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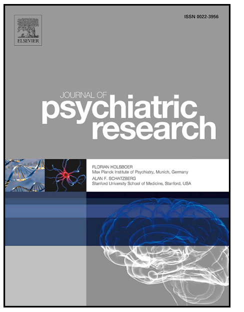

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Impulsivity in the self-harm and suicidal behavior of young people: A systematic review and meta-analysis

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Abstract

Background: Impulsivity is considered a possible phenotype underlying the expression of self-harm and suicidal behaviors. Yet impulsivity is a not a unitary construct and there is evidence that different facets of impulsivity follow different neurodevelopmental trajectories and that some facets may be more strongly associated with such behaviors than others. Moreover, it is unclear whether impulsivity is a useful predictor of self-harm or suicidal behavior in young people, a population already considered to display heightened impulsive behavior.

Methods: A systematic review and meta-analysis of studies published in Medline, PubMed, PsychInfo or Embase between 1970 and 2017 that used a neurocognitive measure to assess the independent variable of impulsivity and the dependent variable of self-harm and/or suicidal behavior among young people (mean age < 30 years old).

Results: 6183 titles were identified, 141 full texts were reviewed, and 18 studies were included, with 902 young people with a self-harm or suicidal behavior and 1591 controls without a history of these behaviors. Deficits in inhibitory control (13 studies, SMD 0.21, p-value= 0.002, 95% confidence interval (CI) (0.08- 0.34), prediction interval (PI)=0.06-0.35) and impulsive decision-making (14 studies, SMD 0.17, p-value=0.008, 95% CI (0.045-0.3), PI=0.03-0.31) were associated with self-harm or suicidal behavior. There were no significant differences between measures of different facets of impulsivity (ie. delay discounting, risky decision-making, cognitive or response inhibition) and self-harm or suicidal behavior.

Conclusion: Multiple facets of impulsivity are associated with suicidal behavior in young people. Future suicide research should be designed to capture impulsive states and investigate the impact on different subtypes of impulsivity.

Keywords
Suicidal behavior, deliberate self-harm, non-suicidal self-injury, young people, adolescent, impulsivity, delay discounting, cognitive inhibition, response inhibition.

1. Introduction

Impulsivity has emerged as a promising phenotype underlying suicidal and self-harm behavior (Mann et al., 2009). Though impulsivity has long been considered an important contributor to the expression of these behaviors, research into the association has been limited by the use of heterogenous definitions of impulsivity (Anestis, 2014; Gvion 2011). Impulsivity is now widely considered 'a predisposition toward rapid, unplanned reactions to internal or external stimuli with diminished regard to the negative consequences of these reactions to the impulsive individual or to the other' (Moeller et al., 2001). Historically, much of the literature examining impulsivity and self-harm or suicidal behavior has used self-report measures of impulsivity exclusively, such as the Barratt Impulsivity scale (Anestis, 2014, Hamza 2015), though recent reviews have made distinctions between self-report and neurocognitive measures (Liu et al 2017). Neurocognitive testing for impulsivity has been growing in favor, in part due to the ability of these tests to capture best performance through experiential testing and a growing interest in proximal, or state-based, factors associated with self-harm and suicidal behavior (Christensen et al., 2016). In a recent meta-analysis, Liu et al. (2017) found the relationship between impulsivity measured proximally (within the last month) to suicide attempts was much stronger than attempts occurring at a more distal time point. Self-report measures, which have generally been designed to capture trait-based impulsivity, may be less objective than neurocognitive tasks in capturing impulsive states. Neurocognitive models of impulsivity have delineated several separate, but related, constructs including impulsive decision-making deficits (delay discounting and risky decision-making) and inhibitory control (response and cognitive inhibition) (Dalley and Robbins, 2017). Though definitions of impulsivity are closer to consensus than in the past, there is still no agreed set of measures used by researchers and clinicians (Fineberg et al. 2014). This review considers varying definitions of impulsivity based on the instruments used within selected studies (Figure 1) and uses the term impulsivity to refer to impulsive decision-making deficits and deficits of inhibitory control. Importantly previous reviews have not assessed whether the association between impulsivity and self-harm and suicidal behavior is moderated by the facet of impulsivity measured (Liu et al 2017, Hamza 2015, Lockwood 2017).

This review considers self-harm and suicidal behavior as a broad construct that includes a number of more specific constructs such as suicide attempts (SA), non-suicidal self-injury (NSSI) and deliberate self-harm (DSH)and uses the terms as they have been used in the primary studies. Despite evidence these behaviors are distinct from each other, in terms of intent, severity, frequency and method, previous findings have suggested these behaviors may represent differing degrees of severity within the same phenotype or differing phenotypes with significant overlap. (Muehlenkamp 2007, Hawton 2012) The high degree of co-morbidity of these behaviors in young people would support such an idea (Muehlenkamp 2007, Nock 2006). Yet it is not clear whether a particular behavior, whether suicide attempt or non-suicidal self-injury, may be more strongly associated with impulsivity. Liu et al (2017) found impulsivity more strongly associated with suicide attempts than non-suicidal self-injury. Hamza et al (2015) found neurocognitive measures were not associated with NSSI, though both reviews included relatively few studies of NSSI.

1.1 Neurocognitive development and suicidal behavior

Deficits in executive function are associated with expression of suicidal behavior, including decision-making and problem-solving deficits, memory biases (overgeneralization, preferential recall of negatively valenced stimuli) and attentional biases (Iorfino et al., 2016; Carballo et al., 2008). Impulsive decision-making and deficits of inhibitory control of cognition and behavior have been linked with self-harm and suicidal behaviors in older age groups and with other associated psychopathology, such as substance abuse (Bickel et al., 2007; Dombrovski et al., 2011; Richard-Devantoy et al., 2012). Less is known about the role of these deficits in the suicidal behavior of young people. Cognitive and motor inhibitory control do not reach full maturity until early adulthood (Hooper et al., 2004). Decision making in developmentally normative young people is considered more impulsive than adults. This impulsivity has been characterized as being a result of higher reward dependency, greater sensation seeking and reduced tolerance for ambiguity of outcome (Steinberg, 2008; Blakemore and Robbins, 2012; Tymula et al., 2012). Thus, the question should be asked: how does the suicide and self-harm literature on impulsivity apply to young people, and in an already impulsive cohort is it useful in identifying those at risk? Further characterizing impulsivity in young people engaging in self-harm or suicidal behaviors may be an important step in understanding the contribution of these development-related vulnerabilities to the expression of the behavior.

