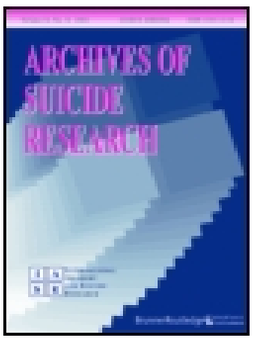

Archives of Suicide Research

ISSN: 1381-1118 (Print) 1543-6136 (Online) Journal homepage: http://www.tandfonline.com/loi/usui20

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To cite this article: Alexander J. Millner, Tara M. Augenstein, Katherine H. Visser, Katie Gallagher, Genesis A. Vergara, Eugene J. D'Angelo & Matthew K. Nock (2018): Implicit Cognitions as a Behavioral Marker of Suicide Attempts in Adolescents, Archives of Suicide Research, DOI: 10.1080/13811118.2017.1421488

To link to this article: https://doi.org/10.1080/13811118.2017.1421488

Archives of Suicide Research, 0:1–17, 2018

ISSN: 1381-1118 print/1543-6136 online
DOI: 10.1080/13811118.2017.1421488

Implicit Cognitions as a Behavioral Marker of Suicide Attempts in Adolescents

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Using self-harm Implicit Association Tests (IATs), we sought to test whether (1) suicidal adolescents show implicit identification with self-harm and whether (2) IATs are reliable and sensitive to psychiatric change and (3) predict future suicide attempts. We administered 6 self-harm IATs to 71 adolescents from a psychiatric inpatient unit and assessed suicidal behaviors at admission, discharge and 3 months after discharge. Results were in the expected direction for each IAT but not statistically significant. After aggregating trials across IATs, suicide attempters showed increased implicit identification with self-harm, compared with non-suicidal controls. IATs showed good reliability and sensitivity to psychiatric change but did not prospectively predict suicide attempts. Adolescent suicide attempters may have stronger implicit associations with self-harm than non-suicidal controls.

Keywords IAT, implicit association, prediction, suicide

From 2010–2014, more than 10,000 adolescents (ages 13–19) intentionally killed themselves in the United States, making suicide the second leading cause of death for this age group (Centers for Disease Control and Prevention, 2016). A major problem plaguing efforts to reduce suicidal outcomes in clinical settings is how to best assess current or prospective risk for suicidal adolescents. The risk assessment approach of clinicians directly asking patients about their suicidal thoughts has several limitations. For example, suicidal thoughts can be fluctuating and fleeting (Nock, 2010) or patients may conceal suicidal thoughts or intentions to avoid hospitalization or facilitate hospital release (Busch, Fawcett, & Jacobs, 2003). Consequently, patient report can be an unreliable indicator of suicide risk.

In order to overcome these limitations, researchers have sought objective behavioral measures that do not require patients' self-report. A promising line of research in this direction is the Implicit Association Test (IAT), a reaction-time task that measures implicit self-identification with particular concepts (Greenwald, Poehlman, Uhlmann, & Banaji, 2009; Nock et al., 2010; Nock & Banaji, 2007a). The IAT uses reaction time (RT) differences while participants classify words into concept

(e.g., death and life) and attribute categories (me and not me) to infer implicit biases (see Methods below).

In adults, implicit self-identification with self-injury- and death-related concepts is elevated among suicidal people, particularly among those with recent suicide attempts (Harrison, Stritzke, Fay, Ellison, & Hudaib, 2014; Nock et al., 2010; Nock & Banaji, 2007a). For example, a study with over 6,000 subjects found increasingly stronger implicit associations with death among non-suicidal controls, recent suicidal ideators, and recent suicide attempters (Glenn et al., 2017) and this was the case for IATs containing death-related stimuli, suicide-related stimuli (i.e., methods of suicide) and non-suicidal self-injury-related stimuli (e.g., pictures of cut skin). Furthermore, the Death and Self-injury IATs have both prospectively predicted suicidal behaviors above and beyond risk factors, such as prior suicidal behaviors (Barnes et al., 2017; Nock et al., 2010; Nock & Banaji, 2007b; Randall, Rowe, Dong, Nock, & Colman, 2013), suggesting that various self-harm IATs could be a powerful tool to assess suicide risk. Although different self-harm IATs predict the same outcomes (e.g., suicide attempts), suggesting that they are related, there is also evidence that they are somewhat unique. For example, in large samples, the Self-injury IAT has larger effects between self-injurers and non-injurers compared with Death and Suicide IATs (Glenn et al., 2017).

To date, the majority of studies on associations between self-harm implicit cognitions and suicidal behaviors are among adults. The only three such studies among adolescents produced mixed findings. One study found increased implicit self-identification with self-injury (i.e., cutting) among suicide attempters compared with non-suicidal controls and this implicit bias was significantly higher for the two people that attempted suicide over the 6-month follow-up (Nock & Banaji, 2007a). A second study failed to find a significant cross-sectional difference between suicide attempters and non-suicidal controls on both self-injury and death/suicide IATs and did not include a prospective prediction component (Dickstein et al., 2015). A third study among adolescents in a short-term residential psychiatric treatment program failed to find significant differences between prior attempters and ideators on the Death IAT administered at admission but found that the Death IAT predicted the severity of suicide ideation at discharge, even after accounting for explicit suicide ideation (Glenn et al., 2017a).

