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Implicit measures of suicide vulnerability: Investigating suicide-related information-processing biases and a deficit in behavioral impulse control in a high-risk sample and healthy controls

Juliane Brüdern [a,*], Lena Spangenberg [a], Maria Stein [b,c], Thomas Forkmann [d], Dajana Schreiber [d], Katarina Stengler [e], Helena Gold [a], Heide Glaesmer [a]

[a] Department of Medical Psychology and Medical Sociology, University of Leipzig, Germany
[b] Department of Clinical Psychology and Psychotherapy, University of Bern, Switzerland
[c] Translational Research Center, University Hospital of Psychiatry and Psychotherapy, University of Bern, Bern, Switzerland
[d] Department of Clinical Psychology and Psychotherapy, University of Duisburg-Essen, Germany
[e] Department of Psychiatry, Psychotherapy and Psychosomatics, Helios Park Hospital Leipzig, Germany

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ABSTRACT

Objective: Relevant implicit markers of suicidal thoughts and behaviors (STBs) have only been studied in isolation with mixed evidence. This is the first study that investigated a suicide attentional bias, a death-identity bias and a deficit in behavioral impulsivity in a high-risk sample and healthy controls.
Method: We administered the Death Implicit Association Test, the Modified Suicide Stroop Task, and a Go/No-Go Task to inpatient suicide ideators ($n = 42$), suicide attempters ($n = 40$), and community controls ($n = 61$).
Results: Suicide ideators and attempters showed a suicide attentional bias and a death-identity bias compared to healthy controls. Ideators and attempters did not differ in these implicit information-processing biases. Notably, only attempters were more behaviorally impulsive compared to controls; however, ideators and attempters did not significantly differ in behavioral impulsivity. Moreover, implicit scores were positively intercorrelated in the total sample.
Conclusion: In line with the Cognitive Model of Suicide, ideators and attempters display suicide-related information processing biases, which can be considered as implicit cognitive markers of suicide vulnerability. Furthermore, attempters have elevated levels of behavioral impulsiveness. These results are highly relevant in the context of crisis intervention strategies and warrant further research.

Suicide is still a leading cause of death globally and suicide rates have increased by 2.6% in the U.S. (Center for Disease Control and Prevention, 2023) and by 9.8% in Germany (Statistisches Bundesamt, 2024) from 2021 to 2022. One of the most important issues for enhancing suicide prevention efforts is improving the detection of acute suicide risk and the prediction of future suicidal thoughts and behavior (STBs). Despite increased research efforts that aim to improve the detection and prediction of STBs, the accuracy of suicide risk prediction has not increased significantly over the last fifty years (Franklin et al., 2017; Large et al., 2016). One important concern is that risk assessment currently mainly involves asking patients to report their own risk level or to assess suicide risk with self-report questionnaires. However, information provided by these methods is limited because patients in clinical settings may conceal suicidal ideation (SI) due to perceived negative consequences or they do not have conscious awareness of their recent and future risk level (Anestis & Green, 2015; Richards et al., 2019). For example, most patients who died by suicide while in hospital or directly after discharge did not report SI during their last contact with a clinician (Busch et al., 2003). Another reason may be the absence of SI at the moment of the assessment, as studies using ecological momentary assessment (EMA) indicate that SI are highly dynamic and fluctuate over minutes and hours (Hallensleben et al., 2018; Kleiman et al., 2017). Indeed, several studies have shown that the use of risk scales failed to adequately capture suicide risk (Steeg et al., 2018), and the Self-harm Guideline of the UK National Institute of Clinical Excellence advices against the use of risk scales for predicting suicide (National Institute for

* Corresponding author. Abteilung für Medizinische Psychologie und Medizinische Soziologie, Philipp-Rosenthal-Str. 55, 04103, Leipzig, Germany.
E-mail address: juliane.bruedern@medizin.uni-leipzig.de (J. Brüdern).

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Health and Care Excellence, 2022).

To overcome these limitations, there has been an increasing interest in the development of behavioral measures in order to assess suicide risk more objectively, which may augment the detection and prediction of STBs (Ballard et al., 2021). Behavioral measures represent a method for capturing implicit processes that run automatically and unconsciously and are less affected by conflicting intentions (Anestis & Green, 2015). Two of the most frequently studied suicide-related behavioral tests are the Suicide Stroop Task (SST) and the Death Implicit Association Test.

The *Suicide Stroop Task (SST)* is a computer-based reaction time task assessing selective attention toward suicide-specific stimuli. This suicide-specific attentional bias is theoretically linked with the Cognitive Model of Suicide proposed by Wenzel and Beck (2008). The model assumes that individuals with an activated suicide schema have difficulties disengaging from relevant suicide-related information (e.g. suicide-related words) because the confrontation with such stimuli activates a suicide-related network including cognitive processes (suicidal thoughts) and associated emotions, and prevents the person from regulating their attention away from these stimuli. Cha et al. (2010) developed the first computerized SST with trials containing neutral, positive, negative, and suicide-related words. Participants have to indicate the color of the presented word by key response. Based on the reaction times, a *Suicide Interference Score (SIS)* is calculated by subtracting the mean reaction time (mean RT) for the neutral words from the mean RT for the suicide related words. Similarly, interference scores are calculated for the positive and negative words resulting in three interference scores. Cha et al. (2010) demonstrated that only interference by suicide-related words was significantly greater among suicide attempters than in patient controls. Suicide interference was also prospectively predictive for a suicide attempt at six-month-follow-up. Although some researchers suggest that a suicide attentional bias is a correlate of suicidal behavior (Cha et al., 2010; Chung & Jeglic, 2017), recent SST studies provided mixed results. Stewart et al. (2017) demonstrated a difference in the SIS between adolescent suicide attempters compared to suicide ideators without a history of suicide attempts using t-tests, which could not be confirmed by a *Group* × *Interference* interaction, indicating that group effects did not significantly vary across interference type. A recent meta-analysis (Wilson et al., 2019) of SST studies compared suicide attempters vs. suicide ideators vs. non-suicidal controls (healthy and patient controls) and found no suicide attentional bias in either suicide ideators or attempters. Due to the lack of significant group differences in previous studies, some authors started generally questioning whether a suicide-attentional bias exists in individuals with STBs (Moscardini & Tucker, 2023).

