quality of Decision-Making after excluding three

attempters with possible or likely neurological damage as a consequence of the attempt. As a further caveat, we cannot comment on the specificity of these effects to the decision-making domain. Quality of Decision-Making was positively associated with years of education, and whilst the four groups did not differ on general cognitive status assessed with the MMSE, it is possible that this scale lacked sensitivity in these populations. Further research is required to assess the specificity of decision-making variables against other cognitive constructs implicated in suicidality, such as executive function (Dombrovski, Butters, et al., 2008; Dombrovski, et al., 2010; Keilp, et al., 2008). Nevertheless, the present data add to a growing number of studies that highlight risk-sensitive decision-making as an important cognitive feature of suicidal behavior in depression. A disposition to make decisions that ignore outcome probabilities may interact with psychosocial stressors such as physical illness (Waern et al., 2002), financial hardship (Duberstein, Conwell, Conner, Eberly, & Caine, 2004) and interpersonal loss (Szanto, Prigerson, Houck, Ehrenpreis, & Reynolds, 1997), to precipitate and perpetuate suicidal crisis in depressed elders.

Acknowledgments

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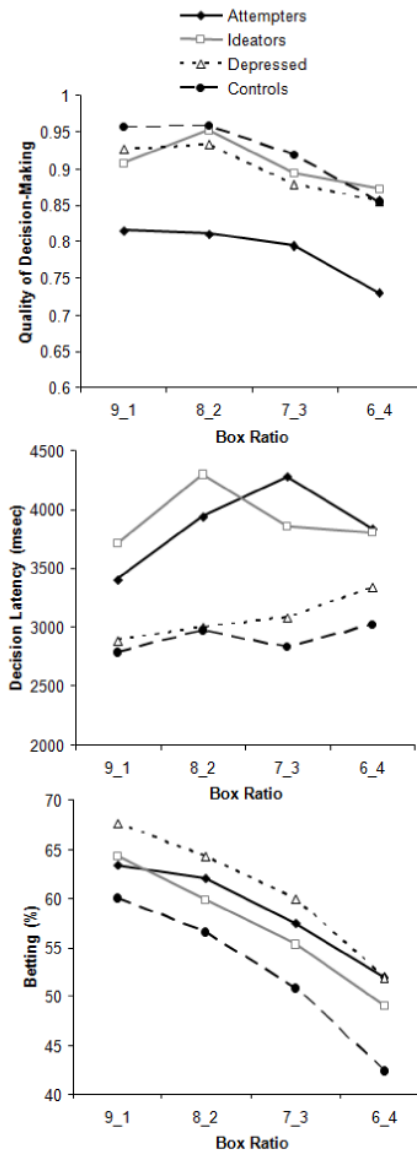
Figure 1.
Performance on the Cambridge Gamble Task in the depressed suicide attempters, depressed ideators, non-suicidal depressed, and non-psychiatric control participant groups. A) Quality of Decision-Making: the proportion of trials where the subject selected the box color in the majority, as a function of box ratio. B) Decision Latency: the latency (msec) to make the red/blue color decision, on trials where the subject selected the color in the majority. C) Betting Behavior: the percentage of the current points total wagered, as a function of box ratio, on those trials where the subject selected the color in the majority.

Table 1

Demographic and clinical characteristics (mean (sd))

