

UC Berkeley

UC Berkeley Electronic Theses and Dissertations

Title

Transdiagnostic Cognitive Control Training for Emotion-Relevant Impulsivity

Permalink

<https://escholarship.org/uc/item/3v2701wr>

Author

Peckham, Andrew David

Publication Date

2016

Peer reviewed|Thesis/dissertation

Transdiagnostic Cognitive Control Training for
Emotion-Relevant Impulsivity

By

Andrew David Peckham

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Psychology

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Sheri L. Johnson, Chair

Professor Silvia Bunge

Professor Dana Carney

Professor Allison G. Harvey

Spring 2017

© by Andrew David Peckham, 2016

Abstract

Transdiagnostic Cognitive Control Training for Emotion-Relevant Impulsivity

By

Andrew David Peckham

Doctor of Philosophy in Psychology

University of California, Berkeley

Professor Sheri L. Johnson, Chair

The tendency to respond impulsively to strong emotions is a surprisingly common trait across many forms of psychopathology. Emotion-relevant impulsivity is closely tied to problems with cognitive control, raising the possibility that strengthening underlying cognitive mechanisms might also reduce aspects of impulsivity. Cognitive control training programs have been used to improve emotion regulation skills in several studies (cf. Siegle, Price, Jones, Ghinassi, Painter, & Thase, 2014), but despite conceptual similarities, it is unknown whether cognitive control training might also reduce emotion-relevant impulsivity. The goal of the present study was to test whether training cognitive control through working memory and response inhibition tasks (two dimensions specifically implicated in emotion-relevant impulsivity) is efficacious in reducing emotion-relevant impulsivity transdiagnostically.

Participants ($N = 52$) were recruited based on self-reported tendencies to experience difficulties with impulsivity in the face of strong emotion, using the Feelings Trigger Action scale (Carver, Johnson, Joormann, Kim, & Nam, 2011). Participants were randomly assigned to either a two-week waitlist condition or to immediately begin six in-lab training sessions (including the adaptive PASAT: a working memory task, and the Go/No-Go task: a response inhibition task in each session) over the course of two weeks.

Results showed a significant reduction in emotion-relevant impulsivity from pre-training to post-training and during the two-week follow-up phase; these improvements were not observed in the waitlist control period. Participants also showed significant improvements on the working memory task, and non-significant improvements on transfer tasks of working memory and response inhibition. Results provide preliminary support for the efficacy of cognitive control training interventions that target emotion-driven impulsivity.

Dedication

To my parents, Nancy Niemi and David Peckham, for always believing in me.

Acknowledgments

Since my first day as a graduate student, Dr. Sheri Johnson has encouraged and mentored me to conduct rigorous, fearless, creative science, and I am so grateful for her constant support and mentorship of my ideas, my writing, and my career. I thank my other dissertation committee members, Dr. Allison Harvey, Dr. Silvia Bunge, and Dr. Dana Carney for their guidance and encouragement beginning long before the start of this dissertation research. I am very grateful for Dr. Harvey's guidance regarding the translational treatment development process, and for mentoring me during the NIMH T32 predoctoral fellowship that supported me during the completion of this work. Dr. Bunge and the members of her Building Blocks of Cognition lab provided countless hours of collaboration and discussion about cognitive training paradigms and the neuroscience of cognitive control, all of which were instrumental in shaping my research plan. In addition to my committee members, Dr. Robert Levenson provided support and encouragement in the earliest days of this project.

I have also been fortunate to have the support of many colleagues outside the University of California, Berkeley. I am deeply grateful for Dr. Greg Siegle's willingness to share his PASAT paradigm, and for his encouragement and enthusiastic support of this study. I would also like to thank the members of ABCT's Neurocognitive Therapies and Translational Research Special Interest Group for 6 years of stimulating conversations, workshops, and meetings, which have had a large impact on the ideas described in this dissertation.

The study described in this dissertation could not have been accomplished without the hard work contributed by many members of Prof. Sheri Johnson's Cal Mania team. In particular, I would like to thank Jordan Tharp, Kiana Modavi, and James Madole, who worked tirelessly to support the completion of this study. I am so grateful for the help of many research assistants who contributed to the execution of this study as well, including Amy Acosta, Laura Fenton, Rebecca Krasnoff, Claire Lee, Katy Mohr, Jaya Roy, Philip Schaff, and Ella Spencer.

Finally, I am grateful for the support of so many friends, colleagues, and family members who supported me during the writing of this dissertation. Most of all, I am thankful to my wife, Rosemary Eger Peckham, for her endless patience and support.

Transdiagnostic Cognitive Control Training for Emotion-Relevant Impulsivity

Impulsive responses to strong emotions are increasingly recognized as a common transdiagnostic feature shared by many diverse forms of psychopathology and addictive behaviors (Berg, Latzman, Bliwise, & Lilienfeld, 2015; Johnson, Carver, & Joormann, 2013). The concept of a distinct emotionally-relevant type of impulsivity began in large part with the publication of Whiteside and Lynam's (2001, 2003) influential UPPS (Urgency, (lack of) Premeditation, (lack of) Perseverance, Sensation Seeking) model, which identified Negative Urgency (the tendency to act impulsively in negative mood states) as an aspect of impulsivity distinct from both sensation seeking and from a lack of planning and perseverance. This model has since been extended to include Positive Urgency, a parallel form of impulsivity characterized by impulsive reactions to positive mood (Cyders, Smith, Spillane, Fischer, Annus, & Peterson, 2007). More recently, evidence has suggested that positive and negative urgency may not be truly distinct factors, but instead may be grouped together into a general feature of emotion-relevant impulsivity (Berg et al., 2015; Carver et al., 2011).

A growing body of work has also attempted to understand the mechanisms that might contribute to emotion-relevant impulsivity. Recent theory suggests this form of impulsivity might be best understood within the context of two-mode models (Bechara, 2005; Carver, Johnson, & Joormann, 2008; Carver, Johnson, & Joormann, 2009; Carver, Johnson, Joormann, & Scheier, 2015), which suggest that behavior is influenced by both a reflexive, impulsive system (such as automatically initiating responses without deliberation) and a reflective, higher-order system (including top-down cognitive control mechanisms). In this model, the tendency to react impulsively during strong emotion and motivation states is shaped by both degree of top-down control, and the relative strength of bottom-up approach and avoidance tendencies (Carver et al., 2008; Carver et al., 2015). Stemming from these two-mode approaches to impulsivity, Carver and colleagues developed a factor-analytically derived composite measure of impulsivity, which identified a factor specific to impulsive reactions to emotion—"Feelings Trigger Action" (FTA)—that includes items from both the Negative and Positive Urgency measures, and adds additional items relevant to reflexive reactions to emotions (Carver et al., 2011; Carver, LeMoult, Johnson, & Joormann, 2014).

Beyond a growing set of articles that clarify the boundaries and features of this form of impulsivity, increasing evidence suggests that this tendency to behave impulsively during times of intense emotion (whether quantified as Negative Urgency, Positive Urgency, or Feelings Trigger Action) is strongly tied to a number of problematic real-world behaviors and clinical diagnoses. Following studies showing that emotion-relevant impulsivity is associated with borderline personality traits (Whiteside, Lynam Miller, & Reynolds, 2005), bulimia (Fischer, Smith, & Cyders, 2008), problem gambling (Whiteside et al., 2005), alcohol use (Cyders, Flory, Rainer, & Smith, 2009), increases in substance use and risky sexual behavior (Zapolski, Cyders, & Smith, 2009), and aggression (Johnson, Carver, & Joormann, 2013), researchers have proposed that emotion-relevant impulsivity may be a broadly transdiagnostic feature of psychopathology (Johnson et al., 2013). More recently, evidence from clinical samples shows that emotion-relevant impulsivity is elevated in persons diagnosed with bipolar I disorder (Muhtadie, Johnson, Carver, Gotlib, & Ketter, 2014), schizophrenia (Hoptman, Antonius, Mauro, Parker, & Javitt, 2014), eating disorders (Bardone-Cone, Butler, Balk, & Koller, 2016), lifetime major depressive disorder (Carver, Johnson, & Joormann, 2013), and cocaine

dependence (Torres et al., 2013). Reflecting this pervasive influence of emotion-relevant impulsivity in psychopathology, a recent meta-analysis of more than 40,000 individuals found that compared to other aspects of impulsivity, urgency was the strongest predictor of every diagnostic category studied (Berg et al., 2015).

Two-mode models of impulsivity provide a theoretical backdrop for why such a diverse range of symptoms and pathologies are linked to impulsive reactivity to emotion: even as the degree of bottom-up approach and avoidance-related tendencies may vary by diagnosis (e.g., enhanced behavioral activation in mania or strong inhibition tendencies in depression), the lack of top-down control leads to a tendency to impulsively react to emotion states across disorders (Johnson et al., 2013; Carver et al., 2015). The goal of the current study was to develop a cognitive training program that will reduce emotion-relevant impulsivity, by drawing on this two-mode model. As background for this study, cognitive mechanisms that are implicated in emotion-relevant impulsivity are first reviewed, followed by literature relevant to cognitive training.