The mixed results of these studies could indicate the lack of implicit self-harm cognitions among suicidal adolescents, although adolescents report both self-harm cognitions (Nock, 2010) and demonstrate implicit biases (Huijding, Wiers, & Field, 2010). Alternatively, these mixed findings could be due to the clinical severity of the samples. The study with positive findings (Nock & Banaji, 2007a) was among a community sample whereas the study with null results (Dickstein et al., 2015) was among psychiatric inpatients. Clinically severe suicidal people have shown deficits in attention and cognitive control (Keilp et al., 2014), which, if the case with this latter study, might have degraded IAT performance. The single-category IAT (SC-IAT), a task similar to the IAT but with one less category, is simpler and fewer cognitively demanding, potentially making it more appropriate for younger and/or more clinically severe populations (Huijding et al., 2010). Identifying IAT parameters that improve the reliable detection of implicit associations among clinically severe adolescents, such as introducing fewer categories or increasing the number of trials, would enhance the IAT's clinical utility.

The first of three aims of the current study was to test for an association between implicit cognitions and suicidal behaviors

by recruiting three groups of adolescents from a psychiatric inpatient unit: those that were never suicidal, recent ideators, or recent attempters. We administered three self-harm IATs with death-, suicide- or self-injury- related stimuli at hospitalization admission to discover which IATs were associated with recent suicidal behaviors and provided the strongest effects. To assess whether simpler tests might lead to stronger effects among adolescents, we administered three self-harm single-category IATs (SC-IATs), which are less cognitively demanding. The same three self-harm SC-IATs (as well as the three IATs included in the current study) were tested in one prior study that examined only prospective prediction and found that none of the SC-IATs significantly predicted suicide attempts (Randall et al., 2013). We hypothesized that SC-IATs would show the strongest association between implicit biases and suicidal behaviors. After initial analyses, we also combined all trials across all admission self-harm IATs to increase statistical power.

The second aim was to examine the reliability of the six different self-harm IATs/SC-IATs. Given that they are less cognitively demanding, we hypothesized that SC-IATs would show the strongest association with suicidal behaviors among adolescents and show higher reliability.

The third aim was to test whether IATs could predict future suicidal behaviors. The same six self-harm IATs/SC-IATs were administered again at discharge. We hypothesized that change in implicit bias from admission to discharge would provide the best prospective prediction of suicidal behaviors, consistent with a prior report showing that changes in suicidal ideation over time prospectively predicted attempts (Prinstein et al., 2008).

In addition to these a priori hypotheses, we also conducted post-hoc analyses in which we combined all trials across all six admission self-harm IATs/SC-IATs to improve the signal-to-noise ratio and test whether doing so increased statistical power to detect group differences, increased reliability and improved prospective prediction.

METHOD

Participants

We obtained assent and parental consent from 137 adolescents recently admitted to a Boston-area psychiatric inpatient unit. We provided a study overview to 249 adolescents (response rate = 55.0%). This sample also provided data for Cha et al. (2016). Exclusion criteria were impairments adversely affecting participation, such as an inability to comprehend English, gross cognitive impairment, or agitated behavior. Among the 137 participants, 66 were excluded prior to data analyses. Fortyfour of these excluded participants received IATs with different stimuli features, such as much larger stimuli text font, in error. Other reasons for exclusion were exhibiting behavioral, medical or cognitive limitations (n = 5), giving inconsistent responses for critical questions regarding suicidal behaviors (n = 12), not meeting criteria for one of the groups (n = 7; see group criteria below), not providing usable IAT data (n = 2) or withdrawing from the study (n = 1). The final sample (see Table 1) consisted of 71 adolescents ranging from 11 to 17 years ($M = 14.8$, $SD = 1.5$), who were predominantly female (71.5%), and white (88.6% white, 2.9% Hispanic, 2.9% African American, 2.9% Asian, 2.9% other), all diagnosed with at least one psychiatric disorder ($M = 2.1$, $SD = 0.9$) and low Global Assessment of Functioning (GAF; $M = 29.6$, $SD = 8.3$). The majority of participants were suicidal in the 3 months before hospitalization (suicidal ideation [$n = 57$; 80.0%]); suicide attempt [$n = 39$; 54.9%]). Of the 71 participants included in the analyses, 64 (90.1%) completed the follow-up assessment at hospital discharge

TABLE 1. **Demographic Characteristics of the Sample**

Variable	Non-suicidal (n = 14)	Suicide ideators (n = 18)	Suicide attempters (n = 39)	Test
Age in years *M (SD)*	14.4 (1.8)	14.4 (1.5)	15.2 (1.3)	$F(2, 68) = 2.61$
Sex (% male)	42.9	27.8	28.2	$\chi^2(2) = 1.15$
Race (%)				$\chi^2(2) = 3.51$
White	100.0	82.4	87.2	
Black	0.0	0.0	5.1	
Asian	0.0	5.9	2.6	
Hispanic	0.0	5.9	2.6	
Other	0.0	5.9	2.6	
Diagnoses (%)				
Any mood disorder	64.3	88.9	92.3	$\chi^2(2) = 6.86$*
Any anxiety disorder	57.1	22.2	43.6	$\chi^2(2) = 4.24$
Any impulse-control disorder	21.4	16.7	20.5	$\chi^2(2) = 0.15$
Any eating disorder	50.0	22.2	17.9	$\chi^2(2) = 5.72$
Any substance use disorder	14.3	5.6	20.5	$\chi^2(2) = 2.12$
Total disorders *M (SD)*	2.5 (1.2)	1.8 (0.9)	2.1 (0.8)	$F(2,68) = 1.87$
GAF *M (SD)*	32.6 (4.3)	31.6 (11.0)	27.7 (7.7)	$F(2, 68) = 2.51$
Lifetime NSSI (%)	28.6	77.8	79.5	$\chi^2(2) = 13.35$*
Prior Hospitalizations (%)	35.7	38.9	46.2	$\chi^2(2) = 0.57$