The *Death Implicit Association Test (D-IAT)* is another class of implicit measures, in which stimuli of different categories have to be classified by keyboard responses to measure implicit cognitions that are mainly outside of conscious control. In the D-IAT, participants have to classify words according to four categories: “me” versus “not me”, and “life” versus “death”. Theoretically, reaction times are faster in compatible trials when associated concept and stimuli share the same response key (e.g., life and me) as compared with incompatible trials (e.g., death and me). Individuals with STBs are expected to react faster when the categories “death” and “me” share the same key as compared to the condition when “life” and “me” are assigned to the same key. A positive *D Score* in the D-IAT indicates that a person holds stronger implicit associations between oneself and death compared to associations with life, which is referred to as a *death-identity-bias*. Findings regarding a death-identity-bias, however, are rather contradictory. Some studies demonstrated differences between suicide attempters and non-attempters, with non-attempters showing stronger associations with life (Glenn, Werntz, et al., 2017; Millner et al., 2018), while others have failed to find a difference in D Scores between suicide attempters and non-attempters (Millner et al., 2019; Rath et al., 2021; Tello et al., 2020). Meta-analytical evidence (Sohn et al., 2021) suggests that dichotomized D Scores discriminated those with a history of suicide attempts from those without and prospectively predicted suicide attempts over a six-month follow-up period.

Besides cognitive information-processing biases, a deficit in impulse control represents a further potential marker of suicidal vulnerability. Several theories of suicide suggest impulsivity as a key risk factor for suicidal behavior (Mann et al., 1999; van Orden et al., 2010). In one of the most recent models of suicidality, the Integrated Motivational-Volitional Model (IMV, O’Connor & Kirtley, 2018), impulsivity is understood as a volitional moderator, that is, a factor that marks the transition from suicidal ideation to suicidal behavior. Thus, people with suicidal thoughts and a decreased impulse control might be at higher risk of acting on these thoughts. However, a recent meta-analysis (Moore et al., 2022) found only a small positive relationship between impulsivity and suicidal behavior. In this regard, an important shortfall of recent suicide theory is that impulsivity is treated as a unidimensional construct, whereas neuroscience (Liu et al., 2017) has conceptualized impulsivity as multidimensional (e.g., cognitive impulsivity, behavioral impulsivity). With respect to the increased risk of acting on suicidal thoughts, the dimension of behavioral impulsivity assessed with task-based measures is of particular interest in suicide research, which refers to a difficulty of preventing the initiation of a behavior or stopping a behavior that has already been initiated (impulsive action). In this regard, task-based measures are more state-sensitive indices of this construct, whereas self-report questionnaires are viewed as trait indicators of impulsivity (Liu et al., 2017). Prior studies have investigated the dimension of behavioral impulse control in individuals with STBs by using several versions of the *Go/NoGo (GNG)* task, which measures difficulties in inhibiting a prepotent motor response. A frequently used measure of the GNG task is the error rate of commission (EOC), which is the number of incorrect “NoGo” trials, where a response failed to inhibit in the presence of a “NoGo” stimulus. There is evidence (Raust et al., 2007; Westheide et al., 2008) that suicide attempters showed an increased behavioral impulsivity compared to healthy controls when using EOC as dependent measure by demonstrating a significantly higher EOC in suicide attempters. However, Millner et al. (2020), who were the first to compare attempters, ideators, and healthy controls using a GNG task, found no differences between the three subgroups regarding EOC, thus contradicting recent theory (O’Connor & Kirtley, 2018).

A critical limitation of prior research is its focus on examining these implicit suicide-specific measures in isolation, and there is a gap in knowledge, as to whether and, if so, how strongly these measures are interrelated. Another limitation is that most studies compared “suicidal” vs. “non-suicidal” groups, or “attempters” vs. non-attempters”, neither of which can isolate factors associated with ideation from those associated with attempts (Millner et al., 2020).

1. Study aims

To address the before mentioned limitations, this study set out to be the first to simultaneously investigate a death-identity bias, a suicide attentional bias and a deficit in impulse control. To further gain insights into how these implicit processes characterize different phases of the transition from suicidal thoughts to behavior, we compared individuals with a recent suicide attempt (suicide attempters), individuals who recently experienced SI but had never engaged in suicidal behavior (suicide ideators), and healthy controls. The aims of the present study were to investigate the following research questions.

1.1. Do suicide ideators and attempters differ in suicide-related implicit measures from healthy controls?

Regarding suicide-related information processing, the Cognitive Model of Suicide (Wenzel & Beck, 2008) postulates that a suicide attentional bias is defined as a *cognitive* component of the suicide schema and that individuals with a suicide schema have difficulties disengaging

from relevant suicide-related information. Accordingly, it can be assumed that both ideators and attempters should display a significantly greater attentional bias regarding suicide-related words compared to healthy controls. Although the Cognitive Model does not explicitly refer to a death-identity bias, similarly to a suicide attentional bias, it can be referred to as cognitive suicide-specific information processing and it can be assumed that ideators and attempters show a stronger implicit association with death compared to healthy controls. Furthermore, recent theories suggest that a deficit in impulse control represents a correlate of suicidal behavior (Mann et al., 1999; O'Connor & Kirtley, 2018; van Orden et al., 2010; Wenzel & Beck, 2008) and enables those who think about suicide to act on these thoughts. Accordingly, suicide attempters should display a greater deficit in behavioral impulse control compared to healthy controls; however, suicide ideators should not differ in their behavioral impulsivity compared to healthy controls.

1.2. Do suicide ideators differ in suicide-related implicit measures from suicide attempters?

The Cognitive Model of Suicide (Wenzel & Beck, 2008) further outlines that an impaired information-processing such as a suicide attentional bias *precedes* suicidal ideation *and* the engagement in suicidal behavior. Accordingly, ideators and attempters should not differ in their degree of a suicide attentional bias and a death-identity bias. Only a few studies have examined differences between ideators and attempters in suicide-related information-processing biases with mixed findings (Millner et al., 2018; Rath et al., 2021; Stewart et al., 2017). Therefore, the present study aimed to add evidence to the question, whether ideators and attempters differ in suicide related information processing biases. Moreover, the "ideation-to-action" framework (Klonsky & May 2015), which includes contemporary suicide theories such as the IMV (O'Connor & Kirtley, 2018) or the Interpersonal Theory of Suicide (van Orden et al., 2010), represents a theoretical concept, postulating that attempters should differ from ideators by displaying higher degrees in suicide-related key variables such as impulsivity. In accordance with this framework, it can be assumed that attempters should exhibit a greater deficit in behavioral impulse control compared to ideators. Given the inconsistent findings on the precise role of impulsiveness in suicidal behavior and with only one study comparing suicide attempters and ideators in behavioral impulse control (Millner et al., 2020), this study contributes to further clarifying the role of an impaired impulse control in ideators versus attempters.

1.3. Are suicide-related implicit measures associated with each other and with self-report measures?

To the best of our knowledge, no prior study has simultaneously examined a suicide attentional bias, a death-identity bias, and a deficit in behavioral impulse control in adults. To close this gap in knowledge, we aimed to investigate the relationships between these suicide-related implicit measures in an explorative way. Here, we were especially interested in examining whether and, if so, how strongly the implicit scores are related in ideators versus attempters. Furthermore, we were interested in how implicit measures are related to self-reported depression, hopelessness, suicidal ideation, and impulsivity.