Impulsivity is Related to Cognitive Control Deficits

Consistent with two-mode models, deficits in cognitive control—the ability to flexibly apply cognitive resources to achieve a goal—seem to overlap substantially with many behavioral conceptualizations of impulsivity (Bickel, Jarmolowicz, Mueller, Gatchalian, & McClure, 2012; Sharma, Markon, & Clark, 2014). Cognitive control encompasses at least three distinct dimensions (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000), and at least two of these dimensions—including updating and monitoring information (encompassing working memory) and inhibition—have been repeatedly documented as relevant for impulsivity. Deficits in both response inhibition (the ability to withhold or cancel a behavioral response) and working memory (the capacity to briefly store, update, and monitor information) are each prospectively associated with the onset of alcohol use in adolescence (Khurana, Romer, Betancourt, Brodsky, Giannetta, & Hurt, 2013; Peeters et al., 2015), suggesting that cognitive control weaknesses in both of these domains precede the initiation of risky behavior. Tasks requiring prepotent response inhibition are frequently used as a laboratory analogue of impulsive behavior (for review, see Bari & Robbins, 2013; Sharma et al., 2014; Cyders & Coskunpinar, 2011), with numerous studies finding evidence for response inhibition deficits as related to substance use, other forms of impulsive behavior (Bari & Robbins, 2013) and many forms of psychopathology, including bipolar disorder, ADHD, schizophrenia, and autism (Lipszyc & Shachar, 2010; Wright, Lipszyc, Dupuis, Thayapararajah, & Shachar, 2014).

In parallel, working memory deficits have also been tied to multiple aspects of impulsivity, including risk-taking and impulsive decision-making (Endres, Rickert, Bogg, Lucas, & Finn, 2011; Finn, Gunn, & Gerst, 2014; Finn, Mazas, Justus, & Steinmetz, 2002; Wesley & Bickel, 2014). Working memory deficits, in turn, have been identified in a variety of clinical samples (Snyder, Miyake, & Hankin, 2015), including depression (Snyder, 2013), substance abuse and dependence (Bickel et al., 2012), and obsessive-compulsive disorder (Snyder, Kaiser, Warren, & Heller, 2014). Together, this evidence shows that working memory and response inhibition deficits each relate to aspects of impulsivity, and each of these features are also observed transdiagnostically. These studies also raise the possibility that deficits in working memory and response inhibition are a common thread that links psychopathology and impulsivity.

Beyond the associations noted for other forms of impulsivity, recent studies have investigated how emotion-relevant impulsivity specifically relates to deficits in cognitive control.

In one such study, factor analysis identified that negative urgency loads on a common factor with self-reported attentional impulsivity and distractibility (Sharma, Kohl, Morgan, & Clark, 2013), consistent with findings of other self-report studies (e.g., Jacob, Gutz, Bader, Lieb, Tüscher, & Stahl, 2010). Providing further support for this relationship, urgency has been linked with impairment on several types of neuropsychological tasks that involve cognitive control, including deficits on the Wisconsin Card Sorting Task and the switching condition of the Trails task (Dolan, Bechara, & Nathan, 2008).

Some evidence has also linked urgency with deficits in working memory capacity (Gunn & Finn, 2015), though other studies have not observed this effect (Dolan et al., 2008; Lozano, 2015). Why might emotion-relevant impulsivity, given its empirical connections with other cognitive deficits, not show a direct link with working memory? Two-mode models of impulsivity provide one compelling explanation for these mixed effects. Several studies have found strong evidence that rather than exerting direct effects on behavior, working memory capacity interacts with bottom-up influences to influence outcomes such as drug and alcohol use, food consumption, and sexual interest (Grenard, Ames, Wiers, Thush, Sussman, & Stacy, 2008; Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Sharbanee, Strizke, Wiers, Young, Rinck, & MacLeod, 2013; Thush, Wiers, Ames, Grenard, Sussman, & Stacy, 2008), as two-mode models of impulsivity would suggest. This same phenomenon appears to be true of urgency: a recent study found that negative urgency was only a predictor of response inhibition deficits in the context of low working memory capacity (Gunn & Finn, 2015). This is consistent with findings from basic cognitive science, showing that working memory capacity is a moderator of performance on inhibition tasks (Minamoto, Osaka, & Osaka, 2010). Thus, inhibition could be moderated by the ability to retain in working memory the goals of a task and the conditions under which it is important to actually inhibit a response. Together, these findings suggest that working memory may be an important moderator of the effects of urgency on inhibition.

Whereas working memory capacity appears to indirectly influence impulsive processes, negative urgency has now been linked to worse performance on response inhibition tasks in multiple studies (Bagge, Littlefield, Rosellini, & Coffey, 2013; Dolan et al., 2008; Gay, Rochat, Billieux, d'Acremont, & Van der Linden, 2008; Roberts, Fillmore, & Milich, 2011; Rochat, Beni, Annoni, Vuadens, & Van der Linden, 2013; Wilbertz et al., 2014), including in a large meta-analysis (Cyders & Coskunpinar, 2011). Positive urgency has also been associated with deficits on the Delayed Memory Task, which is often characterized as a response inhibition task (Cyders & Coskunpinar, 2012), and another recent study found evidence for a link between positive urgency and response inhibition deficits on an anti-saccade task (Johnson, Tharp, Peckham, Sanchez, & Carver, 2016), providing further evidence for the tendency to become impulsive in strong emotion states (either positive or negative) as related to problems with cognitive control. More recently, an updated meta-analysis suggests that the link between urgency and response inhibition deficits is strongest in clinical samples, with much more limited evidence in non-clinical samples (Johnson et al., 2016). These studies provide initial evidence that negative and positive urgency are both related to difficulties inhibiting a prepotent response. To put these findings in context, several studies have identified that there is very little overlap between self-report and laboratory-based measures of impulsivity (Cyders & Coskunpinar, 2011; Sharma et al., 2014), hence, the link between urgency and response inhibition is a particularly notable finding.

In contrast to the emerging pattern of cognitive control deficits associated with emotion-relevant impulsivity in behavioral studies, far less is known about the neural correlates of this construct. This small literature includes one study of the correlates of urgency with neural activation during response inhibition, finding that urgency is correlated with reduced activation of the inferior frontal gyrus during this task (Wilbertz et al., 2014), which again highlights the link between urgency and inhibition deficits. In contrast, a recent study found that people with higher levels of negative urgency showed *increased* prefrontal activation in the context of negative images overlayed on a Go/NoGo task (Chester, Lynam, Milich, Powell, Anderson, & DeWall, 2016). Aside from these two studies, studies of the neural correlates of urgency have not examined neural activation in the context of behavioral tasks posited to evaluate impulsivity or cognitive control, which reduces their comparability to the above-mentioned behavioral studies of the same constructs (e.g., Cyders, Dzemidzic, Eiler, Coskunpinar, Karyadi, & Kareken, 2013; Hoptman et al., 2014; Joseph, Liu, Jiang, Lynam, & Kelly, 2009). Evidence for how emotion-relevant impulsivity impacts connectivity or structural differences in brain areas are also scarce, as the single study that has been conducted in this domain involved patients with schizophrenia (Hoptman et al., 2014), a disorder that is known to have numerous alterations in neural connectivity. Thus, more research is clearly needed to understand how emotion-relevant impulsivity is associated with particular deficits in cognitive control at the neural level.

However, the neural basis of non-emotional aspects of impulsivity have been well studied, and these studies strong support for the idea that impulsivity is related to deficits in cognitive control. Broadly, this literature finds that aberrations across a frontostriatal network of brain regions are related to performance on many behavioral impulsivity paradigms (Aron, 2012; Bari & Robbins, 2013; Kim & Lee, 2011). Though a number of interconnected brain regions are implicated in aspects of behavioral control, lateral prefrontal cortex (PFC), including dorsolateral PFC (dlPFC) and ventrolateral PFC (vlPFC), are routinely identified as important contributors to the regulation of behavior. Experimental manipulation of dlPFC activity through neurostimulation (tDCS or rTMS) has been found to influence impulsive decision-making (Cho, Ko, Pellecchia, Van Eimeren, Cilia, & Strafella, 2010; Figner et al., 2010) and changes in risk-taking (Beeli, Koenke, Gasser, & Jancke, 2008; Fecteau et al., 2007; Knoch et al., 2006). Together, these studies demonstrate that the dlPFC is an important component in control over behavior in a range of paradigms evaluating impulsivity.

Intriguingly, weaknesses in dlPFC function have also been specifically linked to response inhibition and working memory (Khurana et al., 2013; Wesley & Bickel, 2014; Zheng, Oka, Bokura, & Yamaguchi, 2008)—two domains that are highly relevant for emotion-relevant impulsivity. Working memory is clearly reliant on activation of the dlPFC (Curtis & d'Esposito, 2003), and improvements in working memory capacity are associated with reductions in impulsive choice forms of impulsivity (Bickel et al., 2012). Several studies have found evidence that the dlPFC is also an important component of response inhibition success (cf. Garavan, Ross, & Stein, 1999; Rubia et al., 2001; Zheng et al., 2008), though other evidence suggests that the dlPFC may only significantly contribute to response inhibition performance when complex versions of the task are used (e.g., versions that require switching between multiple stimulus-response associations; Simmonds, Pekar, & Mostofsky, 2008). Prospectively, lower activation in the dlPFC and other regions during a response inhibition task significantly predicts the initiation of heavy drinking in later adolescence (Norman, Pulido, Squeglia, Spadoni, Paulus, & Tapert, 2011), implicating weakness of the dlPFC as a risk factor for later problems with impulsive behavior.

Further evidence comes from brain stimulation studies, which show that disrupting dlPFC activation is associated with increased errors on response inhibition tasks (Beeli, Casutt, Baumgartner, & Jancke, 2008). Finally, several studies have demonstrated that training response inhibition is associated with changes in underlying neural networks relative to control conditions, as measured by both fMRI and EEG (Benikos, Johnstone, & Roodenrys, 2013a; Berkman, Kahn, & Merchant, 2014; Chavan, Mouthon, Draganski, van der Zwaag, & Spierer, 2015; Manuel et al., 2010; Manuel, Bernasconi, & Spierer, 2013). In sum, evidence supports a role for the dlPFC in both tasks involving working memory and inhibition. Though response inhibition is clearly dependent on a number of different brain regions (Simmonds et al., 2008), several findings show that the dlPFC is one important component of this network, and that training in response inhibition results in significant changes to underlying cognitive control circuitry.