1.2 The stress-diathesis model: The importance of the impulsive state

While ethical and practical issues have constrained our ability to do research in populations of individuals who are acutely suicidal and distressed, there is evidence that in individuals who have very recently engaged in near fatal deliberate self-harm, intensity of suicidal ideation and intent can fluctuate rapidly (Douglas et al., 2004). Suicidal ideation and behavior have only a weak predictive ability for later completed suicide (Ribeiro et al., 2016, McHugh et al. 2019). Similarly there is evidence that suicide attempters with high trait impulsivity are as likely to plan an attempt as suicide attempters with low trait-impulsivity (May and Klonsky, 2016; Witte et al., 2008). These findings have raised important questions about the relevance of measuring suicidal intent or planning, which has been an essential component of suicide prevention in clinical settings. The limitations of this approach have driven the investigation of cognitive phenotypes, which recognize the importance of the geneenvironment interaction in the development of psychopathology (Mann et al., 2009). Mann's stress-diathesis model (1999) of suicidal behavior proposes that individuals may have a trait-like disposition (diathesis) to expressing suicidal behavior when exposed to stressors, or state variables, such as symptoms of psychiatric illness, psychosocial stress or substance use.

Until recently, most research into associations between impulsivity and self-harm and suicidal behaviors have approached impulsivity as a 'state-independent' trait. It has been considered a personality trait, yet personality is now understood to be more dynamic with maladaptive features becoming accentuated in times of stress (Newton-Howes et al., 2015; McHugh and Balaratnasingam, 2018). What is not clear is how an impulsive trait may interact with impulsive cognitive states to produce suicidal behaviors.

1.2 Measures of impulsivity

1.2.1 Impulsive decision-making

Impulsive decision making can be considered to include several facets, including delay discounting, probabilistic discounting and reflection impulsivity. Delay discounting in economics refers to the individual's tendency to reduce value attached to an outcome based on time until outcome (Bickel et al., 2007). That is, the choice to accept smaller sooner rewards, rather than larger, later rewards. This is also referred to as temporal discounting or time preference. Tests of delay discounting may be self-report or experiential, the latter of which involves real monetary or food rewards. Probabilistic discounting refers to the choice between a smaller reward with higher probability of return, or larger reward, with lower probability of return. Decision-making tasks such as the Iowa Gambling Task (IGT), or the Cambridge Gambling Task (CGT) can be considered to measure probabilistic discounting, but also tap into other neurocognitive constructs such as reinforcement learning (IGT) or delay aversion (CGT) (Brevers, Bechara et al. 2013; Cambridge Cognition 2018). As these measures are not purely measures of probabilistic discounting they will be referred to as measures of risky decision-making. In this review, the term impulsive decision-making will be used to refer measures of delay discounting and these risky decision-making tasks. Explanations of neurocognitive tests of discounting discussed in this review are included in Appendix A1.

1.2.2 Inhibitory Control

Inhibitory control consists of cognitive and motor inhibition and is an essential executive function. In decision making terms, having sufficient inhibitory control may allow an individual to consider value and response selection, and enable them to choose the option with the highest objective value, or utility. Motor inhibition, hereafter referred to as response inhibition, is the failure to inhibit prepotent responses to stimuli. Behavioral tests of response inhibition include the Go/No Go impulsivity paradigm (Dougherty et al., 2005) and the Stop signal test (SST) (Cambridge Cognition, 2018).

Cognitive inhibition, 'the stopping or overriding of a mental process, in whole or in part, with or without intention' (MacLeod, 2007), requires mediating control of attentional processes and working memory. Measures of selective and sustained attention, such as the continuous performance task (CPT), are also often used to measure this type of impulsivity (Dougherty et al., 2002). Commission errors are believed to reflect response initiation aspects of impulsivity because they result from incomplete processing of stimuli leading to rapid but incorrect responses. The Stroop test is another commonly used measure of cognitive inhibition. Explanations of neurocognitive tests of inhibitory control discussed in this review are included in Appendix A1.

The current review aims to establish whether these neurocognitive measures of impulsivity can be used to differentiate young people engaging in self-harm or suicidal behaviors from those who do not, and which, if any, sub-type of impulsivity is more strongly associated with these behaviors. We aim to establish whether age or gender moderates the relationship between impulsivity and such behaviors. A further aim of this review was to understand whether use of neurocognitive measures of impulsivity has identified evidence of impulsivity being more strongly associated with recent self-harm or suicidal behavior, rather than a lifetime history of these behaviors.

2. Methods

Methods of review including eligibility criteria, data collection and synthesis were specified in advance in the form of a review protocol and registered with PROSPERO (CRD42017081260). PRISMA guidelines for systematic review were followed (Liberati et al., 2009).

2.1 Search strategy

Medline, PubMed, PsychInfo, Embase databases were searched for relevant key words and MeSH terms which included 'suicid*' OR 'suicide, attempted' OR 'self-injurious behavior' OR 'auto-mutilation' AND 'impulsiv*' OR 'decision making' OR 'delay discounting' OR 'inhibitory control' OR 'response inhibition' OR 'executive function' OR 'cognitive control'. Studies identified from references of relevant articles were also included. Search criteria selected only studies that were reported in English and published between January 1980 and December 2017.