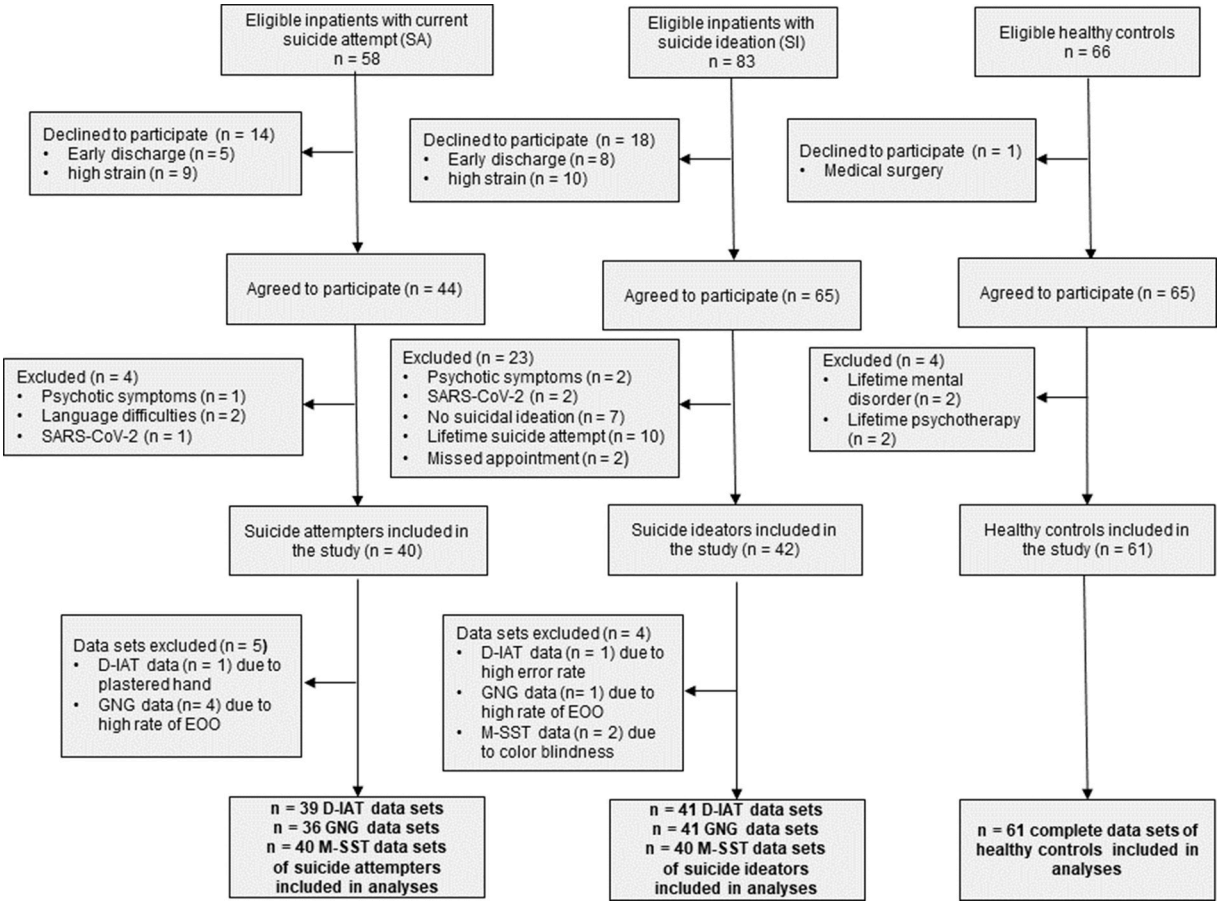

Fig. 1. Flowchart of study inclusion. SA = suicide attempt; SI = suicidal ideation; D-IAT = Death Implicit Association Test; GNG = Go/NoGo Task; M-SST = Modified Suicide Stroop Task; EOO = Errors of omission.

2. Methods

2.1. Participants and procedure

Participants were 143 adults recruited into one of three groups (see Fig. 1): (i) psychiatric inpatients who were hospitalized due to a current suicide attempt (suicide attempters), (ii) psychiatric inpatients who were hospitalized due to recent suicidal ideation without a lifetime history of suicide attempts (suicide ideators) and (iii) control participants without a history of psychopathology and psychotherapy (controls).

Between September 2020 and May 2023, patients at a psychiatric ward of a German hospital were contacted for study participation, if they fulfilled the inclusion criteria of being hospitalized due to a) a current suicide attempt or b) recent suicidal ideation without recent or lifetime suicide attempts and c) being aged ≥18. Exclusion criteria included inability to speak or write German fluently, presence of cognitive impairment, color blindness, dyslexia and being currently psychotic. After checking exclusion criteria, $n = 40$ suicide attempters and $n = 42$ suicide ideators could be included in the study (see Fig. 1). After patients agreed to participate, a research assistant provided information about the purpose of the study, the voluntary nature of their participation and data storage. If patients provided informed consent, an appointment for the test session was scheduled and participants received a battery of self-report questionnaires, which they had to complete until the test session. Patients also gave informed consent to access their diagnoses in their medical records. On the scheduled appointment, the test session took place in the research assistant's office on the psychiatric ward. During the test session, patients completed the M-SST, D-IAT and GNG task in a randomized order followed by a questionnaire assessing the evaluation of the presented word stimuli of the M-SST (description and results of this rating are reported in Brüdern et al., 2024 and are beyond the scope of this paper). Finally, a short version of the Suicidal Thoughts and Behaviors Interview (Fischer et al., 2014) was administered.

The control group was recruited via flyers from local communities. Individuals were eligible, if they were a) aged ≥18 years and were b) without a history of psychopathology including STBs and psychotherapy. Potential participants of the control group were screened via telephone regarding the exclusion criteria, which included inability to speak or write German fluently, the presence of cognitive impairment, color blindness, dyslexia, a history of psychopathology and psychotherapy including a history of suicidal ideation or suicide attempts. If participants agreed to participate, informed consent and self-report questionnaires were sent by mail and an appointment for the laboratory session was scheduled. After obtaining informed consent, control participants attended the session in the lab of the Department of Medical Psychology and Medical Sociology at the University of Leipzig. The procedure was identical to that for patients except that a short version of a German diagnostic interview for mental disorders (Mini-DIPS; Margraf & Cwik, 2017) was administered instead of the SITBI to double check exclusion criteria. Eventually, $n = 61$ healthy controls could be included in the study (see Fig. 1).

Every participant received 30 € as compensation. All procedures were approved by the ethics committee of the Medical Faculty of the University of Leipzig [012/19-ek]. The study was not pre-registered.

2.2. Measures

2.2.1. Beck Depression Inventory (BDI-II)

The German version of the revised Beck Depression Inventory (Beck et al., 1996; Kühner et al., 2007) was used to assess the severity of depression over the previous two weeks. The BDI-II contains 21 items describing depressive symptoms that are to be rated on a 4-point scale (0–3). Total scores range from 0 to 63, with higher scores indicating greater depression severity. The internal consistency in our sample was high with Cronbach's $\alpha = 0.97$.