Alternatively, Buckholz (2015) argued that rather than simply acting as a “brake” on behavior, the dlPFC may exert influence on behavior by changing the value associated with striatal, bottom-up signals (associated with reactivity to immediate reward) and thus improving decision-making. From this perspective, improving response inhibition abilities alone may be insufficient for reducing impulsive behavior, unless the dlPFC is sufficiently engaged in moderating bottom-up signals from the striatum. In the context of designing optimal interventions to reduce impulsivity, response inhibition training may need to be combined with interventions that actively engage top-down mechanisms, a possibility discussed in more detail below.

Cognitive Training for Impulsivity: Applications of Two-Mode Models

Given the extensive evidence for cognitive control deficits underlying impulsivity, one clear hypothesis is that remediating cognitive deficits might yield changes in impulsivity. Increasing evidence shows that cognitive training paradigms show promise for treating a variety of symptoms and deficits (Mishra & Gazzaley, 2014; Subramaniam & Vinogradov, 2013), including schizophrenia (Subramaniam, Luks, Fisher, Simpson, Nagarajan, & Vinogradov, 2012), ADHD (Klingberg et al., 2005), alcohol and substance use disorders (Wiers, Gladwin, Hofmann, Salemink, & Ridderinkhof, 2013), and healthy aging (Anguera et al., 2013). However, many criticisms of this literature have recently emerged, including recent reviews concluding that effects of cognitive training are inconsistent, that evidence for transfer is limited, and that commercially-available cognitive training programs have made claims for efficacy that are not supported by evidence (Buitenweg, Murre, & Ridderinkhof, 2012; Shipstead, Redick, & Engle, 2012). Despite some of the mixed findings, even these more critical reviewers have suggested that cognitive training methods could be useful for improving some specific domains, given further studies with more rigorous methodological standards (cf. Shipstead et al., 2012). Indeed, recent approaches to cognitive training have emphasized the importance of testing training paradigms that target specific neural circuits known to influence psychopathology, and of testing change in specific mechanisms assumed to underlie broader symptom outcomes (Siegle et al., 2007; Wiers et al., 2013). Consistent with this theory, targeted approaches to cognitive training have been found to effectively change specific cognitive and affective mechanisms (Baskin-Sommers, Curtin, & Newman, 2015; Siegle et al., 2007; Siegle et al., 2014). This approach is highly concordant with the NIMH RDoC emphasis (Insel et al., 2010). The current study builds on this idea of targeting more specific mechanisms, rather than broad psychopathologies.

Several previous studies provide evidence of the usefulness of cognitive training interventions focused on specific mechanisms within impulsivity. Drawing from two-mode models, multiple studies have now tested whether improving top-down control may be beneficial

for reducing certain aspects of impulsivity. The evidence to date suggests that training either reflexive or reflective mechanisms may be helpful in reducing some aspects of impulsivity, but some have argued that combining these approaches may be the most effective approach (cf. Wiers et al., 2013). Several studies have used modified response inhibition paradigms in which “no-go” stimuli are replaced by disorder-specific images (e.g., pictures of beer in alcohol use disorders), thus training inhibition in the context of specific cues. These studies have shown efficacy in a number of domains, including that training responses away from alcohol-related stimuli on reduces drinking as measured in the laboratory (Bowley et al., 2013; Jones & Field, 2013) and by self-report (Houben, Havermans, Nederkoorn, & Jansen, 2012; Houben, Nederkoorn, Wiers, & Jansen, 2011). Similarly, modified response inhibition tasks designed to elicit inhibition of food cues have been shown to reduce the likelihood of choosing unhealthy food choices (Veling, Aarts, & Stroebe, 2013) and reduce overall food consumption (Houben & Jansen, 2011) in laboratory tasks.

Though some of these disorder-specific paradigms have yielded promising results, one limitation is that the stimuli employed are specific to a certain type of stimulus, and thus may not generalize to broader gains in cognitive control. Supporting this possibility, some stimulus-specific inhibition studies have reported a lack of transfer to non-trained response inhibition tasks (e.g., Houben, Havermans, et al., 2012), while others have failed to replicate the impressive transfer effects of response inhibition training on self-reported alcohol consumption (Jones & Field, 2013). In contrast to these stimulus-specific studies, others have attempted to train broader context-independent aspects of response inhibition.

In reviewing the literature on inhibition training, Spierer, Chavan, and Manuel (2013) found that inhibition training that involves variability in “go” and “no-go” stimuli, as opposed to maintaining the same Go/NoGo pairings throughout the task, is most effective in generating training and transfer effects, as the variability in stimuli requires more frequent updating of top-down control. These findings are supported by data showing that stronger working memory capacity only improves response inhibition performance when more complex inhibition tasks, requiring more frequent updating information, are used (Redick, Calvo, Gay, & Engle, 2011). In addition, training that responsively adapts to individual skill level has been shown to be optimal for training procedures (cf. Manuel, Grivel, Bernasconi, Murray, & Spierer, 2010), as training effects are maximized when the task reflects a moderate difficulty (Benikos, Johnstone, & Roodenrys, 2013a, 2013b).

Even as these advances in understanding effects of inhibition training have emerged, relatively few studies have directly tested effects of this training on other dimensions of impulsive behavior. In two important exceptions, response inhibition training shows evidence of transfer, including reduced risky decision on a gambling task following one session of training (Verbruggen, Adams, & Chambers, 2012). Another single-session study found that training on a response inhibition task that emphasized withholding, rather than rapid responding, resulted in reduced alcohol consumption (Jones, Guerreri, Fernie, Cole, Goudie, & Field, 2011). In contrast, two studies have failed to document training-related improvements in response inhibition, in children (Thorell et al., 2009) and adults (Cohen & Poldrack, 2008), though neither of these studies tested transfer effects to other domains of impulsivity. Overall, experimental studies of processes involved in response inhibition suggest several clear guidelines for implementing training, but relatively few studies have explored the extent to which this training might reduce impulsivity.

Other studies have tested effects of working memory training. Though working memory training programs have proliferated in recent years, many findings of these initial studies have been criticized on methodological grounds (e.g., Shipstead et al., 2012), and relatively few studies have directly evaluated the effects of these programs on specific aspects of impulsivity. Working memory training in children with ADHD has been demonstrated to show reductions in response inhibition in some studies (Klingberg et al., 2005), while others have found improvements in working memory without change in inhibition in typically developing children (Thorell et al., 2009). In adults, working memory training has been found to effectively reduce delay discounting in people with stimulant abuse disorders (Bickel et al., 2012), and to reduce automatic bias for alcohol cues as well as actual alcohol consumption in people with problem drinking (Houben, Wiers, & Jansen, 2011). However, in the study by Bickel and colleagues (2012), working memory training did not influence response inhibition, indicating that training on one of these facets may not aid the other facet of cognitive control, even while exerting positive effects on other impulsivity outcomes. Given this, one goal of this study was to conjointly train these two skills.

Few studies have employed such combined training to date. Of those that have, much of this literature involves combined training programs for children, with mixed evidence for transfer and efficacy of training. Two such studies in children with ADHD found evidence for reduced symptoms of ADHD (Johnstone, Roodenrys, Phillips, Watt, & Mantz, 2010), with one of the two also reporting improved working memory performance on a transfer task; neither study found evidence of an improvement in response inhibition (Johnstone et al., 2012). However, no studies conducted in adults have tested whether outcomes relevant to impulsivity change as a result of combined working memory and response inhibition training. Specifically, no study has tested whether a combined, adaptive training program for working memory and response inhibition is efficacious in reducing aspects of emotion-relevant impulsivity.

In considering the development of optimal training paradigms for emotion-relevant impulsivity, there is much to be learned from a “near neighbor” in the literature: interventions designed to regulate emotion. Similar to training approaches for addiction, cognitive training paradigms designed to reduce rumination in depression have effectively demonstrated the successful application of a dual-systems approach, with training programs that require top-down control in the presence of emotional frustration and other bottom-up influences. As might be expected, much of the same cognitive control circuitry implicated in impulsivity also appears to be related to regulating emotions. Successful use of reappraisal is linked to engagement of the dlPFC (Buhle et al., 2014) and to dlPFC-reliant cognitive functions such as higher working memory (Schmeichel, Volokhov, & Demaree, 2008). Rumination on negative emotion, on the other hand, is associated with difficulties removing information from working memory in the context of major depressive disorder (Joormann & Gotlib, 2008; see Kircanski, Joormann, & Gotlib, 2012, for review) and with reduced activation in the dlPFC in people with MDD (Disner, Beevers, Haigh, & Beck, 2011). Based on these observations, researchers have begun to develop interventions that directly target cognitive control in order to improve emotion regulation in mood disorders. Siegle and colleagues have shown that an adaptive working memory task (based on the PASAT; Gronwall, 1977) designed to train cognitive control selectively activates the dlPFC (Price, Paul, Schneider, & Siegle, 2013), and that training programs involving this task lead to reductions in rumination in people with MDD (Siegle, Ghinassi, & Thase, 2007; Siegle et al., 2014).

Further research has replicated these findings and shown that greater improvement on working memory capacity is directly correlated with subsequent decrease in rumination (Vanderhasselt et al., 2015). Other studies have shown that PASAT training is associated with decreases in stress reactivity as well as rumination in people with high levels of trait rumination (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015), and with reductions in depression symptoms (Calkins, McMorran, Siegle, & Otto, 2014). Ongoing randomized, controlled trials are underway to test the broader applicability of this training as a preventative measure for depression (Hoorelbeke, Faelens, Behiels, & Koster, 2015). These findings suggest that cognitive training interventions for rumination and depression appear to show efficacy by targeting the same neural circuitry implicated in many forms of impulsivity. Moreover, the growing number of studies that support the use of cognitive control training for depression and rumination on negative affect raise the important point that training tasks need not be affectively-laden in order to engender change in affective processes. From this perspective, interventions to reduce emotion-relevant impulsivity might benefit from training cognitive control in the absence of explicitly emotionally valenced information.