2.2 Eligibility criteria

Using a proforma the first author (CM) screened titles and abstracts for the following inclusion criteria: i) a mean age between 12 and 30 years, ii) compared a group with a self-harm or suicidal behavior to a group without such behaviors iii) used a neurocognitive measure of impulsivity. Self-harm or suicidal behavior was defined as any non-fatal self-injurious behavior, with intent to harm self and/or intent to end one's life, and included suicide attempts (SA), non-suicidal self-injury (NSSI) and deliberate self-harm (DSH). Terms were used as they were in the original studies. A neurocognitive test was considered any task designed to measure impulsivity. Studies with mean age between 12 and 30 years were included to capture changing impulsivity with development.

Studies were excluded if they measured suicidal ideation without behavior, had a control group with self-harm or suicidal behavior, did not report on the association between impulsivity and these behaviors or used a self-report measure of impulsivity exclusively. Articles published in languages other than English were also excluded.

2.3 Identification of studies

Figure 2 outlines the process undertaken to identify studies for this review. 6183 titles were screened to determine appropriateness for screening of abstract. 333 titles and abstracts were screened by two authors (CM and AC). At that stage 192 studies were excluded based on eligibility criteria. The eligibility stage led to 141 full texts being assessed and subsequently a further 123 studies being excluded. The remaining 18 studies were included in this review.

INSERT FIGURE 2- PRISMA FLOWCHART HERE

2.4 Synthesis of results

A proforma was used to extract data from the included studies. This included information on study design (cross-sectional, longitudinal and period of follow up), sample characteristics (sample size, age, gender, population), outcome measures (NSSI, SA, or DSH), recency of self-harm or suicidal behavior (lifetime, or within 1 year), measure of impulsivity used, key findings and limitations. Key findings were evidence of an association between the impulsivity measure and outcome measure.

Neurocognitive measures were grouped together a priori based on the facet (or subtype) of impulsivity the measure was considered to capture- delay discounting, risky decision-making, response inhibition or cognitive inhibition. Key metrics were extracted and examined to ensure appropriateness of entering into meta-analysis. Where studies reported several metrics from the same measure efforts were made to extract the same metrics from each study (ie. commission errors on the CPT, overall proportional bets on IGT) Where studies reported multiple outcome groups (ie. multiple attempts vs. single attempts separately) the two groups were pooled, due to the small number of studies reporting these as separate groups.

2.5 Assessment of study quality

Study quality was assessed using the Newcastle-Ottawa scale for case-control studies and cohort studies (Wells et al, 2018). Studies scoring 5 or less were considered to be of low quality and at greater risk of bias.

2.6 Meta-analysis

The pooled effect size across all facets of impulsivity was estimated with a random effects meta-analysis chosen *a priori* for all estimates because of the diversity of study populations and differences in the methods used in the primary research. Between-study heterogeneity in effect sizes was examined using I-square, Q-value statistics and prediction intervals. The possibility of publication bias was assessed using Egger's regression (Egger, Smith et al. 1997) and was quantified using Duval and Tweedie's trim and fill method (Egger et al., 1997; Duval and Tweedie, 2000). Subgroups according to the facets of impulsivity, strength of reporting and age and sex distribution of the samples were compared using a mixed effects model. Comprehensive Meta-Analysis (CMA; Version 3, Biostat, Englewood NJ) was used for the main analysis.

3. Results

3.1 Study characteristics

Eighteen studies were included in the meta-analysis. Fourteen studies with a total of 632 subjects measured impulsive decision-making, four measured delay discounting, 3 via delay discounting (DD) tasks and 1 via Two Choice Impulsivity Paradigm (TCIP). Nine studies measured risky decision-making, 4 via IGT, 4 via CGT, 1 via the Information Sampling Task (IST).

Thirteen studies with a total of 1195 subjects measured inhibitory control. Eight studies measured response inhibition (6 via SST, 3 via Go No-go or goStop Impulsivity paradigm), six studies measured cognitive inhibition (5 via CPT, 1 via the Stroop test). Three studies used multiple measures, allowing for comparison between different neurocognitive measures of impulsivity. Table 1 summarizes the characteristics of included studies.

INSERT TABLE. 1 HERE Neurocognitive measures of impulsivity in self-harm and suicidal behavior of young people

3.1.1 Assessment of study quality

The median NOS score of the 18 included studies was 4 (range 3-7). Additional detail is included in the supplementary material (Appendix A: 2)

3.2 Meta-analysis

Young people engaging in self-harm or suicidal behavior were significantly more impulsive than those without such behavior (standardized difference in mean 0.19, 95% CI= 0.10-0.28, p-value <0.000, PI= 0.0934-0.29), see figure 3. The degree of variance was less than expected due to sampling error alone (Q=23.05, df=26, I-squared= 0). The funnel plot showed no evidence of publication bias (Appendix A: 3). Egger's regression was not significant (intercept=0.03, t-value=0.0034, df=25, p-value=0.49). Duval and Tweedie's trim and fill did not identify any missing hypothetical studies.

Both impulsive decision-making and deficits of inhibitory control were significantly associated with self-harm and suicidal behavior. Deficits in inhibitory control were associated with a greater effect size (SMD 0.21, p-value= 0.002, 95% CI (0.08- 0.34), PI=0.06-0.35), than impulsive decision-making (SMD 0.17, p-value=0.01, 95% CI (0.05-0.3), PI=0.03-0.31), though the difference between the two groups was non-significant (Q-value=0.13, df=1, p-value=0.72)

Measures of risky decision-making (SMD 0.26, p-value= 0.001, 95% CI 0.11-0.42) and response inhibition (0.22, p-value= 0.005, 95% CI (0.06-0.38), differentiated young people with such behaviors from those without. Measures of cognitive inhibition (ie. CPT) (SMD 0.14, p-value= 0.24, CI -0.09-0.37) and measures of delay discounting (SMD -0.02, p-value= 0.9, CI-0.3-0.3) did not differentiate the suicidal young people from controls. Despite response inhibition and risky decision-making being significantly associated with self-harm or suicidal behavior, but not cognitive inhibition or delay discounting, subtype of impulsivity measure used did not significantly moderate the relationship between impulsivity and these behaviors (Q-value= 3.09, df=3, p-value=0.38).