2.2.2. Beck Hopelessness Scale (BHS)

Hopelessness was assessed with the German version of the Beck Hopelessness Scale (Beck et al., 1988; Kliem & Brähler, 2015) which comprises 20 true-false items that assess hopelessness and pessimistic cognitions. Good reliability and validity have been shown for the BHS (McMillan et al., 2007). Total scores range from 0 to 20, with higher scores indicating stronger hopelessness. The internal consistency in our sample was high with Cronbach's $\alpha = 0.92$.

2.2.3. Beck Scale for Suicide Ideation (BSS)

Suicidal ideation during the past week was assessed using the German version of the Beck Scale for Suicidal ideation (Beck & Steer, 1993; Kliem et al., 2017). The BSS consists of 21 statement groups and is used to assess the severity of suicidal symptoms on a 3-point scale (0–2). Two filter questions (the statement groups four and five) assess the presence of active or passive suicidal thoughts. If participants endorse one of them (i.e., choose a sentence rated 1 or 2), they are to complete the subsequent 14 statement groups which allow for an assessment of the severity of existing suicidal ideation. If participants choose the response option rated "0" for both item 4 and item 5 they skip items 6 to 19 and proceed to the last two statement groups. These last two items address frequency and intensity of former suicide attempts and are again to be answered by all participants. They are not part of the total BSS score. It has shown good internal consistency and construct validity (Kliem et al., 2017). Total scores range from 0 to 38, with higher scores indicating greater suicidality. The internal consistency in our sample was high with Cronbach's $\alpha = 0.89$.

2.2.4. Barratt Impulsiveness Scale-15 (BIS-15)

Impulsiveness was measured using the German short version of the BIS-11 (Meule et al., 2011). The BIS consists of 15 items that are to be rated on a 4-point scale (1–4). The maximum total score is 60, and the scale consists of three subscales: attentional impulsiveness ($\alpha = 0.75$), motor impulsiveness ($\alpha = 0.77$), and non-planning ($\alpha = 0.77$). The internal consistency in our sample was high with Cronbach's $\alpha = 0.84$.

2.2.5. Self-Injurious Thoughts and Behaviors Interview (SITBI)

The German version of the Self-Injurous Thoughts and Behaviors Interview (Fischer et al., 2014; Nock et al., 2007) is a structured interview and assesses the frequency and intensity of the patients' suicidal thoughts, plans and behavior. We only administered the sections "suicidal thoughts", "plans", and "attempts" to the patients. The SITBI-G has good interrater and retest reliability, as well as good convergent validity (Fischer et al., 2014).

2.2.6. Mini-DIPS

The Mini-DIPS (Margraf, Cwik, Pflug, & Schneider, 2017) is a short version of the German Structured Clinical Interview for Mental Disorders. It was administered in the control group to verify that the participants had no present or previous mental disorder.

2.3. Implicit measures

All behavioral tests were presented on a grey screen of a DELL Latitude Laptop with a screen diameter of 15.6 inches.

Death Implicit Association Test (D-IAT). For measuring associations with death, the German version of the D-IAT was conducted (Rath et al., 2018, 2021) by using the Presentation software (Neurobehavioral Systems, 2023). Five stimuli were used for each category, for the concept category "me" (I, myself, my, mine, and self), for the concept category "not-me" (they, them, their, theirs, and other), for the attribute category "death" (die, funeral, deceased, lifeless, and suicide), and for the attribute category "life" (alive, survive, live, thrive, and breathing). The D-IAT consisted of seven blocks: 1, 2, and 5 were used as exercise blocks, while 3, 4, 6, and 7 were used as experimental blocks. Blocks 3 and 4 consisted of 20 trials each. Blocks 6 and 7 consisted of 40 trials each. The

D-IAT was scored using D scores that were recommended by Greenwald et al. (2003). D scores were computed based on differences between reaction times (RTs), meaning that higher (positive) values indexed a stronger association of "me" and "death". Single outlier response times below 300 ms (ms) and above 10,000 ms were automatically excluded before computing the respective D scores (Rath et al., 2018, 2021). Whole IAT data sets were excluded in case of too fast or slow responses in more than 10% of trials over all blocks or more than 25% of trials in one of the four experimental blocks. Additionally, whole IAT data sets were excluded in case of more than 30% erroneous trials over all blocks or more than 40% erroneous trials in one of the four experimental blocks (Rath et al., 2021).

Modified Suicide Stroop Task (M-SST). Prior SST studies (Moscardini & Tucker, 2023; Niu et al., 2021; Wilson et al., 2019) concluded that the SST in its current form demonstrated insufficient psychometric properties and may thus not be able to reveal a suicide-related attentional bias in individuals with STBs. Therefore, we used a modified version of the SST for measuring a suicide attentional bias, which demonstrated improved internal consistency (split-half reliability with Spearman-Brown correction for interference scores ranged from 0.77 to 0.93; for detailed information see Brüdern et al., 2024; Gold et al., 2024). The Modified Suicide Stroop Task (M-SST) was administered using the E-Prime 3.0 software and the response and stimulus device Chronos (Psychology Software Tools, 2023). The M-SST includes four categories of word stimuli: neutral words (e.g., chair, tap) and three different categories of emotional words consisting of positive words (e.g., security, trust) negative words (e.g., jealousy, difficulty), and suicide-related (e.g., suicide, destruction) words (available at https://osf.io/9ngz3/). Each category comprised ten nouns, which were controlled regarding the number of letters and number of syllables. During the M-SST, the ten words of each category were presented in four different font colors (red, yellow, blue, and green) resulting in 40 trials per category, which were presented block-wise. Consequently, the M-SST consisted of four experimental blocks with 40 category-specific trials per block. Participants were instructed to name the font color of the displayed word as quickly and accurately as possible into a microphone, which was connected with the Chronos device. The latter measured the reaction time in milliseconds and provided an audio file with the recorded answer for each trial. Prior to starting the M-SST, a microphone test containing 20 trials (stimuli consisted of words associated with clothing, e.g., jacket) was conducted in order to test the microphone settings. After the microphone test, the M-SST started with 20 practice trials (words describing music instruments) followed by the four experimental blocks. For the experimental blocks of the M-SST, four different block orders were applied, which were randomly distributed across participants in order to avoid position and sequence effects.