Note. *$p < .05$.

and 52 (73.2%) completed the follow-up assessment 3-months after hospitalization. On average, the admission and discharge assessments took place 2 weeks apart ($M = 15.95$ days, $SD = 22.68$ days).

We provide fully transparent disclosure of data collection decisions. Recruitment continued until each of the following three groups had at least 25 participants; controls without past year suicidal ideation, suicidal ideators within past 3 months, and suicide attempters. Prior to conducting statistical analyses, we altered the criteria to be consistent with prior research (Nock & Banaji, 2007b) and to allow for stronger inferences by using "cleaner" controls without a lifetime history of suicidal ideation, rather than past year. The final three groups included in our analyses were: (i) non-suicidal controls without a lifetime history of suicidal ideation (n = 14); (ii) suicidal ideators without a lifetime history of suicide attempts and with suicidal ideation in the 3 months prior to hospital admission (n = 18); and (iii) suicide attempters who had attempted suicide within 3 months prior to hospital admission ($n = 39$).

Procedure

To recruit participants, research assistants identified patients appropriate for study participation, assessed inclusion and exclusion criteria, received approval from the patients' doctors, and obtained assent from patients' parents and informed consent from the patients. Participants were contacted via telephone 3 months after discharge for the follow-up interview. Compensation was $25 gift cards at the completion of each assessment, resulting in a potential total compensation of $75 in this study. The study was approved by the

Institutional Review Boards of Boston Children's Hospital and Harvard University.

Measures

Demographic Information and Psychiatric History. Research assistants obtained demographic and psychiatric information (e.g., age, sex, race-ethnicity, psychiatric disorders, suicidal behaviors) from participants' medical charts.

Self-Injurious Thoughts and Behaviors Interview. Suicide ideation and attempts were assessed at admission using the Self-Injurious Thoughts and Behaviors Interview (SITBI), a 169-item structured interview of self-injurious thoughts and behaviors with good reliability and validity (Nock, Holmberg, Photos, & Michel, 2007). The SITBI assesses the lifetime, past year, past 3 months, and past week presence and frequency of non-suicidal self-injury (NSSI), suicidal ideation, and suicide attempts. For an action to be categorized as a suicide attempt, a person had to engage in a potentially harmful or lethal behavior with some intention of dying. The SITBI was re-administered at discharge and 3-month follow-up to assess suicidal behaviors that occurred between admission and discharge and between discharge and 3 months later. Admission and discharge interviews were administered in person whereas three-month assessments were completed over the phone.

Implicit Association Test. The Implicit Association Test (IAT) is a computer-administered behavioral task that assesses implicit associations by measuring reaction times (RTs) as people categorize words or pictures into different concept-attribute pairings (Greenwald et al., 2009). The IAT procedure has been described elsewhere (Greenwald et al., 2009; Nock et al., 2010; Nock & Banaji, 2007a). The IATs in the current study consisted of 40-trial blocks, which is fewer than prior studies (Nock et al., 2010), which typically have 60 trials per block. In the IAT, a concept category ("Life") and attribute category ("Me") are paired (e.g., "Life-Me") on one side of the screen and share the same response button, while their counterpart categories ("Death-Not Me") are presented on the other side of the screen and share a response button. Participants sort words presented in the middle of the screen into the categories on the left or right of the screen. In the second block, the attribute categories switch sides resulting in new pairs ("Death-Me" and "Life-Not Me"). An implicit bias for a particular pairing set ("Death-Me"\"Life-Not Me") is revealed if RTs during that pairing set are faster than during the other pairing set ("Life-Me"\"Death-Not Me") with the idea that faster RTs mean the concept-attribute pairing is more congruent. In accordance with standard IAT scoring procedures (Greenwald et al., 2009), mean reaction times are compared from each block and divided by the standard deviation over all trials, resulting in a *D* score. Positive *D* scores indicate a stronger association between the self and self-injurious concepts.

We administered three self-harm IATs: the Death, Suicide and Self-Injury IATs. Each IAT contained the categories "me" (target examples: myself, I, my, self, and mine) and "not me" (target examples: they, their, them, and other). The Death IAT contained "death" (target examples: dead, deceased, die, and funeral) and "life" (target examples: job, marriage, live, and survive) categories. In the Suicide IAT, the "death" category was replaced with "suicide" (target examples: cutting, jumping, overdose, hanging, and gunshot). The Self-Injury IAT contained the categories "cutting" (targets were images of cut skin) and "not cutting" (targets were images of uncut skin).

Additional examples of the IAT can be found at www.implicitmentalhealth.com.