3.2.1 Moderator analysis

None of the variables selected a priori significantly moderated the effect between impulsivity and self-harm and suicidal behavior. In some cases, subgroups reached statistical significance while others did not. See table 2. Young people who had engaged in self-harm or suicidal behavior were significantly more impulsive than healthy controls (20 studies, SMD= 0.19, 95% CI=0.09-0.30, p-value=0.0002), but not psychiatric controls (n=7, SMD=0.18, 95% CI= -0.14-0.49, p-value=0.27), though this was a non-significant difference (Q-value=0.01, df=1, p-value=0.92). Study quality, whether low quality (24 studies, SMD=0.206, 95% CI=0.111-0.302, p-value= 0.000) or high quality (3 studies, SMD=0.016, 95% CI=-0.315-0.348, p-value=0.923), did not moderate the relationship between impulsivity and outcome measure.

Type of self-harm or suicidal behavior measure, whether suicide attempt (n= 15, SMD=0.18, 95% CI= 0.02-0.34, p-value=0.003) or NSSI (n=11, SMD=0.20, 95% CI=0.07-0.33, p-value= 0.003), did not moderate the relationship between impulsivity and such behaviors (Q-value=0.04, df=1, p-value=0.85). Timing of self-harm or suicidal behavior, whether lifetime history (n= 13, SMD=0.17, 95% CI=0.04-0.31, p-value= 0.02) or recent (n=14, SMD=0.21, 95% CI=0.07-0.34, p-value=0.002), was associated with similar effect sizes (Q-value=0.12, df=1, p-value=0.73).

Age of sample was not a moderator of the relationship between impulsivity and self-harm or suicidal behavior. The relationship between impulsivity and these behaviors was similar in samples of young adults (n=15, SMD=0.19, 95% CI=0.07-0.30, p-value= 0.002) and adolescents (age < 18 years old) (n= 12, SMD=0.19, 95% CI 0.01- 0.37, p-value=0.04, Q-value=0.003, df=1, p-value=0.96). Gender distribution of the sample also did not moderate the relationship. Though studies with sample sizes of more than 70% females (n=13, SMD=0.15, 95% CI= 0.004-0.29, p-value= 0.04) had a smaller effect size than those with more even gender distribution (n=14, SMD=0.23, 95% CI=0.10-0.36, p-value<0.001, Q-value= 0.72, df=1, p-value= 0.40), the difference was non-significant.

4. Discussion

This review confirms that there are associations between multiple facets of impulsivity and self-harm or suicidal behaviors in young people. Thus, we have provided an important addition to previous meta-analyses which have found self-report measures of impulsivity and such behaviors are weakly associated (Anestis 2014, Hamza 2015) whereas neurocognitive measures of impulsivity and self-harm and suicidal behaviors are associated with a medium to large effect size (Liu et al 2017).

While in several included studies the same sample showed differential deficits of decision-making, cognitive and response inhibition, our overall findings that subtype of impulsivity did not moderate the relationship is an important one. As evidence from the substance use disorder literature has previously suggested that delay discounting and response inhibition are separate domains (De Wit, 2009) and there is evidence that these facets are related to distinct neurocircuits (Fineberg et al. 2014) we had hypothesized that in suicidal populations there may be independence of these executive function deficits. The current review has not found any evidence of this. Although identifying discrete neurocognitive mechanisms and their associated neurocircuits may lead to further characterization of phenotypes of suicidal behavior and ultimately personalized interventions, at present the broader construct of impulsivity may be just as useful as a therapeutic target. Similarly dividing the broader construct of self-harm and suicidal behavior into more specific behaviors, suicide attempts and non-suicidal self-injury, did not moderate the relationship with impulsivity, which may indicate these behaviors are part of the same neurocognitive phenotype. Our finding that impulsivity differentiates between young people with self-harm and suicidal behavior and healthy controls, but not psychiatric controls must be interpreted with caution. Few studies used psychiatric control groups, such that the number of psychiatric controls in the meta-analytic sample was far fewer than healthy controls (161 vs. 1430 respectively). Thus our meta-analysis was likely underpowered to detect an effect between suicidal and self-harming young people and psychiatric controls.

4.1 Risky decision-making predicts self-harm and suicidal behaviors

Risky decision-making tasks such as the IGT and CGT, but not delay discounting tasks, differentiated young people with self-harm or suicidal behavior from controls. The majority of studies of risky decision-making used the Iowa Gambling task (IGT), which is often considered to measure multiple executive functions, such as reinforcement learning, in addition to probabilistic discounting, which may confound interpretation of our findings. Nonetheless these results are consistent with findings in adult populations (Gorlyn et al., 2013) and add to the existing literature as other meta-analysis have not included these decision-making tasks (Liu et al 2017).

Contrary to our hypothesis deficits of delay discounting did not differentiate young people with self-harm or suicidal behavior from controls. However, only a small number of studies (4) measured delay discounting, which suggests the analysis may have been underpowered in testing our hypothesis. Discounting is sensitive to a number of different conditions including order of magnitude (i.e. the larger the amount, the more steeply people discount), sign effect (positive outcomes discounted more than negative outcomes), duration (distant outcomes discounted more than proximal) and affective states (in ‘hot’ affective states persistence of current preferences overestimated) (Tucker et al., 2010). One potential model of decision-making in self-harm and suicidal behavior may involve the individual under stress valuing the smaller sooner rewards (ie. cessation of emotional pain) over the larger, later rewards that may come with continuing living. The current value of life may be suddenly decreased due to loss of social role or connection. Put alternatively the costs associated with these behaviors in the present, such as physical pain and fear, may be less than perceived costs of continued living with emotional pain. This is consistent with evidence from healthy populations that individuals in ‘hot’ affective states, such as in emotional crisis, are likely to overestimate the likelihood that current conditions will persist (Madden and Johnson, 2010). Under this model of self-harm and suicidal decision-making the individual may believe the immediate choice of the self-harm or suicidal act is the option with the highest utility. Other hallmarks of the suicidal crisis, including intoxication and sleeplessness have all been shown to cause steeper discounting of future gain (Tucker et al., 2010).