Each trial started with the presentation of a "+" in the centre of the screen for 500 ms followed by the stimulus, which was displayed on the screen until the microphone registered the participant's answer. Each trial was limited to a maximum response time of 4000 ms. If no response was registered within this time frame, the reaction time for this trial was automatically set to zero and the trial was excluded. The time between trials was set to 1000 ms. Between each experimental block, participants had a rest of 30 s before the next block started automatically. During the administration of the M-SST, the experimenter was blind to the block order and manually registered incorrect responses (naming the wrong font color or reading the word) by using a blind checkbox. Trials with incorrect responses were excluded from the analysis. Outlier response times were defined as response latencies <200 ms (Mogg & Bradley, 2002; Munafò et al., 2003) and were excluded before calculating the mean reaction times and interference scores. Based on the procedure by Cha et al. (2010), a Suicide Interference Score (SIS) was calculated by subtracting the mean RT for the neutral words from the mean RT for the suicide related words (Mean $RT_{Suicide\ words}$ − Mean $RT_{Neutral\ words}$). Similarly, interference scores were calculated for the positive (Mean $RT_{Positive\ words}$ − Mean $RT_{Neutral\ words}$) and negative words (Mean $RT_{Negative\ words}$ − Mean $RT_{Neutral\ words}$), resulting in three interference scores. The word material of the M-SST and E Prime files have been made available in an open repository (https://osf.io/9ngz3/).

Go/NoGo (GNG) Task. A deficit in impulse control was measured with a GNG task, which required participants to inhibit a prepotent response tendency. For the task, we used the E-Prime 3.0 software and the response and stimulus device Chronos (Psychology Software Tools, 2023). Participants were instructed to press a key on the Chronos device in response to trials consisting the letter "X" or "Y" ("Go" trials) and to withhold a response when the same letter appears on the display in two consecutive trials ("NoGo" trials). The task started with an exercise block of 50 trials, followed by an experimental block of 150 trials with 126 "Go" trials (84%) and 24 "NoGo" trials. Using EOC as measure of performance, reaction times of trial performance are not considered. Therefore, we decided to use the *Balanced Integration Score (BIS)*, a combined performance measure that integrates measure of speed (mean RTs) and accuracy (percentage of correct responses) in a way that attenuates speed-accuracy trade-offs (SAT) effects while maintaining "real effects" (Liesefeld & Janczyk, 2019, 2022). We calculated the BIS according to the formula by Liesefeld and Janczyk (2019) that considers varying SAT across participants. After calculating the BIS, we inverted the score for better interpretation, meaning the more positive the BIS, the higher the deficit in behavioral impulse control. The R code of the BIS and the E Prime file of the GNG task have been made available in an open repository (https://osf.io/9ngz3/).

2.4. Statistical analyses

To test whether the three subgroups differ in the three implicit measures, we calculated separate *Group* (controls, ideators, attempters) one-way ANOVAs with the D Score as the dependent variable for the D-IAT, with SIS as the dependent measure for the M-SST, and with the BIS as the dependent measure for the GNG task. In order to compare our results with prior GNG research, we additionally ran the analysis with the EOC score for the GNG task. When the results of the one-way ANOVAs showed a significant main effect, we conducted Bonferroni *post-hoc* tests for pairwise comparisons within the ANOVA procedure. An a priori power analysis for a *3 Group one-way* ANOVA was conducted with a statistical power set at 0.8 and alpha set at 0.05, suggesting a required sample size of 159 individuals for detecting medium effects ($f = 0.25$). With a total number of 141 available datasets, the study was underpowered for detecting medium effects, but at least provided adequate power for detecting effects sizes larger than 0.30 ($N = 141$, $\alpha = 0.05$, $f = 0.30$, $1 - \beta = 0.89$).

To control for the three interferences types within the repeated measure design of the M-SST, we additionally conducted a repeated measure ANOVA with *Group* (controls, ideators, attempters) as the between-subject factor and *Interference* (Positive, Negative, Suicide) as the within-subject factor. In case of a significant interaction effect, we chose Bonferroni post hoc procedure. An a priori power analysis for a repeated measure ANOVA with a within-between interaction was conducted with a statistical power set at 0.8 and alpha set at 0.05, suggesting a required sample size of 30 individuals for detecting medium effects ($f = 0.25$). To further gain insights into differences between the three subgroups regarding the investigated implicit markers, we conducted receiver operating characteristics (ROC) analyses for the controls vs. patients with STBs comparison and for the ideators vs. attempters comparison and calculated AUC (area under the curve) values for the D Score, BIS, and SIS.

For determining the associations between the three implicit markers as well as their associations with clinical characteristics, we calculated Pearson's correlation coefficients for each subgroup and the total sample. Correlation analyses for the total sample were sufficiently powered ($N = 141$, $\alpha = 0.05$, $1 - \beta = 0.96$) to detect medium effects ($r = 0.30$), whereas correlational analyses for the subgroups were underpowered ($N = 40$, $\alpha = 0.05$, $1 - \beta = 0.60$). For statistical analyses, we used the

statistical software R (version 4.2.0–2, R Core Team, 2020) and SPSS (version 29.0).

3. Results

3.1. Descriptive results

Data on sociodemographic and clinical characteristics were missing for one suicide attempter. Sociodemographic and clinical characteristics are presented in Table 1. In the group of suicide attempters, $n = 15$ reported a single suicide attempt and $n = 24$ reported two or more lifetime suicide attempts (range: 2–20). On average, attempters had their last suicide attempt 11.03 days ($SD = 5.27$ days, range 4–25 days) prior to the assessment. Furthermore, ideators indicated a shorter time period of having experienced suicidal thoughts prior to the assessment ($M = 3.97$ days $SD = 3.87$) compared to attempters ($M = 6.23$ days $SD = 5.40$), $t(69) = 2.03$, $p = 0.046$.

3.2. Data integrity

As presented in the study flow chart (Fig. 1), the D-IAT data of one suicide ideator and one suicide attempter had to be excluded. Furthermore, GNG data of one suicide ideator and four suicide attempters, and the complete M-SST data sets of two suicide ideators had to be excluded. Moreover, 272 incorrect trials (1.21%) and 226 trials (1%) with an outlier response time in the M-SST were removed. Separately analyzed by group, we excluded 227 (2.33%) error trials from a total of 9760 trials in the control group, 127 (1.98%) error trials from a total of 6400 trials in the ideators group, and 144 (2.25%) error trials from a total of 6400 trials in the attempters group. The number of excluded error trials did not significantly differ between groups, $F(2, 138) = 0.33$, $p = 0.717$.

Table 1
Sociodemographic and clinical characteristics.

Variable	Controls *M (SD)*	Ideators *M (SD)*	Attempters *M (SD)*	Test Statistic	*p*
Age (in years)	30.54 (13.08)	29.93 (11.44)	33.38 (11.93)	F (2, 139) = 0.93	0.726
Gender (%)				$X^2(4, N = 142) = 3.79$	0.429
Male	37.7	47.6	30.8		
Female	60.7	52.4	69.2		
Non-binary	1.6	0	0		
BDI	3.95 (3.83)	37.21 (10.58)	36.62 (11.25)	$t(79) = 0.25$[b]	0.806
BHS	2.92 (1.99)	14.81 (4.72)	14.24 (4.55)	$t(78) = 0.55$[b]	0.583
BSS	0.03 (0.18)	16.64 (8.96)	18.29 (11.25)	$t(78) = -0.73$[b]	0.469
BIS-15	28.56 (6.17)	34.93 (8.07)	35.74 (6.55)	$t(79) = -0.50$[b]	0.621
Diagnoses (%)				$X^2(3, N = 81) = 13.37$[b]	0.004
Mood disorders	–	54.8	46.2		
Neurotic-, stress- and somatoform disorders	–	35.7	15.4		
Substance use disorders	–	2.4	0		
Personality disorders	–	7.1	38.5		

Note. M = mean, SD = standard deviation, BDI = Beck Depression Inventory, BHS = Beck Hopelessness Scale, BSS = Beck Scale for Suicide Ideation, BIS-15 = Barratt Impulsiveness Scale-15 [b] Comparisons are between attempters and ideators only.