Aims of the Present Study

Given evidence that emotion-relevant impulsivity is tied to a diverse range of behavioral and psychopathological outcomes, that impulsivity during strong emotional states is closely related to cognitive control difficulties, and that cognitive control interventions to improve emotion regulation are showing promising early results, the goal of this study was to test whether cognitive control training that combines working memory and response inhibition exercises is beneficial in a transdiagnostic sample of people reporting emotion-relevant impulsivity.

From the perspective of two-mode models, this training combined two exercises that are similar in that they are each designed to improve top-down control, while also differing in the way in which control over bottom-up reactivity is achieved. Working memory training is primarily designed to increase top-down control through activation of the dlPFC, though this task still requires the ability to resist the urge to give up on a challenging and frustrating task (cf. Siegle et al., 2007). Notably, some studies have used time spent completing non-adaptive forms of the PASAT as a measure of distress tolerance (e.g., Brown, Lejuez, Kahler, & Strong, 2002), again emphasizing the idea that practicing this task could improve both broad top-down control while also reducing bottom-up impulsive reactivity to negative emotion.

In contrast, the response inhibition training (Complex Go/No-Go) more directly involves inhibiting bottom-up reactivity, while still requiring flexibility and updating of top-down control mechanisms in order to successfully complete the task (e.g., to switch from inhibiting one stimulus to another). Unlike other forms of response inhibition training which decrease bottom-up reactivity to one specific type of stimulus, the complex training in this study allows for training of bottom-up reactivity in the context of applying top-down control to stimuli that are frequently changing.

In sum, despite the increasingly well-documented effects of emotion-relevant impulsivity as a transdiagnostic concern, the applicability of two-mode models to inform treatment development, and the advent of interventions to improve cognitive control via cognitive training paradigms, there are no available treatment options for emotion-relevant impulsivity. The development of such a treatment was the goal of this study. Given previous criticisms of cognitive training (Noack, Lovden, & Schmiedek, 2014; Shipstead et al., 2012; Shipstead, Hicks, & Engle, 2012), this study directly targeted two underlying mechanisms involved in emotion-relevant impulsivity, emphasized the use of multiple outcome measures to test the extent to

which this cognitive training intervention transfers beyond the immediate task, and established a clear theoretical motivation for the specific training tasks used.

Other central goals included testing whether this intervention shows “transfer” effects to other tests of cognitive control and impulsivity, including working memory, response inhibition, and a risk-taking task. As secondary goals, this study tested whether the cognitive intervention improved indices of emotion regulation and psychopathology symptoms, given the overlap between these two constructs. Emotion regulation and symptoms were evaluated before and after the intervention, using self-report measures.

Primary Hypotheses

Change in performance on the training tasks. We predicted that accuracy on the non-adaptive PASAT and non-adaptive Go/NoGo task would improve from pre-training to post-training.

Transfer effects of working memory and response inhibition. We predicted that performance on the Digit Span task would increase pre-training to post-training, and that this increase in performance would correlate with improved performance on the PASAT. Similarly, we predicted that performance on the antisaccade task would increase from pre- to post-training, and that this improvement would correlate with improved performance on the Go/NoGo task.

Change in emotion-relevant impulsivity. The primary study hypothesis was that scores on the Feelings Trigger Action scale would decrease from pre- to post-training.

Secondary Hypotheses

Change in emotion regulation. Secondary analyses tested predictions that the brooding facet of rumination would decrease from pre-training to post-training, and that use of reappraisal would increase from pre-training to post-training. Reductions in rumination have been reported in several studies using the same adaptive PASAT as the present study, in both clinically depressed individuals and students reporting selected based on high levels of ruminative tendencies (Hoorelbeke et al., 2015; Siegle et al., 2007; 2014; Vanderhasselt et al., 2015). In the present study, the goal was to test whether comparable reductions in rumination can be observed in a broader population characterized by a more diverse range of psychopathology. In addition, several studies have found associations of reappraisal ability with working memory capacity (Schmeichel, Volokhov, & Demaree, 2008), as well as dlPFC activation (Buhle et al., 2014; Goldin, McRae, Ramel, & Gross, 2008), so one goal of the present study was to test the degree to which cognitive training transfers to improvements in this putatively adaptive emotion regulation strategy.

Change in Risk-Taking. We predicted that participants would show a significant decrease in risk-taking from pre-training to post-training, as measured by performance on the BART task, a well-validated behavioral measure of willingness to take risks in the context of reward.

Change in symptoms. Regarding symptoms, secondary analyses tested whether a cluster of internalizing and externalizing symptoms relevant to emotion-relevant impulsivity also decrease as a result of the cognitive training intervention. The symptoms evaluated for this study encompass seven domains that have been identified by meta-analysis (Berg et al., 2015) and by prior transdiagnostic research (Johnson et al., 2013) as having the strongest associations with emotion-relevant impulsivity: aggression, substance use, non-suicidal self-injury (NSSI) and suicidal ideation, borderline personality traits, symptoms of bulimia, depression, and anxiety. To assess these traits, we identified measures from these domains that capture dependent variables that could be expected to change over the course of the two-week intervention period. The goal

of this analysis was to identify for future studies whether cognitive control training may be beneficial in reducing broad-band symptoms of diverse forms of psychopathology. As these measures assess symptoms occurring during the past two weeks, primary analyses tested change from pre-training to the follow-up assessment two weeks after the training has ended.

Method

Participants were recruited through online and print advertising in the community, and through advertisements sent to support groups and community clinics for specific populations known to have frequent difficulties with emotion-relevant impulsivity, including mood and anxiety disorders, eating disorders, borderline personality disorder, and substance use disorders. Some additional participants were undergraduate students recruited from classes at UC Berkeley, who received extra credit for taking the pre-screening survey. Potential participants were directed to an online consent form that pertained only to the pre-screening survey, at which point they could choose whether or not to complete an online version of the Feelings Trigger Action impulsivity scale (Carver, Johnson, et al., 2011). Based on previous studies, normative data is available for several hundred people on the Feelings Trigger Action Scale (see Carver, Johnson, et al., 2011); in the present study, individuals whose *z*-score fell at least one standard deviation above these established norms were invited to participate in the study. Potential scores on this measure range from 26 to 130; participants were informed that they were eligible to continue with the study if their score was 92 or higher (corresponding to an average response of 3.5 on a 5-point scale). Participants endorsing this high degree of emotion-relevant impulsivity were invited to provide their contact information to learn more; if they did so, they were invited to complete a phone screening session with a member of study staff.

A brief phone screening measure was used to ensure eligibility for the main study. Exclusion criteria assessed during this call included age outside of the study range (18-65), inability to attend the six in-lab training sessions detailed below, history of traumatic brain injury, brain tumor, or neurological disorders (e.g., Alzheimer's disease, Parkinson's disease, dementia), lack of proficiency in English, or acute suicidality or psychotic symptoms. There were no restrictions for race, ethnicity, or gender. Individuals with evidence of intellectual disability were also excluded, on the basis of an estimated IQ score equal to or lower than 70, based on performance on the Wechsler Test of Adult Reading (WTAR) administered at the enrollment session. If participants were determined to be eligible for study enrollment after the screening phone call, they were either randomized to the waitlist control condition or to the non-waitlist condition. Those participants randomized to the waitlist condition were invited to the laboratory to complete a pre-waitlist session, followed by the baseline session two weeks later. The pre-waitlist session included informed consent, the WTAR, the brief mental health history interview, and several of the same questionnaire measures as the baseline session (see Table 1). Participants randomized to the non-waitlist group were scheduled for the baseline session at their earliest convenience. This allowed for a comparison of pre- to post-training effects across both the waitlist and the intervention groups, as well as a comparison of training effects vs. no training in comparing changes in key variables over two weeks in the waitlist and intervention groups.

At the baseline session, all participants completed self-report and laboratory-based measures of impulsivity, cognitive control, emotion regulation, and symptoms, as described below. Current medication usage and dosage information was also assessed during this session. Table 1 lists the measures used in this study as well as the timeline for their administration.

Following the emotion regulation cognitive control training literature (e.g., Siegle et al., 2014), training included six in-lab training sessions (including the adaptive PASAT: a working memory task, and the Go/No-Go task: a response inhibition task) over the course of two weeks, with key dependent variables being change in impulsivity (both self-report and lab-based measures) from pre to post-intervention. Task order was randomized such that sessions began with either the PASAT or the Go/NoGo task each day. Each training session lasted approximately 35 minutes and took place on the UC Berkeley campus. Training sessions were scheduled based on participants' availability, with the only requirement being that participants must schedule training sessions for both weeks of the study (i.e., training could not be condensed into one week of the two-week intervention period). After the six training sessions, a post-training session was conducted that contained most of the same measures as the baseline session (see Table 1). Finally, participants were asked to participate in a follow-up session (to be completed via online questionnaires) two weeks after the post-training session. The purpose of this follow-up session was to assess change in symptoms relevant to psychopathology, substance abuse, emotion regulation, and impulsive behavior after the intervention had been fully completed.

Measures

Wechsler Test of Adult Reading (WTAR; Wechsler, 2001). The WTAR is a brief screening measure used to estimate intellectual functioning. It involves reading a list of 50 words out loud, and overall accuracy in pronunciation, together with demographic data, is used to estimate intellectual functioning. Previous validation studies have found that the WTAR estimates of IQ are correlated between 0.73 and 0.75 with full-scale intellectual testing (Wechsler, 2001).