4.2 Deficits in inhibitory control are associated with self-harm and suicidal behavior in young people

Young people with self-harm or suicidal behavior were significantly slower in responding appropriately to stimulus in response inhibition tasks relative to controls. This finding is in keeping with current psychological models of suicidal behavior. A deficit in response inhibition, which is the motor, or behavioral component of inhibitory control may explain why some individuals engaging in self-harm and suicidal behavior describe having engaged in the act before they have had a chance to stop themselves (Skegg, 2005).

Measures of cognitive inhibition, however, did not differentiate young people with self-harm and suicidal behavior from controls, contrary to our hypothesis. Only six studies measured cognitive inhibition, which likely makes our analysis underpowered. We had hypothesized that deficits in cognitive inhibition, or the ability to override mental processes, may have particular effects on the suicidal mind, resulting in increased ideation, a predictor of behavior (Nock et al., 2010). Once an individual is in crisis they may be unable to shift attention from negative thoughts or thoughts of self-harm or suicide, which is likely to lead to increased frequency and perceived lack of control over ideas of self-harm or suicide. Suicidal ideation and behavior scales that measure frequency and control over suicidal thoughts have previously been shown to be more robust measures of suicidal ideation, relative to dichotomous descriptors (Batterham et al., 2015). Deficits of cognitive inhibition may be related to rumination, which has also been associated with these behaviors (Rogers and Joiner, 2017).

4.3 The role of state-based impulsivity is poorly understood

Only two studies used individuals who had self-harmed or made a suicide attempt within the last week to month (Horesh, 2001; Oldershaw et al., 2009) and less than half the studies recorded suicide attempts or self-harm within the previous year (Janis and Nock, 2009; Stewart et al., 2015; Ackerman et al., 2015; Bridge et al.; Bridge et al., 2015; Fikke et al., 2011; Giannetta et al., 2012). The only study that compared current and former self-harmers, found adolescents who were current self-harmers made more high-risk choices on IGT than those with a history of self-harm, or healthy controls (Oldershaw et al., 2009). Current self-harmers were the only group who did not improve over the course of the task. This deficit of studies examining impulsivity and cognition proximally to self-harm and suicidal behavior in young people is particularly important, given the findings from Liu et al's (2017) meta-analysis that in adults the odds of impulsivity in recent (<1 month) suicide attempters was greatly increased.

It is possible that decision-making processes are more state based than measures of inhibitory control, which would mean the methodological limitations of the literature may mask the true effect of these deficits on self-harm and suicidal behavior. Indeed previous reviews have found inhibitory control may be less impacted by stress conditions than other executive functions (Shields et al., 2016). Discounting of reward has been shown to be strongly impacted by other state variables, including both acute intoxication and chronic substance use (Bickel et al., 1999). Certainly a growing body of evidence suggests conditions of stress may significantly impact decision-making and inhibitory control in healthy individuals. It will be vital for research to get closer in time to self-harm and suicidal behaviors and measure associated state-based variables. For example, in this review few studies controlled for current or past substance use. Traditionally, measuring cognitive states has been difficult, in both clinical and research settings. Advances in technology, however, have increased both the accessibility and sophistication of neurocognitive testing, such as CanTab or Cogstat (Fray et al., 1996, Maruff et al., 2009). With these advances it may be possible to measure suicidal cognition in real-time, outside the domains of the clinical or research setting (Nock et al., 2009). Using measures that quantify state differences are likely to be more useful in understanding etiology, recognizing risk clinically and in prevention.

4.4 Impulsivity and self-harm or suicidal behavior in development

Impulsivity is associated with suicidal behavior in young people. Despite impulsive choice and behavior being a feature of normative development, deficits of inhibitory control and discounting still meaningfully differentiated groups of young people with self-harm or suicidal behavior from those without. While previous reviews have examined facets of impulsivity in development of healthy adolescents and populations of substance using young people, less is known about changing impulsivity in young people engaging in self-harm or suicidal behaviors. This analysis found the average age of the sample, either over 18 years or below, did not moderate the association between impulsivity and these behaviors. It is possible that dividing age dichotomously introduces error into the analysis. Examining age associations in meta-analysis can be problematic as each study generally reports the mean age of the sample, rather than for cases and controls. No individual studies in the current review had a study design sufficient to comment on changing impulsivity with age, which will be an important question for future research.

Half of the included studies had a sample of greater than 70% female, which suggests there may be sampling bias in the literature on impulsivity and self-harm and suicidal behavior. If sex is associated with either delayed development of inhibitory control or decision-making, the current literature may have underestimated the relationship between these behaviors and impulsivity due to sampling bias.

Self-harm, with or without suicidal intent, is considered to be more prevalent in females (Skegg, 2005). Cultural difference in expression of emotion, and biological factors (ie. testosterone and aggression), have both been hypothesized to contribute to such an effect (Bresin and Schoenleber, 2015). Yet studies using broader definitions of self-harm, have shown less of a gender difference in prevalence, which suggests methodological issues in suicide research may at least in part contribute to this finding (Muehlenkamp and Gutierrez, 2004). Rippon et al. (2014) have outlined the way in which methodological error (ie. inappropriate consideration of age and development) can confound relationships between sex and various outcomes in the neurosciences. Gender bias in sampling is particularly important to consider in the study of self-harm and suicidal behavior.