3.3. Do suicide ideators and attempters differ in suicide-related implicit measures from healthy controls?

The one-way *Group* ANOVA with D Score as dependent measure revealed a significant *Group* effect (Table 2). *Post-hoc* tests revealed that the differences in means (MD) of the D Scores between healthy controls and suicide ideators, $MD = -0.27$, $SE = 0.07$, $p < 0.001$, 95% CI [−0.43, −0.11], and between healthy controls and suicide attempters, $MD = -0.27$, $SE = 0.07$, $p < 0.001$, 95% CI [−0.43, −0.10], were significant, indicating that the mean D score of healthy controls was significantly more negative compared to the mean D Score of ideators and attempters (Table 2). For distinguishing between controls and patients with STBs, the D Score revealed an $AUC_{D\ Score} = 0.73$, 95% CI [0.64–0.81], $p < 0.001$, which can be considered acceptable (Hosmer et al., 2013).

The one-way *Group* ANOVA with BIS as dependent variable revealed a significant *Group* effect (Table 2). *Post-hoc* tests revealed that the difference in means of the BIS between controls and ideators was not significant, $MD = -0.58$, $SE = 0.26$, $p = 0.079$, 95% CI [−1.21, 0.05]. *Post-hoc* tests comparing controls with attempters showed that the mean BIS of controls was significantly more negative compared to attempters, $MD = -0.99$, $SE = 0.27$, $p < 0.001$, 95% CI [−1.65, −0.34]. For classifying between controls and patients with STBs, the analysis revealed an $AUC_{BIS} = 0.68$, 95% CI [0.59–0.77], $p < 0.001$, which can be considered as weak (Hosmer et al., 2013). The one-way *Group* ANOVA with EOC as dependent variable revealed no significant *Group* effect ($p = 0.08$; detailed results of the EOC are included in the Supplementary Material Table S1).

The one-way *Group* ANOVA with SIS as dependent variable revealed a significant *Group* effect (Table 2). *Post-hoc* tests showed that the mean SIS of controls was significantly smaller compared to suicide ideators, $MD = -109.83$, $SE = 28.99$, $p < 0.001$, 95% CI [−180.10, −39.57], and suicide attempters, $MD = -95.23$, $SE = 28.99$, $p = 0.004$, 95% CI [−165.49, −24.97].

The repeated measure ANOVA yielded a significant main effect for *Group* $F(2, 138) = 5.29$, $p = 0.01$, $\eta_p^2 = 0.07$, and for *Interference*, $F(2, 276) = 31.62$, $p < 0.001$, $\eta_p^2 = 0.19$. There was a significant *Group* × *Interference* interaction, $F(4, 276) = 6.58$, $p < 0.001$, $\eta_p^2 = 0.09$. *Post hoc* tests revealed that controls showed a significantly smaller interference for suicide-related words compared to ideators ($p < 0.001$), but did not differ in their interference scores regarding positive words ($p = 0.10$) and negative words ($p = 0.18$). When comparing controls with attempters, controls showed a smaller suicide-specific interference for suicide-related words ($p = 0.004$), but not for positive and negative words ($ps = 1.00$). Furthermore, the SIS differentiated between controls and patients with STBs with an $AUC_{SIS} = 0.75$, 95% CI [0.66–0.83], $p < 0.001$, which can be considered acceptable (Hosmer et al., 2013).

3.4. Do suicide ideators differ in suicide-related implicit measures from suicide attempters?

For all three implicit scores, *post hoc* tests of the one-way *Group* ANOVAs revealed no significant differences between suicide ideators and attempters ($ps > 0.05$). Box plots of all three implicit scores are presented in the Supplementary Material (Figs. S1–S3). Furthermore, *post hoc tests* of the repeated measure ANOVA yielded no significant group differences between ideators and attempters for all three interference types ($ps > 0.05$). Classification metrics for differentiating between ideators and attempters for the implicit measure scores were as follow: $AUC_{D\ Score} = 0.49$, 95% *CI* [0.36–0.62], $p = 0.843$; $AUC_{BIS} = 0.57$, 95% *CI* [0.44–0.70], $p = 0.328$; $AUC_{SIS} = 0.53$, 95% *CI* [0.40–0.66], $p = 0.640$, indicating that all three scores do not classify between ideators and attempters.

Table 2
Implicit scores across groups.

Measure	Control group		Suicide ideators		Suicide attempters		Test statistic p	ES
	M (SD)	95% CI	M (SD)	95% CI	M (SD)	95% Ci		
D Score	−0.56 (0.32)	−0.65–−0.48	−0.29 (0.36)	−0.41–−0.18	−0.30 (0.33)	−0.40–−0.19	F (2,138) = 11.37 < 0.001	0.14
BIS	−0.43 (1.09)	−0.71–−0.15	0.15 (1.27)	−0.25–0.55	0.56 (1.57)	0.03–1.09	F (2,135) = 7.21 < 0.001	0.10
SIS	10.23 (50.53)	−2.71–23.17	120.06 (202.79)	55.21–184.92	105.46 (163.71)	53.10–157.81	F (2,138) = 9.06 < 0.001	0.12

Note. M = mean, *SD* = standard deviation, D Score = Score of the Death Implicit Association Test (N = 141), BIS = Balanced Integration Score of the Go/NoGo Task (N = 138), SIS = Suicide Interference Score of the Modified Suicide Stroop Task (N = 141). Means and standard deviations of the SIS are reported in milliseconds. ES = Effect size (η^2).

3.5. Are suicide-related implicit measures associated with each other and with self-report measures?

The results of the correlational analyses are presented in Table 3. In the total sample, all three implicit measures were significantly positively related with each other. In healthy controls, the implicit scores were not significantly interrelated. In ideators, all three implicit scores were moderately linked in a positive direction, but only the association between the D Score and the BIS reached significance, suggesting the more strongly patients were implicitly relating themselves to death, the more difficulties they showed in controlling impulsive action. In attempters, there were no significant associations between implicit measures.