Single-category IATs (SC-IAT; Karpinski & Steinman, 2006) are identical to regular IATs except the "Life" concept is omitted and there are 48 trials per condition, rather than 40 as in the regular IAT. By only responding to 3 total categories (e.g., "Me," "Not Me," and "Death"), the SC-IAT is simpler. We administered a Death SC-IAT, Suicide SC-IAT and a Suicide SC-IAT with picture targets, such as the picture of a noose or pills next to a person lying down.

In total, six self-harm IATs were administered: Death, Suicide and Self-Injury IATs as well as Death, Suicide and Suicide Picture SC-IATs (Table 2 for categories and stimuli of each task). For the IAT, we reduced the number of trials from 60 to 40 in order to administer all 6 IATs within a feasible amount of time. One other study used the same six IATs/SC-IATs included in the current study and found that the Death IAT prospectively predicted self-injurious events using 40 trials (Randall et al., 2013). All tasks were administered and discharged on a laptop with Inquisit software (Version 3).

Explicit Self-Report Measures. We also assessed explicit self-reported identification with suicide- and death-related concepts. Participants were asked, "which is more like you?" and were presented with three visual analog scales containing the following anchors on the far left and right sides, respectively: "death-life," "suicide-life," and "cutting-not cutting." For the other two explicit measures, participants were asked, "which is more like death/suicide?" with "me-not me" anchors. All reports were highly correlated (*r*s mean = 0.71, *SD* = 0.05) so we averaged all scores across admission.

Risk Factor Questionnaires. Risk factors assessed included depression symptoms as measured by the Children's Depression Inventory (Kovacs, 1992), hopelessness measured by the Hopelessness Scale for Children (Kazdin, Rodgers, & Colbus, 1986), suicide ideation measured by the Beck Scale for Suicide Ideation (Beck, Steer, & Ranieri, 1988), and rumination measured by the Children's Response Styles Questionnaire (Abela, Vanderbilt, & Rochon, 2004). We do not provide a full explanation of these measures as they were not included in the current analyses. We include full description of all measures, including psychometric information, as well as additional measures collected during this study in the Supplemental Materials.

Data Analysis

We provide fully transparent disclosure of all data collection decisions, hypotheses, and statistical tests conducted. First, hypotheses stated in the introduction were *a priori* hypotheses. Second, we used specific data collection guidelines discussed above in the Participants section.

Our first aim was to determine whether suicidal adolescents, particularly suicide attempters, showed a stronger implicit association with self-harm than non-suicidal adolescents. A recent paper on self-harm IATs with over 6,000 adults reported medium effect sizes comparing similar groups (eta squared = .07–.09; Glenn et al., 2017). Despite the low statistical power, we entered the *D* scores from each of six admission IATs into separate one-way (Group: controls, ideators, attempters) Analyses of Variance (ANOVAs). After obtaining only one significant result and none that remained after correcting for multiple comparisons, we determined that we needed additional power; yet, recruiting additional participants was not an available option. Therefore, given the conceptual overlap between the task stimuli, that all results were non-significantly in the same

TABLE 2. **IAT Reliability and Sensitivity to Change in Ideation and Explicit edentification**

	Categories	Stimuli	Trials	Admission Split-half	Discharge Split-half	Test Retest	Test Retest among Controls	IAT Change w/Ideation Frequency	IAT Change w/Explicit Identification
Death IAT[1]	Me\Not Me, Life\Death	words (e.g., dead)	40	0.69	0.65	0.35*	0.38	0.45*	0.39*
Suicide IAT[2]	Me\Not Me, Life \Suicide	words (e.g., overdose)	40	0.62	0.64	0.37*	0.65*	0.05	0.11
Self-Injury IAT[3]	Me\Not Me, No Cutting\Cutting	pictures of cut skin	40	0.76	0.72	0.21	−0.38	0.14	0.02
SC-Death IAT[2]	Me\Not Me, Death	words (e.g., dead)	48	0.44	0.62	0.29*	0.47	0.18	0.18
SC-Suicide IAT[2]	Me\Not Me, Suicide	words (e.g., overdose)	48	0.78	0.62	0.03	0.05	0.20	0.30*
SC-Suicide Pic IAT[2]	Me\Not Me, Suicide	pictures (e.g., noose)	48	0.74	0.69	0.12	0.25	0.14	0.24
Aggregate self-harm *D* score	all of the above	all of the above	264	0.75	0.73	0.44*	0.42	0.33*	0.41*

Note. $^{*}p < .05$. We do not provide statistical significance for permutation split-half procedure. [1]Nock et al. (2010) [2]Suicide IAT and all Single-Category (SC) IATs were tested in Randall, Rowe, Dong, Nock, & Colman (2013) but specific results were not reported [3]Nock and Banaji (2007a), (2007b).

direction (i.e., attempters > controls) and to increase power, we created two aggregated *D* scores in which we combined each subjects' SC-IAT\IAT trials across (1) all Death and Suicide SC-IATs and IATs with word stimuli (excluding the Suicide Picture SC-IAT and Self-Injury IAT) and (2) all available admission IATs. In both cases, we merged blocks where the self-concept (i.e., "Me") and self-injurious concept (e.g., "Death") were paired and calculated a (1) Death\Suicide aggregate self-harm *D* score and (2) an aggregate self-harm *D* score, respectively, for each subject. Of note, the Death SC-IAT and Death IAT shared the same stimuli, as did the Suicide IAT and Suicide SC-IAT. Furthermore, prior studies have used IATs that contained stimuli that were both suicide- and death-related (Nock et al., 2010), akin to the combining the stimuli from Death and Suicide IATs.