4.5 Limitations

The current review had a limited ability to look at important moderators, including other executive function deficits, and potential confounders such as substance use. This reflects the relatively small number of studies examining neurocognitive measures of impulsivity in young people with self-harm or suicidal behavior. We were only able to broadly examine the role of individual characteristics, such as age or gender, at a study level, which likely introduces bias. There were relatively few studies reporting facets of impulsivity, which likely resulted in the meta-analysis being underpowered to detect an effect. It is still not clear how to measure clinically meaningful differences in impulsive decision-making and inhibitory control. This makes it difficult to know whether the findings of this review are clinically meaningful.

5. Conclusion

The current review has demonstrated that impulsivity differentiates young people engaging in self-harm or suicidal behavior from healthy controls. This relationship exists despite the age or gender of the sample. There is limited evidence of a differential association between particular facets of impulsivity and the expression of such behaviors in young people. Deficits of response inhibition and riskier decision-making were associated with these behaviors, though deficits of cognitive inhibition and steeper delay discounting were not significantly associated. Recency of self-harm or suicidal behavior or type of behavior measured did not moderate the relationship. Future research into self-harm and suicidal behaviors and decision making should focus on state impulsivity by studying decision making processes in populations with recent self-harm or suicidal behavior. Greater understanding of trajectories of impulsive decision-making and behavior across adolescence and adulthood would increase our understanding of the contribution of this important executive function in expression of self-harm and suicidal behavior.

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Figure 1. Definitions of impulsivity and suicidal behavior

	Definition
Impulsivity	A predisposition toward rapid, unplanned reactions to internal or external stimuli with diminished regard to the negative consequences of these reactions to the impulsive individual or to others (Moeller, Barratt et al. 2001)
Response inhibition	The process of the overriding of a planned or already initiated action (Bari and Robbins 2013)
Cognitive inhibition	The stopping or overriding of a mental process, in whole or in part, with or without intention (MacLeod 2007)
Delay discounting	The tendency to choose small rewards that are given immediately over larger rewards that are given after a relative delay (Fineberg, Chamberlain et al. 2014) Also referred to as temporal discounting, or time-preference.
Probabilistic discounting	The tendency to choose larger but less likely option, over the smaller, more likely option. (Robbins and Dalley 2016)
Suicidal behavior	Any intentional action that may cause a person to die.
Suicide attempt	A potentially self-injurious behavior associated with at least some intent to die.
Non-suicidal self-injury	Self-injurious behavior with no intent to die.
Deliberate self-harm	Any type of self-injurious behavior, including suicide attempts and non-suicidal self-injury.
Suicidal ideation	Active: Thoughts about taking action to end one's life, including identifying a method, having a plan, or having intent to act. Passive: Thoughts about death or wanting to be dead without any plan or intent