Three-Factor Impulsivity Questionnaire (Carver, Johnson, et al., 2011). The Three-Factor Impulsivity Questionnaire is a composite self-report measure of scales relevant to impulsivity. The scale yields three factor-analytically derived subscales, which include Pervasive Influence of Feelings (the tendency for emotions to shape many aspects of life), Lack of Follow-Through (encompassing distractibility, lack of perseverance, and low self-control), and Feelings Trigger Action. This scale encompasses items rated from 1 to 5 regarding Positive Urgency (7 items), Negative Urgency (12 items), and Reflexive Reactions to Feelings (7 items). In previous studies, internal reliability for each of the three scales has been good, with alphas of 0.84 for Positive urgency items, 0.85 for reflexive reaction to feelings, and 0.90 for negative urgency (Carver, Johnson et al., 2011).

As mentioned above, Feelings Trigger Action has been associated with many self-reported forms of psychopathology (Johnson, Carver et al., 2013), with suicide attempts (Auerbach, Stewart, & Johnson, 2016), and with polymorphisms relevant to serotonin and dopaminergic function (Carver, Johnson et al., 2011; Carver, LeMoult, et al., 2014). This scale was the screening measure and the primary outcome variable, and was administered at screening, baseline, post-training, and follow-up.

At the baseline session, participants also completed the remaining two scales of the Three-Factor Impulsivity Measure not included in the pre-screening: Pervasive Influence of Feelings, which includes subscales of Negative Generalization, Sadness Paralysis, Emotions Color Worldview, Lethargy, and Urgency.³ The other dimension of the Three-Factor Impulsivity Measure is Lack of Follow-Through, which contains subscales of Lethargy, Lack of Perseverance, Lack of Self-Control, and Distractibility³.

Ruminative Response Scale - Brooding subscale (RRS; Nolen-Hoeksema, 1991). The RRS measures the tendency to ruminate on negative affect. The RRS yields several subscales pertaining to different types of repetitive thought; in the present study, only the brooding subscale was included, as this has been identified as most relevant to psychopathology (Treynor, Gonzalez, & Nolen-Hoeksema, 2003) and has been shown to decrease in previous studies of cognitive training using the PASAT (e.g., Siegle et al., 2014). Previous studies have identified that the brooding subscale has moderate reliability ($\alpha = 0.77$) and moderate test-retest reliability ($r = 0.62$ over one year) (Treynor et al., 2003).

Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). The ERQ is a measure of two commonly studied emotion regulation strategies - cognitive reappraisal (6 items) and expressive suppression (4 items). Initial validation of this scale showed good reliability (reappraisal $\alpha = 0.79$; suppression $\alpha = 0.73$) and test-retest reliability ($r = 0.69$ over three months; Gross & John, 2003). Hypotheses relevant to reappraisal are presented in “Analyses” below. Participants also completed the Emotion Regulation Questionnaire-Self Efficacy Scale (Goldin et al., 2012), a modified version of the ERQ that asks participants to rate their perceived capability of using reappraisal and suppression, using similar content to the original ERQ.

Borderline Symptom List-Short Form (BSL-23; Bohus et al., 2009). The BSL-23 is a shortened version of the full 95-item BSL, which assesses current symptoms of borderline personality disorder. It correlates strongly with the original full BSL, displays good psychometric properties (internal consistency: $\alpha = 0.94-0.97$), and is sensitive to changes in symptoms during psychosocial treatment (Bohus et al., 2009). Symptoms are evaluated on a 0 (“Not At All”) to 4 (“Very Strong”) scale, encompassing the past week. Symptoms of borderline personality disorder have been strongly associated with negative urgency in previous studies (Berg et al., 2015). As in some previous studies (e.g., Bohus et al., 2009), the BSL-23 was paired with a question asking about a participants’ overall global functioning, rated on a Visual Analogue Scale from 0 to 100. The BSL-23 also included a supplemental question set assessing the frequency of 11 behaviors sometimes associated with borderline symptoms. These include risk-taking, drug and alcohol use, bingeing and purging, non-suicidal self-injury, and suicidal ideation, and are rated on a 1 (“Not at All”) to 5 (“Daily or More Often”) scale for the past week. We included these additional items given their relevance to emotion-relevant impulsivity; items from this scale have been used in several previous studies evaluating similar constructs to emotion-relevant impulsivity, such as urges to engage in NSSI (Svaldi, Dorn, Matthies, & Philipsen, 2012).

Subtypes of Antisocial Behavior (STAB; Burt & Donellan, 2009). The STAB is a 31-item validated self-report questionnaire that addresses physical aggression ($\alpha = 0.85$), social aggression ($\alpha = 0.86$), and rule-breaking behaviors ($\alpha = 0.87$; Burt & Donellan, 2009), all of which are highly correlated with impulsivity. The STAB subscales also predict instances of daily-life antisocial behavior over one week (e.g., having the urge to hit someone, engaging in illegal activities) in an experience sampling study (Burt & Donellan, 2010). In a sample of undergraduate students, all three dimensions of the STAB correlated between .38 (social aggression) and .51 (physical aggression) with the Feelings Trigger Action measure (Johnson et al., in preparation), and aggression has also been identified as a strong correlate of negative urgency in meta-analysis (Berg et al., 2015).

Mood, Anxiety, and Stress Questionnaire-Short Form (MASQ-SF; Watson et al., 1995). The MASQ-SF is a 62-item abbreviated version of the original MASQ, based on the tripartite model of depression and anxiety (Watson et al., 1995). This scale assesses current (past

week) symptoms of depression and anxiety, and has been validated in a number of studies of psychopathology and/or impulsivity (e.g., Johnson et al., 2013). It includes subscales of General Distress-Depression symptoms and General Distress-Anxiety symptoms, as well as Anxious Arousal (e.g., physiological symptoms of anxiety) and Anhedonic Depression (e.g., lack of positive affect). Several previous studies have linked emotion-relevant impulsivity to symptoms of anxiety and depression (e.g., Carver et al., 2013; Johnson et al., 2013).

DSM-5 Self-Rated Level 1 Cross-Cutting Symptom Measure-Adult Version. To screen for substance use, participants completed the 3-item substance abuse section from the DSM-5 Self-Rated Level 1 Cross-Cutting Symptom Measure-Adult Version (American Psychiatric Association, 2013). This measure screens for the presence of problematic alcohol use, use of illicit drugs, and tobacco use. Drug and alcohol use often correlates with various dimensions of emotion-relevant impulsivity, with several studies finding evidence for both positive and negative urgency correlating with frequency of use (Berg et al., 2015; Cyders et al., 2010; Fischer et al., 2004; Zapolski et al., 2009).

Alexian Brothers Urge to Self-Injure scale (ABUSI; Washburn, Juzwin, Styer, & Aldridge, 2010). The ABUSI evaluates the frequency and intensity of urges to self-injure. It contains 5 items evaluating the frequency and intensity of urges to engage in NSSI; initial validation work suggests that this scale has good reliability ($\alpha = .92$ to 0.96) and validity, correlating with other established measures of suicidal ideation and self-harm (Washburn et al., 2010). Self-injury, suicidal ideation, and suicide attempts have all been found to associate with emotion-relevant impulsivity (Auerbach et al., 2016; Berg et al., 2015; Hamza, Willoughby, & Heffer, 2015), and negative urgency prospectively predicts the onset of NSSI (Riley, Combs, Jordan, & Smith, 2015).

Analysis of Self-Report Measures. Table 2 presents reliability data (Cronbach's α) for self-report scales mentioned above. Reliability ranged from acceptable to excellent for all measures, with the exception of the STAB Rule-Breaking subscale, which fell in the questionable range. To evaluate overall change in psychopathology, a composite measure was created based on selected self-report measures. The domains tested included aggression (STAB-Physical Aggression, STAB-Social Aggression, and STAB-Rule Breaking), substance use (DSM-5 substance abuse screener: binge drinking and drug use; BSL-23 behavioral supplement: "got drunk," "took medication not prescribed to me," and "took drugs" questions), NSSI and suicidal ideation (ABUSI; BSL-23 Behavioral Supplement "hurt myself by cutting, burning, strangling, headbanging etc.," "told other people that I was going to kill myself"), borderline personality traits (BSL-23), symptoms of bulimia (BSL-23 Behavioral Supplement "had episodes of binge eating," "induced vomiting"), depression (MASQ depression subscales), and anxiety (MASQ anxiety subscales). To create this composite measure, scores on each scale were transformed into z-scores for ease of comparison across measures. Z-transformed total scores of each scale were then summed to create a composite measure of pre-and post-treatment psychopathology. Given recent evidence that Feelings Trigger Action may be more relevant to externalizing symptoms (Johnson, Tharp, Peckham, Carver, & Haase, submitted), additional analyses separately tested change in composite variables made up of internalizing symptoms (anxiety, depression, suicidal ideation and self-harm urges, and symptoms of borderline personality disorder [BSL-23]) and externalizing symptoms (aggression, substance use, NSSI, and bulimia).

Antisaccade task. The antisaccade task is a computerized task that measures the ability to inhibit visual responses (Hallett, 1978), and is a commonly used, well-validated measure of

response inhibition (Friedman & Miyake, 2004). In the present study, a version of this task that contains a 10-trial prosaccade practice block and a 40-trial antisaccade trial block was used, based on procedures implemented in a previous study (cf. Unsworth, Schrock, & Engle, 2004). On each antisaccade trial, a cue is flashed quickly on one side of the screen, and participants are instructed to look at the opposite side of the screen as the cue to identify a letter. The task takes approximately 5 minutes to complete. Previous research has identified deficits in anti-saccade performance as a correlate of positive urgency (Johnson et al., 2016). The antisaccade was included primarily as a measure of “far transfer” of response inhibition training effects.