After creating these two aggregated self-harm *D* scores, we conducted two additional one-way ANOVAs with the aggregate self-harm *D* scores as the dependent variables and group status as the independent variable and applied a False Discovery Rate (FDR; Benjamini & Hochberg, 2000) correction to control for eight multiple comparisons. A Bonferroni correction would have over-corrected because of the correlation between the aggregate *D* scores and the original *D* scores (Ness et al., 2010). We used Holm *post hoc* tests to test for differences between the three groups. After determining that ANOVAs with the two aggregate *D* scores each resulted in significant group differences, we used only the full aggregate *D* score only for the remaining analyses.

The second aim was to assess the reliability of different IATs. First, we examined the inter-correlations of the six IATs and report statistical significance (alpha = .05) without correcting for multiple tests. Second, we assessed internal reliability of each IAT by implementing a split-half correlation Monte Carlo permutation procedure (Courrieu, Brand-D'abrescia, Peereman, Spieler, & Rey, 2010), in which each subject's IAT trials were randomly split into two separate data sets with equal numbers of trials from each condition. Two *D* scores were calculated for each subject from each data set and correlated across subjects. This process was then repeated 10,000 times resulting in a distribution of correlation values representing IAT split-half internal reliability. Third, we calculated the test-retest reliability by correlating admission and discharge *D* scores. We also examined test-retest reliability within control subjects under the assumption that their implicit cognitions were less susceptible to change during hospitalization that could adversely affect test-retest reliability. We also tested whether implicit cognitions were sensitive to change in explicit suicidal ideation or self-identification with self-injurious concepts over the course of hospitalization. To do this we subtracted admission from discharge *D* scores and correlated admission-discharge *D* score change with (i) frequency of ideation during hospitalization and (ii) admission-discharge change in average explicit self-identification. We evaluate the degree of reliability and sensitivity analyses based on correlation magnitude and do not report significance.

The third aim was to prospectively predict suicide attempts during the 3-month follow-up period among adolescents with a suicide attempt history. Similar to prior studies, we focused on prior attempters because attempt history is associated with increased risk (Nock et al., 2008). However, our ability to prospectively predict these outcomes was limited because only five lifetime attempters attempted suicide in the follow-up period. In order to provide preliminary prospective evidence, we compared those with and without an attempt using a *t* test on *D* scores from each IAT and the aggregate self-harm *D* score at admission, at discharge and change from admission to discharge.

Data Analysis Software

The data were analyzed using Python 2.7 packages pandas (McKinney, 2010) for data management, matplotlib (Hunter, 2007) and Adobe Illustrator for plotting, numpy (van der Walt, Colbert, & Varoquaux, 2011) for math functions, and scipy (Jones, Oliphant, & Peterson, 2001) and statsmodels (http://statsmodels.sourceforge.net/) for statistics.

RESULTS

Demographic and Psychiatric Differences Among Groups

The groups were well matched on demographic and psychiatric factors, though suicidal participants had more lifetime NSSI frequency and higher rates of depression (Table 1).

Differences Among Groups on Admission IATs

Group comparisons on the individual self-harm IATs were all in the expected direction (i.e., higher scores for suicidal participants, particularly attempters) but effect sizes were relatively small and ANOVAs were not significant after applying an FDR correction for conducting six tests (Fs = 0.68-3.45, ps > .15, η^2s = 0.01–0.10; the only significant group differences ANOVA results prior to FDR correction was for the Suicide SC-IAT [$F(2,64) = 3.45$, $p = .04$, $\eta^2 = .10$]). Figure 1 shows mean D scores for all individual IATs and Tables S1 and S2 show sample sizes and ANOVA results for each IAT, respectively. In contrast, both the Death \Suicide aggregate self-harm D score and the aggregate self-harm D score differed significantly across groups after a FDR correction for conducting eight ANOVAs, (Death\Suicide aggregate: [$F(2,66) = 4.79$, $p < .05$, $\eta^2 = 0.13$]; aggregate: [$F(2,67) = 6.17$, $p < .05$, $\eta^2 = 0.15$]; Figure 2). Aggregating trials reduced error within each group, as evinced by the smaller error bars (Figure 2), resulting in a small-to-moderate effect size and statistically significant group differences despite group means similar to the individual IATs (Figure 1). Post hoc Holm tests revealed a significant difference between controls and attempters on both the Death\Suicide aggregate self-harm D score and the aggregate self-harm D score ($p < .05$). Because the aggregate D score using all IATs provided a larger effect size than the Death\Suicide aggregate D score, we used the full aggregate D score for the remaining analyses.