	Attempters	Ideators	Depressed	Controls	
N	25	13	35	22	
Age (years)	67.1 (7.5)	69.9 (7.5)	70.7 (8.4)	67.8 (5.1)	ns
M:F	13:12	8:5	13:22	14:8	ns
Education	12.7 (2.6)	16.2 (2.8)	14.5 (2.9)	15.1 (3.5)	p=.004
White (%)	19/25	10/13	31/35	21/22	ns
CIRS-G	7.9 (3.4)	6.5 (2.5)	10.0 (3.6)	6.8 (2.6)	p=.001
MMSE	27.7 (2.0)	27.9 (2.4)	28.4 (1.5)	28.3 (1.4)	ns
SSI	19.0 (9.1)	15.9 (8.0)	1.1 (4.3)	-	p<.001
HDRS	20.6 (6.0)	19.9 (4.9)	18.2 (3.7)	-	ns
ATHF	2.3 (2.2)	1.6 (1.9)	1.4 (1.6)	-	ns
SCID diagnoses: *Lifetime (current)*					
MDD (current)	25	13	35	-	
GAD	9 (7)	5 (5)	14 (13)	-	
Phobias	4 (3)	2 (1)	9 (3)	-	
Panic Disorder	7 (6)	2 (0)	5 (1)	-	
Alcohol	11 (5)	4 (0)	6 (1)	-	

CIRS-G: Cumulative Illness Rating Scale adapted for Geriatrics. MMSE: Mini-Mental State Exam (Folstein, et al., 1975). SSI: Scale for Suicidal Ideation. HDRS: Hamilton Depression Rating Scale (17 item, excluding item 3) (Hamilton, 1960). ATHF: Antidepressant Treatment History Form - cumulative (Sackeim, 2001). SCID: Structured Clinical Interview for DSM Diagnoses (First, et al., 1996). MDD: Major Depressive Disorder. GAD: Generalized Anxiety Disorder. Additional subjects (≤3 per cell) met criteria for post-traumatic stress disorder, eating disorders, obsessive-compulsive disorder, and substance dependence to cannabis, stimulants or opiates.

Table 2

Performance measures on the Cambridge Gamble Task (mean (sd))

	Attempters	Ideators	Depressed	Controls
Quality of Decision-Making	0.79 (0.21)	0.91 (0.11)	0.90 (0.12)	0.92 (0.09)
Decision Latency (msec)	3864 (1608)	3918 (1390)	3076 (1258)	2900 (1049)
Bet (% of current score)				
Ascend	40.4 (24.0)	32.9 (27.4)	42.7 (20.6)	38.9 (22.7)
Descend	77.0 (21.9)	81.2 (13.8)	79.1 (18.9)	65.9 (25.9)
Risk Adjustment				
Ascend	0.80 (1.05)	0.93 (0.97)	0.91 (0.99)	1.22 (0.73)
Descend	0.49 (0.86)	0.48 (0.80)	0.42 (0.57)	0.62 (0.72)
Bankruptcies (max 8)	2.00 (1.78)	1.54 (1.61)	1.49 (1.46)	1.23 (1.48)
Points Total	2459 (2843)	1728 (1208)	2736 (2854)	2741 (1744)

Table 3

Scores on the Social Problem Solving Inventory (Revised) (mean (sd))

	Attempters	Ideators	Depressed	Controls	
SPSI Total	87.3 (18.6)	104.9 (18.5)	101.7 (16.1)	119.2 (9.3)	A<I,D,C; D<C
Positive Problem Orientation	91.8 (15.9)	99.2 (17.2)	97.3 (15.2)	114.1 (12.5)	A,I,D>C
Negative Problem Orientation	110.3 (15.9)	99.5 (16.0)	98.1 (13.2)	87.6 (10.5)	A>D,C; D>C
Rational Problem Solving	95.1 (16.3)	107.5 (19.2)	99.2 (15.1)	113.0 (9.4)	A<C; D<C
Impulsivity / Carelessness	106.6 (19.3)	92.7 (13.8)	93.0 (13.6)	86.6 (8.7)	A>I,D,C
Avoidant	113.9 (20.0)	96.1 (17.3)	99.7 (18.0)	83.6 (8.0)	A>I,D,C; D>C

All one-way ANOVAs attain statistical significance (F(3,85)>5.13, p<.003), and the final column indicates significant between-group comparisons using Tukey's tests (p<.05) where A=Attempters, I=Ideators, D=Non-suicidal Depressed, C=Non-psychiatric Controls.