Figure 2. PRISMA flowchart

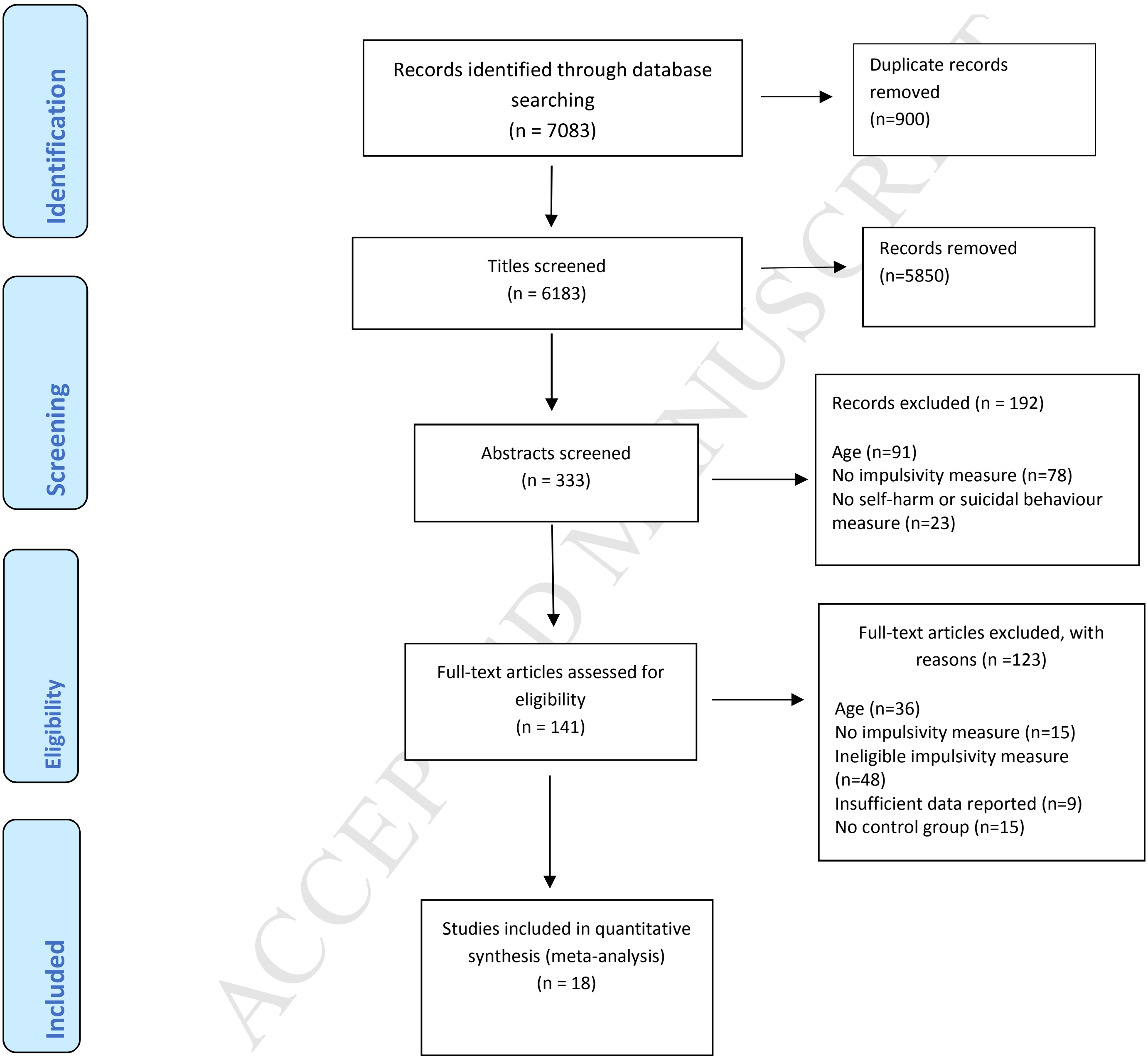


Table 1. Neurocognitive Measures of Impulsivity

Study	N total (subjects, controls)	Age range in years (mean)	Population	Design	Outcome measure	Cognitive test *Self-report*	Findings
Ackerman et al. 2015 (Ackerman, McBee-Strayer et al. 2015)	14 SA 14 psychiatric controls	15-19 (16.9)	Community, ED F 64%	Case-control	SA *Recent (1 yr)*	CGT	CGT scores higher in SA
Allen & Hooley 2015 (Allen and Hooley 2015)	33 NSSI 31 healthy controls	18-53 (23.7)	Community F 75%	Case-control	NSSI *Lifetime*	SST *SNAP impulsivity*	No differences between NSSI and HCs on any dimension of the SST
Bridge 2012 (Bridge, McBee-Strayer et al. 2012)	40 SA 40 psychiatric controls	13-18 (15.5)	Community F 75%	Case-control	SA *Recent (1yr)*	IGT *BIS*	SA performed worse on IGT than controls, difference persisted once affective disorder, psychotropic use, self-report impulsivity and hostility adjusted for
Bridge 2015 (Bridge, Reynolds et al. 2015)	40 SA 40 psychiatric controls	13-18 (15.6)	Community F 75%	Case-control	SA *Recent (1yr)*	DD	SA were more aggressive, those on medication were less aggressive, no differences on DDQ
Chamberlain et al. 2013 (Chamberlain, Odlaug et al. 2013)	16 SA 288 healthy controls	18-29 (21.8)	Community F 30%	Case-control	SA *Lifetime*	CGT	CGT performance was associated with a significant incremental benefit in predicting suicidality, over clinical and demographic variables
Fikke et al. 2011 (Fikke, Melinder et al. 2011)	33 high-NSSI 29 low- NSSI 35 healthy controls	14-15 (14.8)	Schools F 71%	Case-control	NSSI *Recent (1yr)*	SST	Low-severity NSSI more impulsive than controls and high-severity NSSI
Gianetta et al. 2012 (Giannetta, Betancourt et al. 2012)	23 DSH 23 healthy controls	10-14 (11.6)	Schools F 30%	Case-control	DSH *Recent (1 year)*	Stroop, *YSR*	SI and DSH assoc. with impulsivity by self-report Cognitive measures not associated
Glenn et al. 2010 (Glenn and Klonsky 2010)	82 NSSI 82 healthy controls	(19)	Community F 73%	Case-control	NSSI *Lifetime*	SST *UPPS*	NSSI vs. HC: no difference in Stop signal results Urgency differences greater than lack of premed. or sensation seeking
Grant et al. 2014 (Grant, Derbyshire et al. 2014)	32 any suicidality 142 no suicidality	18-29 (21.7)	Community F 31%	Case-control	NSSI *Lifetime*	CGT *BIS, EIS*	Suicidality associated with relative impairments in decision making and cognitive flexibility
Horesh	37 SA	(15)	Inpatient	Case-	SA	CPT: TOVA	IMP higher in suicide attempters

2001 (Horesh 2001)	23 psychiatric controls		F 34%	control	*Current, recent*	*ICS*	Correlation between self-report and cog. measure low, but significant
Janis et al. 2009a (Janis and Nock 2009)	64 NSSI 30 healthy controls	12-19 (17)	Outpatient F 80%	Case-control	NSSI *Lifetime*	IGT, CPT	No difference between self-harmers and controls
Janis et al. 2009b (Janis and Nock 2009)	20 NSSI 20 healthy controls	18-30 (23-24)	Outpatient F100%	Case-control	NSSI *Recent*	IGT, CPT, DD *K-SCADS-PL*	No difference between self-harmers and controls
Mathias et al. 2011 (Mathias, Dougherty et al. 2011)	22 multiple SA 15 SA 22 psychiatric controls	13-17	Inpatients F 100%	Case-control	SA *Lifetime*	TCIP, goStop	Multiple SA>single SA>no attempts on TCIP No differences on goStop
Milner 2015 (Milner 2015)	30 SA 34 healthy controls	18-55 (26.8)	Inpatient F 60%	Case-control	SA *Recent*	SST, DD, IST, CPT, Go-no go *BIS, UPPS-P*	No significant differences on any of the tasks
Oldershaw et al. 2009 (Oldershaw, Grima et al. 2009)	30 current DSH 24 past DSH 22 depressed controls 57 healthy controls	12-18 (15-16.5)	Outpatient Schools F 80%	Case-control	DSH *Current, Lifetime*	IGT	IMP higher in current DSH >past DSH > depressed controls > healthy controls Past DSH able to learn low risk strategy
Pan et al. 2011 (Pan, Batezati-Alves et al. 2011)	15 SA 15 depressed controls 14 healthy controls	13-17 (16.2)	Outpatient F 57%	Case-control	SA *Lifetime*	Go-no go	No significant differences in any of the go-no go dimensions
Schatten 2015 (Schatten, Andover et al. 2015)	48 NSSI 72 non-NSSI	18-29 (21.9)	Population F 64%	Case-control	NSSI *Lifetime*	IGT	NSSI status not associated with IGT performance either before or after social exclusion task
Stewart et al. 2015 (Stewart, Kim et al. 2015)	59 SA 101 depressed controls	13-18 (15.6)	Inpatient F 77%	Case-control	SA *Recent (1 yr)*	Grad CPT	Disinhibition moderates relationship between CSA and recent suicide attempt