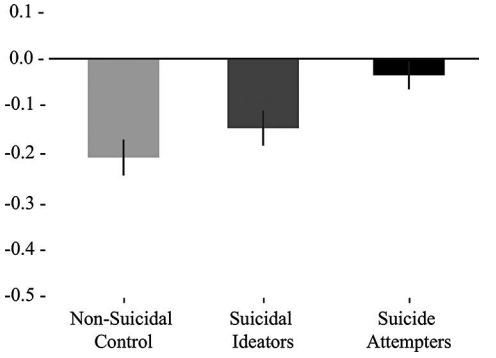

FIGURE 1. *Mean D scores of non-suicidal controls, suicidal ideators and suicide attempters on six different IATs assessed at hospital inpatient admission. Error bars are standard error.*

Correlations and Reliability of Admission IATs

There were moderate-to-large correlations between the Death IAT and Death SC-IAT ($r = .47$), the Death IAT and Suicide SC-IAT ($r = .37$), and the Suicide IAT and Suicide SC-IAT ($r = .28$), as well as between the aggregate self-harm D score and each of the individual IATs used to

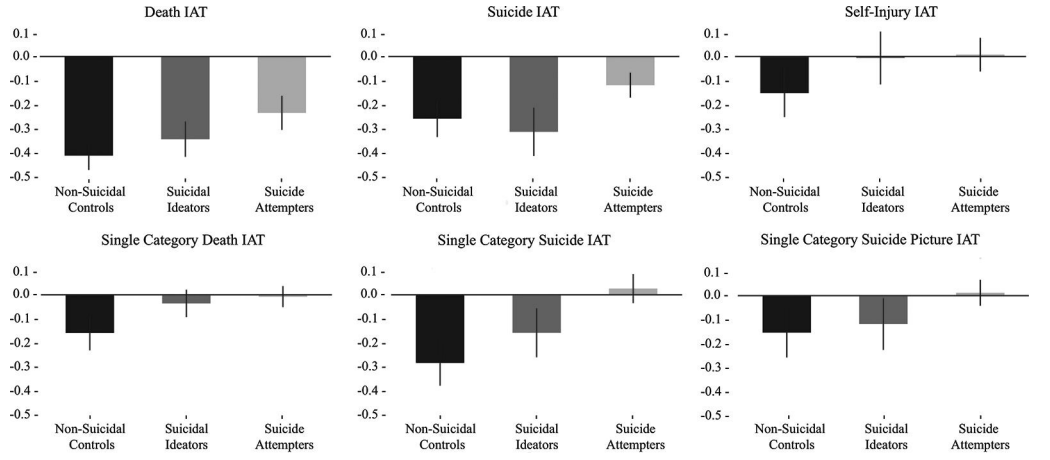

FIGURE 2. *Mean D scores of non-suicidal controls, suicidal ideators and suicide attempters after aggregating all trials across six different IATs assessed at hospital inpatient admission. Error bars are standard error.*

compose it (*r*s = .41–.59). Otherwise, the correlations among the different IATs \SC-IATs were small and non-significant (*r*s = –.12–.21; Table 3).

In terms of reliability, the aggregate self-harm *D* score and Death IAT showed favorable reliability across all reliability metrics. For the split-half Monte Carlo permutation analysis, we used the mean of each resultant distribution of *r* values as each were approximately normal. Applying the Spearman-Brown correction to the means of these distributions revealed acceptable internal consistency for all IATs/SC-IATs at admission (.69–.77) except for the Suicide IAT (*r* = .62) and the Death SC-IAT (*r* = .44; Table 2). Split-half reliability was similar at admission and discharge for each IAT except for the Death SC-IAT and Suicide SC-IAT, which had, respectively, increased and decreased reliability at discharge. Test-retest reliability was fair-to-low for each IAT. The Death IAT and the aggregate self-harm *D* score showed the highest relationships between admission-discharge change and frequency

TABLE 3. **IAT Reliability and Sensitivity to Change in Ideation and Explicit Identification**

	Admission Split-half	Discharge Split-half	Test Retest	Test Retest among Controls	IAT Change w/Ideation Frequency	IAT Change w/Explicit Identification
Death IAT	0.69	0.65	0.35*	0.38	0.45*	0.39*
Suicide IAT	0.62	0.64	0.37*	0.65*	0.05	0.11
Self-Injury IAT	0.76	0.72	0.21	–0.38	0.14	0.02
SC-Death IAT	0.44	0.62	0.29*	0.47	0.18	0.18
SC-Suicide IAT	0.78	0.62	0.03	0.05	0.20	0.30*
SC-Suicide Pic IAT	0.74	0.69	0.12	0.25	0.14	0.24
Aggregate self-harm *D* score	0.75	0.73	0.44*	0.42	0.33*	0.41*

Note. *$p < .05$. We do not provide statistical significance for permutation split-half procedure.

of suicidal ideation, in addition to change in explicit identification with self-injurious concepts. Thus, the Death IAT and aggregate self-harm *D* score had among the highest reliability and the highest sensitivity \external validity to change over treatment, suggesting that treatment effects did not reduce test-retest reliability.

Prospective Prediction

There was limited statistical power to prospectively predict suicide attempts because only five lifetime attempters made attempts during follow-up and for most IATs/SC-IATs, only three or four follow-up attempters had usable data. All *t* tests comparing follow-up attempters and follow-up non-attempters at admission, discharge and admission-to-discharge change failed to support differences between the two groups and statistical outcomes varied greatly (ts = −1.38–1.00, ds = −0.78–0.89; Table S3). The self and clinician predictions, as well as explicit identification with self-harm concepts also revealed non-significant differences (ts = 0.32–0.55, ds = −0.15–0.26; Table S3).