Individual trials of the antisaccade task were cleaned using a two-stage process. First, trials were excluded from analysis if reaction times were greater than three standard deviations above the mean or three standard deviations below the mean. This resulted in elimination of 1.45% of antisaccade trials, and zero percent of prosaccade trials. Second, the remaining trials were again subject to the same procedure, resulting in removal of an additional 0.47% of antisaccade trials. Participants were excluded from analysis if they achieved less than chance performance (50% accuracy) on the prosaccade practice trial block; this resulted in exclusion of three participants, leaving a final sample of 40 participants with valid baseline antisaccade task data. The same procedures were implemented for the post-training anti-saccade task. 1.25% of antisaccade trials were removed on the first pass of cleaning, and 0.67% were removed on the second pass. Two participants were excluded for failure to achieve greater than 50% performance on the prosaccade block, leaving a final sample of 32 participants at post-training.

Digits Forward and Digits Backwards Task (WAIS-IV; Wechsler et al., 2008). The Digits Forward and Digits Backwards subtests from the Wechsler Adult Intelligence Scale-4th Edition were administered as a measure of short-term memory and working memory capacity, respectively. These subtests were administered by a member of study staff who provided increasingly long strings of numbers for participants to repeat in order, or on the backwards trial, in reverse order. Each subtest includes up to 8 trials, with each trial containing two strings of digits of the same length. The task begins with two digits and progresses up to an eight-digit string; the task is discontinued when participants do not accurately recall both items in a given trial. This task is conceptually similar to the PASAT in that it involves briefly storing verbally-presented numbers in short-term memory. The digit span task was chosen to evaluate working memory primarily because these tasks have been used to evaluate working memory in numerous studies of psychopathology (e.g., Bourne et al., 2013). This task was included as a measure of “far transfer” of working memory training effects.

Paced Auditory Serial Attention Task (PASAT; Gronwall, 1977; Siegle et al., 2007). The PASAT is a computerized working memory task that takes approximately 15 minutes. The version of the PASAT used in the current study is the same that has been used in previous cognitive training studies (Siegle et al., 2007; Siegle et al., 2014). Participants listen to numbers presented one at a time and are instructed to add each number to the previous number, and then enter their response on the computer screen by clicking a number that corresponds to the correct answer. Thus, participants are continuously adding two numbers together over the course of the task, which lasts about 5 minutes. Previous studies of cognitive control training have used the non-adaptive PASAT as a baseline measure of working memory, and as a measure of “near transfer” of working memory training effects (e.g., Hoorelbeke & Koster, 2016; Siegle et al., 2007). For the non-adaptive PASAT used at baseline and post-training, task accuracy was evaluated based on the proportion of correct answers out of the total number of trials.

Complex Go/No-Go task. The go/no-go task is a commonly-used computerized response inhibition task. Participants are instructed to press a button in response to a certain letter (the “go” stimulus) and to withhold responses to another letter (the “no-go” stimulus). Because most trials are “go” trials, the task measures the tendency to withhold a previously learned response. The task is programmed in E-Prime (version 2.0) and is similar to tasks used in previous response inhibition training paradigms (e.g., Chavan et al., 2015). As opposed to Stop-Signal tasks, which evaluate the capacity to stop an already initiated response, Go/No-Go tasks measure the ability to inhibit a response before it has started, which has been argued to be a conceptually more useful for application of response inhibition paradigms to clinical populations (Aron, 2012). As in previous studies using Go/No-Go paradigms in the context of training, the Letters Go/No-Go task used in this study is considered a “complex” Go/No-Go task because it involves multiple different “go” and “no-go” cues. The cues used in the present study were the letters T, X, O, E, I, S, A, M, and H. The use of multiple different cues has been shown specifically to activate the dlPFC (Simmonds et al., 2008), and several researchers have suggested that this aspect of training is important for training top-down control (Spierer et al., 2013). For the non-adaptive GNG used at baseline and post-training, task accuracy was evaluated based on the percentage of false alarms (i.e., “go” responses to “no-go” cues).

Balloon Analogue Risk Task (BART; Lejuez et al., 2002). The BART is a computerized task that evaluates propensity to take risks in the context of possible rewards. Specifically, participants are tasked with pressing a key to pump up an image of a balloon on each trial; the larger the balloon gets, the more points they can win, but the balloon pops at a randomly determined point and no points are saved. However, participants can choose to “save” their winnings and stop pumping up a balloon at any point in a given trial; thus, exploding more balloons is conceptualized as a greater propensity to take risks for the possibility of reward. Performance on the BART task has been linked with a number of behaviors relevant to impulsivity, such as use of alcohol and drugs and risky sexual behaviors (Lejuez et al., 2002); relevant to the present study, higher scores on the positive urgency measure have been correlated with greater risk-taking on the BART (Cyders, Zapolski, Combs, Settles, Fillmore, & Smith, 2010). To increase motivation, participants in the present study were told that they would be entered into an additional drawing for a gift card for an online retailer, with a \$10 value, if they scored enough points to be in the top 10% of all study participants. A total of 31 trials were completed, with no time limit on each trial. The primary dependent variable analyzed was the proportion of balloons exploded across all trials.

Training Sessions

Adaptive PASAT (Siegle et al., 2007). The adaptive PASAT is a computerized working memory task that is identical to the task given at baseline, with the only exception being that the adaptive version either speeds up or slows down (increases or decreases the inter-stimulus interval) based on participants’ performance. Specifically, the inter-stimulus interval (ISI) begins at 3000 msc and increases by 100 msc following four incorrect responses, or decreases by 100 msc following four correct responses. Adapting the task in this way is designed to minimize frustration while still allowing for improvement in cognitive control (Siegle et al., 2007). This ensures that the participant is practicing the task at a difficulty level consistent with their cognitive control abilities. Training consists of three 5-minute blocks, for a total of 15 minutes. The task provides real-time feedback onscreen, showing the number of correct, incorrect, and missed responses throughout the task. The DV for the adaptive PASAT was the median ISI (in milliseconds) per training day, which reflects the adjusted speed at which participants were

completing the task (consistent with prior studies using the adaptive PASAT; e.g., Siegle et al., 2007).

Adaptive Go/No-Go. The adaptive go/no-go task is similar to the Go/No-Go task given at baseline, with the exception that the response time window for “go” responses is varied based on performance, with an increasing response “deadline” for incorrect trials and decreasing deadline for correct trials (cf. Manuel et al., 2010). This ensures that participants are consistently performing the task at a moderate difficulty level, which is optimal for response inhibition training (Benikos et al., 2013). In the present study, responses to “go” trials were initially marked as accurate if the participant responded within 300msc of stimulus onset. Following a correct “go” response, the deadline for a response to be counted as accurate was decreased by 25msc on each trial; following an incorrect “go” response (either a response that was not made, or a response that was outside of the deadline), the deadline was increased by 25msc. The minimum deadline possible was 50msc, and the maximum was 1000msc. Each day of training involves completing three blocks that are each about 5 minutes long, with a different “no-go” stimulus for each block. At the end of each block, a feedback screen showed participants their overall false alarm rate for that block. The dependent variable for the GNG task was the average false alarm rate per training day, averaged over all three blocks.

Treatment expectancy and credibility checks. Participants completed a brief set of rating scales before and after each training session, assessing beliefs about the rationality and perceived helpfulness of the cognitive training. Similar questions have been applied to previous similar studies of cognitive training (Hoorelbeke, Faelens, et al., 2015; Siegle et al., 2014), as expectancy effects has been shown to be a predictor of performance on some cognitive tasks (Oken, 2008). Before each training session, participants were asked to rate on a 1 (“Not at All”) to 5 (“A lot”) scale the following questions: “How much do you think these tasks will help to improve your self-control?,” “How much do you think these tasks will help you to regulate emotions?,” and “How confident in your ability to do these tasks do you feel right now?” Following each training session, participants again responded to these same questions, as well as responding to questions of “How hard were these tasks for you to complete?” and “How much effort did you put forth in completing these tasks?”

Analysis Plan

Confounds. Before conducting main analyses, all variables were graphed, checked for normality, and assessed for the presence of confounds. Chi-square tests were used for dichotomous variables and Pearson correlations were used for continuous variables. Where sphericity was violated in ANOVA, Greenhouse-Geisser corrected statistics are presented. Cohen’s d_z was calculated to assess the magnitude of within-subjects effects (cf. Lakens, 2013). Potential confounds that were tested included gender, as some prior research has found that negative urgency scores are slightly lower in men than in women (Cross, Copping, & Campbell, 2011); use of psychiatric medication and use of illicit drugs were considered as a potential confounds as well. Finally, treatment expectancy was tested as a potential correlate of improvement on the training tasks, given some previous evidence that treatment expectancy effects are important to consider in cognitive tasks (Oken, 2008).

Waitlist control tests. Preliminary analyses considered whether the waitlist period was associated with significant change on performance of cognitive control tasks and measures of emotion-relevant impulsivity, emotion regulation, and symptoms. Specifically, paired t -tests evaluated change between variables at the pre-waitlist condition as compared to the baseline

condition. Data for both the waitlist and intervention groups were then collapsed across conditions, in order to test overall changes from baseline to post-training, as described below.

Management of attrition. Previous studies with six-session training have found attrition rates of about 18 to 21% of randomized participants (Siegle et al., 2007, 2014). We minimized attrition in several ways. Participants received reminder calls and e-mails from study staff before their training sessions, and study staff attempted to schedule all training sessions at the baseline session. Participants received a list of their scheduled training sessions at this initial session. Study staff were available for appointments during business hours and some evenings, to accommodate variability in participants' schedules. To minimize attrition due to transportation problems, efforts were made to recruit participants from neighborhoods close to the UC Berkeley campus, and participants received a parking pass or public transit reimbursement if necessary.

Results

The Feelings Trigger Action (FTA) scale¹ was administered to a total of 926 adults; of those who completed the survey, 221 were potentially eligible on the basis of their high score on the FTA measure (see Figure 1). Of the 221 potential participants who were eligible on the basis of their impulsivity scores, 110 provided their contact information and indicated their willingness to complete a phone screen, and 63 were found to be eligible and scheduled for randomization into the main study. Eleven of these participants canceled or did not attend their enrollment session, resulting in a final sample of 52 participants. Table 3 shows relevant demographic and clinical variables for all 52 participants.