Table 2. Moderators of effect

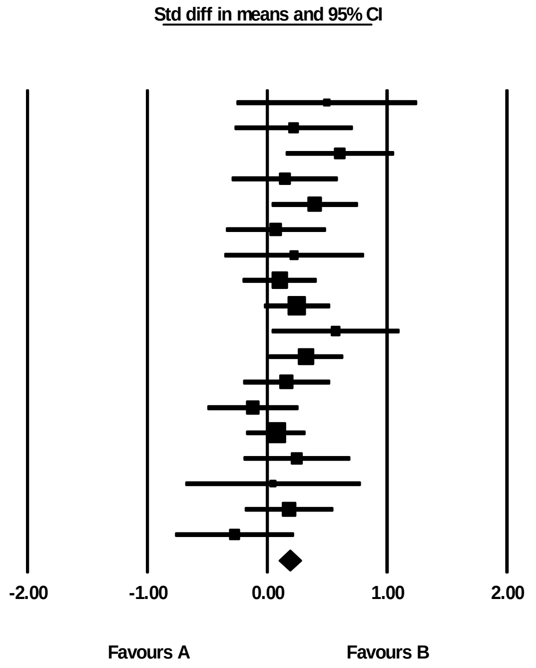
Group	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df	p-value
Cognitive inhibition	6.000	0.139	0.119	0.014	-0.094	0.372	1.168	0.243			
Delay Discounting	4.000	-0.019	0.149	0.022	-0.310	0.273	-0.125	0.900			
Risky decision-making	9.000	0.262	0.079	0.006	0.107	0.416	3.324	0.001			
Response inhibition	8.000	0.219	0.080	0.006	0.062	0.375	2.739	0.006			
Total between									3.093	3.00	0.377
Lifetime	13.000	0.173	0.071	0.005	0.034	0.311	2.440	0.015			
Recent	14.000	0.207	0.068	0.005	0.073	0.340	3.032	0.002			
Total between									0.119	1.00	0.730
Healthy	20.000	0.193	0.053	0.003	0.090	0.296	3.663	0.000			
Psychiatric	7.000	0.177	0.160	0.026	-0.136	0.490	1.108	0.268			
Total between									0.009	1.00	0.926
Adolescent	12.000	0.192	0.092	0.008	0.011	0.372	2.082	0.037			
Adult	15.000	0.186	0.060	0.004	0.069	0.303	3.109	0.002			
Total between									0.003	1.00	0.956
Less	14.000	0.230	0.066	0.004	0.102	0.358	3.511	0.000			
Over 70% female	13.000	0.147	0.073	0.005	0.004	0.290	2.011	0.044			
Total between									0.721	1.000	0.396
Impulsive decision-making	14.000	0.173	0.065	0.004	0.045	0.300	2.657	0.008			
Inhibitory control	13.000	0.206	0.066	0.004	0.076	0.336	3.110	0.002			

Total between									0.128	1.00	0.721
NSSI	11.000	0.197	0.066	0.004	0.068	0.327	2.992	0.003			
SA	15.000	0.177	0.081	0.007	0.019	0.336	2.191	0.028			
Total between									0.036	1.00	0.849
High quality	3	0.016	0.169	0.029	-0.315	0.348	0.097	0.923			
Low quality	24	0.206	0.049	0.002	0.111	0.302	4.234	0.000			
Total within									1.159	1.00	0.282

Figure 3. Forest plot of impulsivity

Meta Analysis

Study name	Subgroup within study	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Ackerman et al. 2015	Risky Decision-making	0.498	0.384	0.147	-0.255	1.250	1.296	0.195
Allen & Hooley 2015	Response inhibition	0.220	0.251	0.063	-0.272	0.712	0.877	0.380
Bridge 2012	Risky Decision-making	0.606	0.229	0.052	0.158	1.054	2.650	0.008
Bridge et al.	Delay Discounting	0.146	0.224	0.050	-0.292	0.585	0.654	0.513
Chamberlain 2013	Combined	0.396	0.182	0.033	0.039	0.753	2.176	0.030
Fikke et al. 2011	Response inhibition	0.071	0.211	0.045	-0.343	0.486	0.337	0.736
Gianetta et al. 2012	Cognitive inhibition	0.225	0.296	0.088	-0.355	0.805	0.760	0.447
Glenn et al. 2010	Response inhibition	0.104	0.156	0.024	-0.202	0.411	0.668	0.504
Grant et al. 2014	Combined	0.248	0.139	0.019	-0.024	0.520	1.786	0.074
Horesh 2001	Cognitive inhibition	0.571	0.271	0.073	0.041	1.101	2.110	0.035
Janis et al. 2008a	Combined	0.324	0.157	0.025	0.016	0.633	2.062	0.039
Janis et al. 2008b	Combined	0.161	0.183	0.034	-0.198	0.520	0.881	0.378
Mathias et al. 2011	Combined	-0.119	0.192	0.037	-0.495	0.257	-0.621	0.535
Millner 2018	Combined	0.072	0.125	0.016	-0.173	0.318	0.578	0.563
Oldershaw et al. 200[illegible]	Risky Decision-making	0.247	0.226	0.051	-0.196	0.691	1.093	0.274
Pan et al 2011	Response inhibition	0.048	0.372	0.138	-0.680	0.777	0.130	0.896
Schatten et al. 2015	Risky Decision-making	0.182	0.187	0.035	-0.184	0.548	0.977	0.329
Stewart et al. 2015	Cognitive inhibition	-0.273	0.251	0.063	-0.765	0.220	-1.085	0.278
		0.189	0.046	0.002	0.098	0.280	4.075	0.000



Meta Analysis