DISCUSSION

The goals of the current study were to test whether suicidal adolescents show implicit identification with self-harm across different self-harm IAT\SC-IAT versions, examine the reliability and sensitivity\external validity of these IATs/SC-IATs, and to test whether implicit cognitions predicted future suicide attempts. We found that although most of the individual IATs/SC-IATs at hospital admission showed effects in the hypothesized direction, large error and low power prevented any from being statistically significant. To increase power, we calculated a Death\Suicide aggregate self-harm *D* score and aggregate self-harm *D* score by combining trials from multiple IAT\SC-IAT at admission. Both aggregate self-harm *D* scores revealed significantly increased identification with self-harm among attempters compared with non-suicidal controls. Both the aggregate self-harm *D* score and Death IAT were reliable and sensitive to psychiatric change during hospitalization. Finally, looking among attempters, no implicit measures were increased for those with attempts in the 3 months following hospitalization. A few findings warrant additional comment.

The results of the current study suggest that, compared with non-suicidal controls, adolescents that recently attempted suicide exhibit stronger implicit identification with self-harm, a similar pattern to that observed among adults (Glenn et al., 2017). Although, as expected, scores for suicidal ideators were between those for controls and attempters, these differences were not statistically significant. This general pattern of controls, ideators and attempters respectively showing increasing identification with self-harm also resembles adults (Glenn et al., 2017).

Both the Death\Suicide aggregate self-harm *D* score (i.e., an aggregate D Score without the Self-Injury or Suicide Picture IATs) and the full aggregate self-harm D score resulted in significant group differences. There are at least two possible reasons this could be the case. First, the self-harm IATs/SC-IATs may tap similar underlying implicit cognitions. Under this explanation, the lack of significant group differences and low correlations among the individual IATs is due to substantial statistical noise within each task that is reduced by increasing number of trials. However, the idea that the tasks tap a similar construct is contradicted by the fact that that the majority of pairwise correlations between these tasks were small and non-significant, near zero or negative.

Therefore, a second possibility is that the various IATs/SC-IATs tap different implicit cognitions but, as the current study

shows, suicide attempters show stronger implicit associations with all the different self-harm concepts. Therefore, when aggregated, the different tasks account for different variance but each in a similar direction (i.e., attempters > controls). Thus, the aggregate self-harm *D* score may represent multiple processes but using multiple self-harm stimuli and/or IAT modality (e.g., regular versus SC) could improve concurrent prediction (i.e., identification of group status) because associations between each IATs/SC-IATs and suicidal behaviors are in the same direction.

Although there were differences between SC and regular IATs, there was not an unambiguous advantage for one approach. Recall that SC-IATs omit the life concept thereby revealing an implicit association only with death or suicide concepts. Among the individual IATs administered at admission, the Suicide SC-IAT had the largest effect size and the highest split-half reliability. Yet, significant group differences on this SC-IAT were non-significant after correcting for multiple comparisons and its test-retest reliability was nearly zero. Both the SC-Suicide and SC-Death IATs also had the most variable internal consistency between admission and discharge. Future studies should test whether SC-IATs provide more sensitivity than regular IATs, perhaps with more trials.

The most notable distinction between the SC and regular IATs was that the SC-IATs generally produced less negative *D* scores for all groups. In most prior studies, groups' average *D* scores are generally negative and have been interpreted as suicidal participants' degraded association with life rather than an increased association with death (Harrison et al., 2014). However, in addition, the IAT *D* score could also reflect healthy participants' negative association with death (i.e., longer RT during Death/Me pairings than if a neutral word was paired with me) and suicidal participants less negative association. The SC-IAT helps clarify this because it does not contain life stimuli. Without the presence of the life stimuli only non-suicidal controls showed a negative association with death/suicide (one-sample *t*-test $p < .05$; suicidal participants $p > .20$). These results suggest that, in addition to a diminished implicit association with life, group differences between non-suicidal and suicidal participants on regular IATs could be due to suicidal participants' failure to show a similar negative association with self-harm that is observed among non-suicidal controls.

Reliability among individual IATs was mixed. The split-half reliability at admission generally was high but test-retest reliability was fair-to-poor (rs = 0.02–0.44) but mostly higher for control participants. Other IAT studies have reported higher test-retest correlations (median $r = .56$ (Nosek, Greenwald, & Banaji, 2007)), although two studies, each with over 200 10–14 year-olds, found comparable test-retest reliability (rs = 0.14–0.39) for an aggressiveness IAT (Gollwitzer, Banse, Eisenbach, & Naumann, 2007; Lemmer, Gollwitzer, & Banse, 2014). One possible explanation for modest test-retest reliability is the marked changes in psychiatric condition or other life circumstances during hospitalization rather than unreliability of the IAT. Alternatively, these IATs may have poor reliability and/or require more trials. Outcomes with highest test-retest reliability (i.e., Death IAT and aggregate self-harm *D* score) also tracked changes in explicit self-identification with death/suicide and frequency of suicidal ideation during hospitalization, suggesting that the more reliable approaches were also the most sensitive to psychiatric change and externally valid. Future studies should assess test-retest reliability outside of the hospital and use more trials to determine whether test-retest reliability or sensitivity can be improved.