Examination of scores on the clinical self-report measures showed that many participants scored below threshold scores commonly used to identify clinically elevated syndromes. Scores on the DSM-5 Screening Measure for Substance Use Disorders indicated that 37% ($n = 17$) of participants met the threshold recommended for further screening for alcohol use disorders, and 32.6% ($n = 15$) met the threshold recommended for further screening for problems with illicit drug use. No participants scored above the commonly used cutoff (average score of 2 or higher) representing possible borderline personality disorder, and only one participant scored above the cutoff for possible sub-clinical symptoms of borderline personality disorder (average of 1.5 or higher). Urges to self-injure (ABUSI mean scores) were similarly well below average scores for clinical samples; all participants scored lower than the average ABUSI score for a treatment-seeking sample of individuals engaging in NSSI (Washburn et al., 2010). Average STAB physical aggression scores were slightly lower than average scores for college-age students in other samples (Burt & Donellan, 2009); while social aggression and rule-breaking scores on the same measure were comparable to previous studies of college-age students (Burt & Donellan, 2009). Overall, at the baseline session, 76.5% of participants reported either a clinically elevated score or a recent impulsive behavior on at least one measure. Most participants (nearly 83%) reported a history of past mental health diagnosis; participants with any past diagnosis scored higher on the MASQ General Distress-Anxiety scale, $t(45) = 3.37, p < .01$, and reported more frequent binge drinking and drug use ($ps < .05$), but did not differ from non-diagnosed participants on other measures of psychopathology (all $ps > .07$).

Regarding depression and anxiety symptoms, various cut-off scores for the MASQ have been proposed. 25.4% ($n = 12$) of the present sample scored at or above the average anxiety (Anxious Arousal) score in a sample of people diagnosed with anxiety disorders, and 38.3% ($n =$

18) scored at or above the average depression score (Anhedonic Depression) attained by a sample of people diagnosed with depression (Boschen & Oei, 2007).

Given these low base rates, analyses were conducted to examine whether undergraduate students differed from the community sample on symptom levels. Students did not differ from the community sample on any measure, including depression, $t(45) = -.09, p = .93$; anxiety, $t(45) = -1.20, p = .24$; the aggression scales (all $ps > .65$); the BSL behavioral supplement items (all $ps > .16$); self-injury urges, $t(45) = -.37, p = .71$; or substance use, $ps > .54$.

Analysis of Attrition

As shown in Figure 1, not all participants were able to complete the study. A total of five participants were lost to follow-up, seven participants dropped out of the study (one of whom returned to complete the follow-up measures), and one participant was too symptomatic to begin training sessions, resulting in an overall attrition rate of 23.08% (39 completers). However, 92.3% of participants completed the baseline measures and at least one full cognitive training session, allowing for an analysis of factors influencing dropout. Non-completers did not differ from completers on demographic variables (age, years of education, race, student vs. non-student status, or ethnicity, $ps > .10$), self-report measures of impulsivity (3-Factor Impulsivity Scales, all $ps > .08$), use of psychiatric medications ($p = .25$) or cognitive measures (WTAR, Digit Span task, baseline PASAT, baseline Go/NoGo false alarm rate, all $ps > .14$). However, non-completers were more symptomatic than study completers on several different dimensions. Non-completers reported more symptoms of Borderline Personality Disorder, $t(44) = 3.20, p = .003$, lower global quality of life, $t(20.54) = 2.82, p = .01$, and more current depression (MASQ General Distress-Depression, $t(45) = 2.31, p = .03$) and anxiety symptoms (MASQ Anxious Arousal, $t(45) = 2.65, p = .01$; MASQ General Distress-Anxiety, $t(45) = 2.00, p = .05$). Non-completers were also more likely than completers to endorse a history of one or more psychiatric hospitalizations ($\chi^2(1) = 4.14, p = .04$), and reported higher levels of aggression on all three subscales of the STAB ($ps < .05$). However, participants who did not complete the study did not differ from completers on problems with substance use ($ps > .11$, the Anhedonic Depression scale, $t(45) = -1.78, p = .08$, or frequency of binge eating, $t(7.28) = -2.04, p = .08$).

Pilot Phase

To pilot test treatment feasibility and acceptability, the first ten participants were automatically enrolled in the non-waitlist condition. Seven of these ten participants successfully completed the study, one was lost to follow-up after two training sessions, one dropped out after three training sessions but returned to complete the post-treatment questionnaires, and one participant did not attend their enrollment session. Participants enrolled in this phase were asked open-ended questions in which they provided feedback about the feasibility of the study design; participants generally indicated that having more flexibility in scheduling training sessions was their most prominent concern. Additional study staff were added in response to this feedback, allowing participants to be scheduled five days per week, including on two evenings.

Participants also completed a short feedback questionnaire during the first training session, in which they responded to several questions about the two training tasks on a five-point scale. Responses to these questions indicated that participants ($n = 9$) found the training session to be moderately challenging ($M = 3.33, SD = 0.50$), that they reported using a relatively high amount of effort to complete the tasks ($M = 4.44, SD = 0.73$), and that they felt relatively confident in their ability to complete the training tasks ($M = 3.44, SD = 1.13$). Based on this feedback, the pilot phase was concluded and all following participants were randomly assigned to either begin the study or enroll in the waitlist condition.

Waitlist Comparison Condition

Including the initial nine participants, a total of 28 participants were enrolled to the non-waitlist condition and 24 were enrolled to the waitlist. Individuals on the waitlist began the active training phase an average of 36.5 days ($SD = 24.25$) after they were initially screened with the FTA measure as compared to a 24.25-day ($SD = 21.06$) average time in the non-waitlist condition. Thus, individuals allocated to the waitlist condition had an average additional wait time of 12.32 days (slightly less than the 14-day waitlist target, due to scheduling problems and room availability).

Those on the waitlist showed a modest decrease in FTA scores between their initial screening and the beginning of training that did not reach significance, $t(18) = 1.16, p = 0.26$; for comparison, those in the non-waitlist condition showed a similar trend towards decreasing impulsivity, $t(26) = 1.92, p = .07$. Those allocated to the waitlist condition also completed a battery of additional (pre-baseline) self-report measures approximately two weeks before they began training.² During this waiting period, individuals on the waitlist did not report significant changes in quality of life, $t(15) = 1.60, p = .13$, nor changes in impulsive behaviors on the BSL-23 behavioral supplement (e.g., bingeing, purging, use of drugs and alcohol, self-harm, physical aggression, or reckless driving, all $ps > .16$). Those on the waitlist also did not show changes in anxiety or depression symptoms on the MASQ (all subscales $p > .28$), nor on the subscales that make up the Pervasive Influence of Feelings or Lack of Follow-Through scales ($ps > 0.17$). However, participants reported a decrease in symptoms related to Borderline Personality Disorder during the waitlist period, $t(18) = 4.19, p = .001$. Overall, these analyses show that the waitlist period was not associated with significant changes in impulsivity, impulsive behaviors, or mood or anxiety symptoms. Individuals on the waitlist were thus combined with the remainder of the sample for all following analyses of pre- and post-treatment indices.

Analysis of Potential Confounds and Baseline Correlations

Tables 4 and 5 show Pearson correlation matrices of major study variables at the baseline session. Scores on self-report measures showed normal distributions with the exception of some which assess behaviors expected to have lower base rates, including the ABUSI (skewness = 1.85), the Behavioral Supplement items of the BSL-23 (skewness for the 11 items ranged from 0.9 to 5.3), and the DSM-5 Substance Use Screening Measure (skewness of 1.1 for alcohol use and 1.8 for drug use). Table 4 shows correlations of baseline Feelings Trigger Action (FTA) scores with demographic and cognitive variables, and Table 5 shows baseline FTA correlations with baseline clinical variables. By design, FTA scores were constricted to the upper range of this scale; therefore, correlations comparing the FTA to other measures should be interpreted cautiously given the limited strength of these analyses. As planned, participants' scores on the baseline FTA scale were compared to several other variables to test for potential confounding effects. Men ($M = 4.13, SD = 0.53$) and women ($M = 3.87, SD = 0.47$) did not differ on their baseline scores for the FTA scale, $t(44) = 1.62, p = .11$; nor did they differ on the Urgency subscale specifically, $t(44) = 0.19, p = 0.85$. Similarly, FTA scores for participants taking medication ($M = 4.10, SD = 0.49$) did not differ from those who were not taking medication ($M = 3.89, SD = 0.49, t(44) = 1.66, p = .11$). As shown in Table 5, current illicit drug use was also not significantly correlated with baseline FTA scores. Finally, undergraduate students did not differ from non-student participants on their baseline FTA scores, $t(44) = 1.63, p = .11$.

Primary Analyses

Change in performance on the training tasks. A 2 (time: pre, post) by 2 (task: non-adaptive PASAT, non-adaptive GNG) analysis of variance (ANOVA) with task accuracy as the

dependent variable was used to test whether performance improved on the two cognitive training tests from pre- to post-intervention. Results showed a significant main effect of time, $F(1, 38) = 43.14, p < .001$, partial $\eta^2 = 0.53$; a significant main effect of task, $F(1, 38) = 16.95, p < .001$, partial $\eta^2 = 0.31$; and a significant Time x Task interaction, $F(1, 38) = 70.6, p < .001$, partial $\eta^2 = 0.65$. Post-hoc paired t -tests showed that performance on the non-adaptive PASAT significantly increased, $t(38) = 10.22, p < .001$, Cohen's $d_z = 1.66$; while performance on the non-adaptive Go/NoGo actually decreased slightly (i.e., an increased false alarm rate), $t(38) = 2.03, p = .05$, Cohen's $d_z = 0.33$. Participants' average reaction times to "Go" trials also decreased significantly, from an average of 219.9 msc to 147.2 msc, $t(38) = 6.85, p < .001$, Cohen's $d_z = 1.10$. For both the PASAT and Go/NoGo, baseline performance was strongly correlated with post-training performance, $r = .58, p < .001$ for PASAT, and $r = .57, p < .001$ for Go/NoGo.