Regarding the associations between implicit measures and self-report questionnaires, in the total sample, all implicit scores were significantly positively correlated with self-reported depression (BDI), hopelessness (BHS), suicidal ideation (BSS), and impulsivity (BIS-15), except the BIS, which was not significantly correlated with self-reported impulsivity (BIS-15). In suicide attempters, the D Score was significantly positively correlated with self-reported depression (BDI) and suicidal ideation (BSS), indicating the more strongly attempters were implicitly related to death the higher they scored on self-reported depression and suicidal ideation.

4. Discussion

As a first of its kind, the present study investigated three implicit measures that have been linked with STBs, namely a death-identity bias, a suicide attentional bias and a deficit in behavioral impulsivity, in an adult sample. To advance our knowledge about the relationship between these implicit measures and the different phases of the transition from suicidal thoughts to behavior, we compared suicide attempters, suicide ideators, and healthy controls. In this context, the present study aimed to investigate three research questions, and the main findings will be discussed in the following.

4.1. Do suicide ideators and attempters differ in suicide-related implicit measures from healthy controls?

Based on the theoretical postulations of the Cognitive Model of Suicide (Wenzel & Beck, 2008), we assumed that suicide ideators and attempters display a suicide attentional bias and a death-identity bias in comparison to healthy controls. With regard to a death-identity bias, we found that ideators and attempters showed significantly more positive D Scores compared to controls. This suggests that ideators and attempters have a stronger implicit association with death than controls, thus revealing a death-identity bias in ideators and attempters. The D Score was also able to distinguish adequately between controls and patients with STBs. For the SIS, we found that ideators and attempters showed significantly greater interferences for suicide-related words compared to controls, indicating a suicide attentional bias in ideators and attempters. This finding was confirmed by the repeated measure ANOVA. Here, we could detect an interaction effect for *Group* and *Interferences* by showing that ideators and attempters displayed greater interferences for suicide-related words compared to controls; however, the differences in interferences for positive and negative words were non-significant for controls against ideators and controls against attempters. Furthermore, the SIS demonstrated an adequate classification accuracy to differentiate between healthy controls and patients with STBs. Our results of a suicide attentional bias challenge prior research findings that failed to show a suicide attentional bias in individuals with STBs compared to healthy controls (Niu et al., 2021; Wilson et al., 2019). Moreover, our results regarding a death-identity bias and a suicide attentional bias support assumptions of the Cognitive Model of Suicide (Wenzel & Beck, 2008), postulating that individuals with a suicide schema exhibit distorted suicide-specific information-processing, which represents an implicit cognitive marker of suicidal vulnerability.

Table 3
Correlations between implicit scores and with clinical variables and number of suicide attempts.

		D Score	SIS	BDI	BHS	BSS	BIS-15	Number of SAs[a]
HC	D-Score	–	–	−0.02	−0.11	0.04	−0.10	–
	SIS	−0.14	–	−0.11	0.17	0.21	0.06	–
	BIS	−0.16	−0.20	−0.07	−0.01	−0.09	−0.21	–
SI	D-Score	–	–	0.03	−0.02	0.28	0.15	–
	SIS	0.24	–	0.16	−0.03	0.17	0.16	–
	BIS	0.40**	0.27	0.08	0.01	0.03	0.01	–
SA	D-Score	–	–	0.32*	0.23	0.44**	0.26	0.05
	SIS	0.02	–	0.03	0.15	−0.07	0.06	0.19
	BIS	0.28	0.08	0.20	0.23	0.28	0.23	0.28
Total Sample	D-Score	–	–	0.39***	0.35***	0.45***	0.24**	–
	SIS	0.21*	–	0.34***	0.32***	0.29***	0.24**	–
	BIS	0.24**	0.21*	0.29***	0.28**	0.31***	0.13	–

Note. HC = healthy controls, SI = suicide ideators, SA = suicide attempters, D Score = Score of the Death Implicit Association Test.
SIS = Suicide Interference Score of the Modified Suicide Stroop Task, BIS = Balanced Integration Score of the Go/NoGo Task.
BDI = Beck Depression Inventory, BHS = Beck Hopelessness Scale, BSS = Beck Scale for Suicide Ideation.
BIS-15 = Barratt Impulsiveness Scale-15, SAs = suicide attempts.
*p < 0.05 **p < 0.01 ***p < 0.001.
[a] Correlations for suicide attempters only.

Based on assumptions of recent theories (Mann et al., 1999; O'Connor & Kirtley, 2018; van Orden et al., 2010; Wenzel & Beck, 2008) that view impulsivity as a correlate of suicidal behavior, we assumed that suicide attempters should display a greater deficit in behavioral impulse control than healthy controls; however, ideators should not differ in their behavioral impulsivity compared to controls. When using the EOC score as outcome variable, our results indicate no differences between controls, ideators and attempters in behavioral impulsivity, which correspond to findings by Millner et al. (2020). However, compared to Millner et al. (2020), we additionally used the BIS as dependent measure of the GNG task, because the BIS attenuates variations of SAT in between-participants designs and is therefore recommended for analyzing the "real" effects in GNG tasks (Liesefeld & Janczyk, 2022). When using the BIS as dependent measure, our results revealed that attempters displayed significantly more positive values of the BIS compared to controls, indicating that individuals with a recent suicide attempt have more difficulties inhibiting a prepotent response, which is an indicator of impulsive action (Liu et al., 2017; Millner et al., 2020). However, we could not detect a significant group difference in the BIS between ideators and controls, which is in line with our assumptions. Yet, this finding should be viewed as tentative, because the one-way ANOVA was underpowered for detecting small effects. Like attempters, ideators also demonstrated a positive mean value in the BIS compared to a negative mean value in the control group, which cautiously indicates that individuals with recent suicidal thoughts also tend to act more impulsively in the GNG task compared to individuals who had never experienced a suicidal crisis.

4.2. Do suicide ideators differ in suicide-related implicit measures from suicide attempters?

Based on the postulations of the Cognitive Model of Suicide (Wenzel & Beck, 2008), we assumed that ideators and attempters do not significantly differ in a suicide attentional bias and death-identity bias. Results of the *post hoc* tests revealed that ideators and attempters showed no differences in the death-identity bias, which is in line with prior D-IAT findings (Millner et al., 2018; Rath et al., 2021). Furthermore, we found no differences in the suicide-related interferences between ideators and attempters. By using the M-SST with improved psychometric properties compared to the prior SST (Brüdern et al., 2024; Gold et al., 2024), insufficient psychometric properties can be excluded as a reason to explain this non-significant finding. However, the sample size provided only limited statistical power to detect small to medium effects for the one-way ANOVA group comparisons. Therefore, these results should be viewed as preliminary and we cannot conclusively determine whether ideators and attempters differ in their cognitive implicit information processes. Nevertheless, the repeated measures ANOVA with the SIS as outcome were conducted with adequate statistical power and failed to detect a significant group difference between ideators and attempters, confirming the result of the one-way ANOVA. Altogether, our results of a suicide attentional bias and death-identity bias are in line with the Cognitive Model of Suicide (Wenzel & Beck, 2008), holding that individuals with suicidal ideation or behavior showed distorted information processing compared to individuals without a history of STBs, suggesting that these biases represent implicit cognitive markers of suicide vulnerability.