We did not find any metric that prospectively predicted suicide attempts among those with a lifetime history of

suicide attempts. Three prior studies have found that the Death IAT prospectively predicted attempts (Barnes et al., 2017; Nock et al., 2010; Randall et al., 2013) and one found that the Self-Injury IAT did so (Nock & Banaji, 2007b). As true effects will occasionally appear null, this failed replication does not necessarily falsify prior work, particularly given the low power of the current study. On the other hand, the prior results may have been spurious. The only other study where the IAT prospectively predicted attempts among adolescents included only two follow-up attempters (Nock & Banaji, 2007b). Moreover, Randall et al. (2013) tested the same six IATs used here among an adult sample and found that only the Death IAT predicted follow-up self-injury, not suicide attempts specifically. However, these researchers used the IAT to predict both suicidal and non-suicidal self-injury combined as a single outcome. Across all studies examining prediction of suicide attempts using self-harm IATs, this would be the first null result but, on the other hand, each study period has had less than 30 participants attempt suicide in the follow-up period. Clearly, more research is needed to determine whether the IAT prospectively predicts suicide attempts.

These results bring up several larger issues regarding the IAT, in general, and self-harm IATs in particular. First, there is a general controversy over whether the IAT is a useful tool for predicting actual behaviors (Greenwald, Banaji, & Nosek, 2015; Greenwald et al., 2009; Oswald, Mitchell, Blanton, Jaccard, & Tetlock, 2013, 2015). One important difference between most prior studies associating implicit cognitions with the IAT and actual behaviors (e.g., racially biased behaviors), is that self-harm behaviors are non-arbitrary (i.e., not measured on a Likert-scale (Blanton & Jaccard, 2006)) significant, real-world behaviors. Thus, self-harm behaviors may result in stronger associations with the IAT than behaviors that are proxies for real-life behavior and more conducive to being measured in a laboratory (e.g., proximity to a Black or White confederate to assess racial bias (Todd, Bodenhausen, Richeson, & Galinsky, 2011)).

Second, a prior study found that those that completed a 5-minute failure-related priming manipulation showed a reduced implicit bias for life compared with those that did not complete such a prime (Tang, Wu, & Miao, 2013). Thus, some study materials, such as interviews about suicidal history, may also reduce an implicit bias for life more for people with suicidal histories than without and drive group differences. These types of variables need to be brought under experimental control in order to assess their strength and importance in both determining group differences and prospective prediction. There are several other related areas of research necessary to increase our understanding of self-harm IATs, including how well it performs in different settings (emergency department vs. inpatient unit vs. online vs. lab) and whether increasing the number of trials improves reliability or using different types of IATs increases predictive accuracy.

Third, it is currently unclear how self-injury IATs should be integrated with other risk assessment information. Recent work has found that suicide can be predicted fairly accurately using machine learning models with electronic medical records (EMR) alone. One question that we will address soon is whether the IAT can add incremental value within this type of model and, more broadly, how implicit cognitions, self-report measures and clinicians expertise should all be incorporated to determine who is at greatest risk of suicidal behaviors and needs to be hospitalized or remain in the hospital.

There were several limitations to this study. First, the main limitation was the low power for baseline and prospective prediction due to the small sample size and the low number of attempters that attempted

suicide in the follow-up period. Second, we conducted several statistical tests, although we have transparently reported which tests included a correction for multiple comparisons and which did not. Third, the aggregate self-harm *D* score, which was the basis of significant group differences, was developed only after non-significant results for individual IATs. However, these results held after a multiple comparisons correction. A related limitation was that we aggregated over IATs that were not well correlated. We have argued that low correlations represent noise that aggregation helps address but, if low correlations mean that IATs tap different processes, then aggregation would be unjustified. Fourth, test-retest reliability was fair-to-poor. It is possible that implicit cognitions about suicide or self-injury fluctuate over time, weakening test-retest reliability. Alternatively, IATs may have poor reliability and may require increased trials or other changes to improve reliability. Fifth, group comparisons within inpatient hospital samples can be subject to Berkson's bias, in which differences in ascertainment between cases and controls (e.g., greater clinical severity required to get admitted to an inpatient unit in the absence of suicidal behavior) can result in spurious group differences (Westreich, 2012).

Although these limitations constrain conclusions, these results provide preliminary evidence that, compared with non-suicidal controls, adolescent suicide attempters show increased implicit identification with self-harm.

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The authors would like to thank Charlene Deming, MA, and Mark Knepley, BA, of Harvard University and Temple University, respectively, for their assistance with recruitment and data collection. The authors also thank Jeffrey Glenn, MA, and Katarina Slama, ScB, of University of Virginia and University of California at Berkeley, for their assistance with data management and IAT scoring.

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FUNDING

Dr. Millner has received research support from the Military Suicide Research Consortium. Dr. D'Angelo has received research support from the Tommy Fuss Fund. Dr. Nock has received grant or research support from the National Institute of Mental Health, the MacArthur Foundation, the U.S. Department of Defense, the Military Suicide Research Consortium, and the US Army. Ms. Visser has received research support from the National Science Foundation

Graduate Research Fellowship Program. She owns shares of the XBI ETF. The Linda and Timothy O'Neill Foundation supported Ms. Augenstein, Ms. Visser and Ms. Gallagher. Funding sources had no role in the design, execution, analyses, writing or any other part of this study.

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