Based on theoretical assumptions of the ideation-to-action-framework (Van Orden et al., 2010; Klonsky & May 2015; O'Connor & Kirtley, 2018), we hypothesized that attempters should exhibit a greater deficit in behavioral impulse control compared to ideators. In our study, attempters showed a nearly fourfold increase in the BIS compared to ideators; however, this difference was non-significant, which might be linked to the limited statistical power of our analysis. Therefore, failure to reject the null hypothesis does not necessarily suggest that ideators and attempters do not differ in their levels of behavioral impulsivity, and more studies are needed with larger samples using the BIS as outcome variable.

4.3. Are suicide-related implicit measures associated with each other and with self-report measures?

Besides our first aim of comparing attempters, ideators and healthy controls in suicide-related implicit measures, we aimed to examine the relationships between these implicit scores and with self-report measures in an explorative way. In the total sample, we found significant positive associations between the investigated implicit scores with the strongest association between a death-identity bias and behavioral impulsivity, suggesting that cognitive and behavioral implicit processes are interconnected. In order to obtain a more fine-grained picture, we analyzed these associations separately for each subgroup.

In suicide ideators, all three implicit scores were moderately positively interrelated, but only the association between the D Score and the BIS reached significance, indicating that the more strongly patients were implicitly relating themselves to death, the more difficulties they showed in controlling impulsive action. Compared to attempters, which showed no significant associations between the three implicit scores, the correlational pattern found in ideators might reflect a state of implicit suicidogenic alertness or suicidal mode, as it is postulated in the Dual-System Model of Suicidality (DSMS, Brüdern et al., 2022). The DSMS points to an influence of implicit suicide-related processes on suicidal trajectories, which might display temporal dynamics similar to the fluctuating nature of suicidal ideation (Hallensleben et al., 2018). By assuming such temporal dynamics of implicit markers, attempters might also have experienced such an activated implicit suicidal mode, which might be detectable most likely around the time of their suicide attempt. The fact that the time from last having experienced suicidal thoughts was significantly shorter in ideators compared to attempters might additionally support this assumption. However, this interpretation should be considered as hypothetical in the context of the explorative analysis with low statistical power.

Regarding the associations between implicit scores and self-report questionnaires, we found significant positive associations between all implicit scores and self-report questionnaires in the total sample, indicating that higher scores in the D-IAT, M-SST and GNG task correspond with higher self-reported clinical burden with one exception: behavioral impulsivity was not significantly linked with self-reported impulsivity. This is in line with prior findings showing that self-report and behavioral measures generally fail to correlate (Cyders & Coskunpinar, 2011; Millner et al., 2020).

Subgroup analyses in healthy controls and ideators revealed that associations between implicit and explicit measures were weak and non-significant in both groups. In attempters, implicit scores of the D-IAT and GNG task were more strongly correlated with explicit measures, with significant associations between the death-identity bias and self-reported depression and suicidal ideation, thus demonstrating convergent validity in this subgroup.

5. Limitations and future directions

Besides several strengths of our study, such as having investigated different suicide-related measures in one study and using a sample that enables us to differentiate between different stages of the suicidal spectrum, some important limitations must be considered when interpreting our findings. First, the time between the hospital admission and the assessment in the present study was longer compared to prior studies in which inpatient samples had been administered the D-IAT or SST within 48 h (Cha et al., 2010; Nock et al., 2010; Stewart et al., 2017), which might have influenced our results. There were several reasons for this: for example, all patients had to be tested for COVID-19 after admission, leading to a delay of the initial contact. Furthermore, some patients stated at the initial contact that they needed more time to decide about their study participation. Suicide attempters also indicated

a longer period from having last experienced SI compared to ideators, which might have a potential impact on our results. Second, we did not include patient controls without STBs. Thus, we were unable to determine whether the investigated suicide-specific markers, especially a death-identity and suicide attentional bias, are uniquely related to STBs or represent general indicators of psychopathology – an issue that should be addressed in future research. Third, while the repeated measures ANOVA with the SIS and the correlation analyses of the total sample were adequately powered for detecting medium effects, the one-way ANOVAs and correlational analyses of the subgroups were underpowered for detecting small-to medium effects, which we have addressed when discussing the results. In the context of this limitation, the non-significant findings between ideators and attempters should be considered as preliminary. Fourth, the study was not pre-registered. Finally, our study had a cross-sectional design and no prospective suicide attempt data was available. On the one hand, this precludes our ability to determine the predictive validity of these implicit markers in relation to future suicide attempts. On the other hand, we were not able to examine the temporal dynamics of these markers and to determine whether suicide-specific information-processing and behavioral impulsivity are state-related or behave trait-like. For example, recent hospitalization for suicide risk as well as treatment of STBs might influence these implicit processes. Therefore, investigating temporal fluctuations of such an implicit suicidal mode is of high clinical relevance and future studies should examine implicit markers of suicidal vulnerability during hospitalization as well as post-discharge, for example by adapting and integrating these tests into an ecological momentary assessment, to examine critical change processes of this implicit suicidogenic network.

6. Conclusion

To conclude, our study provided evidence for a death-identity bias and a suicidal attentional bias in patients with a recent suicidal crisis, which especially addresses prior doubts about the existence of a suicide-specific attentional bias in patients with STBs (Moscardini & Tucker, 2023). Our results suggest that these biases represent a cognitive vulnerability of suicidality, which should also be viewed in the light of recommended intervention strategies. This leads to the following question: How capable are at-risk individuals with a cognitive suicidal vulnerability of using crisis intervention strategies such as “distraction” or “positive refocusing” in high-risk situations? Together with difficulties of controlling for impulsive action, as we have found in suicide attempters, these implicit processes might greatly challenge successful coping with suicidal urges in high-risk situation, when cognitive resources are depleted (Brüdern et al., 2022). To date, we have little knowledge about the influence of implicit processes on suicidal crises and more importantly, their interaction with involved processes, like emotion-regulation, decision-making and coping with stress. Therefore, further research on implicit processes and their potential impact on critical processes related to a suicidal crisis is urgently needed to gain a more integrative and holistic understanding of a complex problem such as suicidality. However, patients and clinicians might already benefit from the awareness that an implicit suicidal mode could exist and use this for enhanced self-reflection during a high-risk situation.

CRediT authorship contribution statement

Juliane Brüdern: Writing – original draft, Project administration, Methodology, Funding acquisition, Conceptualization. **Lena Spangenberg:** Writing – review & editing, Conceptualization. **Maria Stein:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Thomas Forkmann:** Conceptualization. **Dajana Schreiber:** Methodology. **Katarina Stengler:** Resources. **Helena Gold:** Investigation. **Heide Glaesmer:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2024.104601.

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