Repeated-measures ANOVAs with training day as the repeated measure were also computed for both the adaptive PASAT and Go/No-Go tasks, to test whether participants' performance improved on the actual training programs. For these analyses, the first five days of training were used, as this was the closest whole number to the average number of training days completed by participants (resulting in a subsample of $n = 32$; using six administration points would reduce this number to 25 participants). Participants' accuracy on the adaptive PASAT task significantly improved during training, $F(1.94, 64.13) = 51.03, p < .001$, partial $\eta^2 = 0.61$. Post-hoc tests showed significant decreases in median ITI between each consecutive timepoint ($p < .01$ for each comparison) for an overall linear improvement. Similarly, average false alarm rate on the adaptive Go/NoGo task decreased significantly across training, $F(2.29, 73.23) = 5.30, p < .01$, partial $\eta^2 = 0.14$. However, improvement on the Go/NoGo task was less consistent than the PASAT. Post-hoc pairwise comparisons showed no change between the first and second day of training on the Go/No-Go task ($p = 0.36$); a significant decrease between days 2 to 3 ($p < .001$), an increased error rate from days 3 to 4 ($p = .03$), and finally a decrease in the error rate again from day 4 to 5 ($p = .03$). Thus, although performance improved on the adaptive inhibition task, these improvements were not consistently observed across days of training.

Tests of transfer effects of working memory and response inhibition. Paired t -tests showed that participants improved on their performance (longest digit span recalled) from pre- to post-training of both the Forward Digit Span task, $t(38) = 1.28, p = .21$, Cohen's $d_z = .20$, and Reverse Digit Span task, $t(38) = 1.09, p = .28$, Cohen's $d_z = .17$, but these changes did not reach significance. To compare these tasks with the PASAT, change scores were first calculated by subtracting the post-training performance from pre-training performance for both the Digit Span task and the PASAT. Change in PASAT accuracy rate from pre to post-treatment was not significantly correlated with change in Forward span ($r = -.07, p = 0.68$) or Reverse span ($r = 0.21, p = 0.21$) scores.

Performance on the antisaccade task was used to test potential transfer of response inhibition. Paired t -tests of the antisaccade task showed a significant improvement (a decrease in the proportion of trial failures) in pre- to post-training scores, $t(28) = 2.31, p = .03$, Cohen's $d_z = .37$. The failure rate on pro-saccade trials remained stable, $t(28) = 0.50, p = 0.62$, Cohen's $d_z = .09$, suggesting that improvement in response inhibition, rather than task familiarity, was responsible for the change in performance on antisaccade trials. Change in Go/NoGo false alarm rates was non-significantly correlated with change in antisaccade error rate, $r = 0.20, p = 0.31$.

Testing change in emotion-relevant impulsivity. Figure 2 shows change in Feelings Trigger Action scores for individuals who completed all three assessment points. A paired t -test comparing baseline emotion-relevant impulsivity (Feelings Trigger Action) to post-training

scores on the same measure showed a significant decrease, $t(36) = 4.04, p < .001$, Cohen's $d_z = 0.66$. An analysis of the 30 individuals who completed the FTA measure at baseline, post-training, and follow-up showed a significant main effect of time, $F(2, 58) = 13.88, p < .001$, partial $\eta^2 = 0.32$; post-hoc contrasts showed that FTA scores significantly decreased from post-training to the follow-up in this group, $F(1, 29) = 4.14, p = .05$.

Post-training FTA scores for the 39 completers were compared to change scores in the cognitive control variables, to test whether change in cognitive control contributed to level of impulsivity at the conclusion of training. Lower scores on the FTA scale at post-training were non-significantly correlated with improvements on the PASAT, $r = -.25, p = .13$, and were not significantly correlated with improvements on the Go/NoGo task, $r = -.08, p = .62$. Additional analyses showed that for participants who completed at least 5 training sessions, change in the adaptive versions of the PASAT and Go/NoGo were also not correlated significant with post-training FTA scores; PASAT: $r = .05, p = .79$, Go/NoGo: $r = .13, p = .48$.

Treatment expectancy and training outcome. Pearson correlations were used to test whether treatment expectancy at the beginning of training significantly predicted change in FTA scores during training. Results showed that having a greater belief that the training would improve self-control ($r = .30, p = .08$), having a greater belief that training would improve emotion regulation ($r = .27, p = .11$), and confidence in one's own ability to complete the training tasks ($r = .06, p = .74$) were not significantly correlated with change in FTA scores (though some were marginally correlated).

Training "dose" effects. Post-hoc analyses of training "dose" found that the number of training sessions completed was not correlated with change in performance on the non-adaptive PASAT ($r = .08, p = .64$) nor on the non-adaptive Go/NoGo ($r = .13, p = .45$). Regarding transfer tasks, number of training sessions completed was marginally correlated with an improvement on the Digits Backwards task, $r = .27, p = .09$, but not on the Digits Forward task, $r = .09, p = .59$. Number of sessions completed was significantly correlated with improvement on the antisaccade task, $r = 0.41, p = .03$. The number of completed training sessions was not significantly related to post-training Feelings Trigger Action scores, $r = -.06, p = .74$.

Results: Secondary Analyses

Change in risk-taking. A comparison of the number of balloons popped on the BART test from post-training compared to pre-training showed that contrary to hypotheses, participants popped significantly more balloons at post-training, indicating higher risk-taking, $t(32) = 2.39, p = .02$, Cohen's $d_z = .42$.

Change in emotion regulation. Secondary analyses tested effects of the cognitive control training in two domains: change in emotion regulation and change in symptoms relevant to impulsivity. Regarding emotion regulation, analyses included two separate paired t -tests for rumination (brooding) and for reappraisal. Brooding decreased significantly from baseline to post-training, $t(36) = 2.97, p < .01$, Cohen's $d_z = .49$; and continued to decrease from post-training to the follow-up, $t(30) = 2.24, p = .03$, Cohen's $d_z = .40$. Lower brooding scores at post-training were marginally but not significantly correlated with improvements on the PASAT, $r = -.27, p = .09$, and were not significantly correlated with changes in Go/NoGo accuracy, $r = -.22, p = .18$. Reappraisal (not assessed at post-training) significantly increased from pre-training to follow-up, $t(32) = 2.96, p < .01$, Cohen's $d_z = .52$; similarly, reappraisal efficacy also increased, $t(31) = 2.13, p = .04$, Cohen's $d_z = .38$. Changes in performance on the PASAT and Go/NoGo were not significantly correlated with these scores ($p > .15$ for all comparisons). For comparison,

neither suppression ($p = 0.81$) nor suppression efficacy ($p = .95$) significantly changed from pre-training to follow-up.

Change in symptoms. Regarding symptoms, secondary analyses tested whether a cluster of internalizing and externalizing symptoms relevant to emotion-relevant impulsivity also decrease as a result of the cognitive training intervention. The composite self-report psychopathology measure did not significantly change from pre-training to follow-up, $t(26) = 1.67, p = .11$, Cohen's $d_z = .32$. Analyses of individual composite scores showed that borderline symptoms ($p < .001$) and the aggression composite ($p = .01$) significantly increased, the depression composite indicated a non-significant increase ($p = .23$), and the remainder of the composite measures all indicated non-significant decreases (anxiety composite, $p = .13$; bulimia composite, $p = .16$; NSSI composite, $p = .19$; substance composite, $p = .79$). A second set of analyses tested change in externalizing symptoms separately from change in internalizing symptoms of psychopathology. These analyses indicated a marginal decrease in Externalizing symptoms, $t(27) = -1.71, p = .098$, Cohen's $d_z = .32$, and a non-significant decrease in Internalizing symptoms, $t(27) = -1.19, p = .243$, Cohen's $d_z = .22$.

As described above, most individuals enrolled in the study endorsed scores below clinical thresholds for symptoms, and many did not endorse any of the low base rate symptoms, such as NSSI; this raises the possibility of a floor effect in psychopathology measures that would interfere with the ability to detect changes. Of the six participants with scores above threshold on the MASQ Anxious Arousal scale who completed the study, anxiety non-significantly decreased from 39.57 to 32.67, $t(5) = 1.62, p = .17$, Cohen's $d_z = .66$. Similarly, of the nine participants with elevated scores on the MASQ Anhedonic Depression scores who completed the study, depression also non-significantly decreased from 82.67 to 75.33, $t(8) = 1.18, p = .27$, Cohen's $d_z = .39$.

The 12 participants with elevated ABUSI scores who completed the study showed a non-significant decrease in self-harm urges, $t(11) = .73, p = .48$, Cohen's $d_z = .21$. The 11 participants who reported binge drinking within the past two weeks and completed the study showed a non-significant decrease in binge frequency, $t(10) = 1.46, p = .18$, Cohen's $d_z = .44$. Among the eight participants who reported illicit drug use in the past two weeks and completed follow-up measures, frequency of drug use non-significantly decreased, $t(7) = 1.76, p = .12$, Cohen's $d_z = .62$. The nine participants who reported binge eating episodes (BSL-23) and completed follow-up showed a non-significant decrease in binge eating frequency, $t(8) = 1.18, p = .27$, Cohen's $d_z = .39$.

Change in components of impulsivity. Exploratory analyses were conducted to test which specific dimensions of impulsivity responded to the cognitive training intervention. Within the FTA scale, the subscales of Urgency ($t(37) = 3.42, p = .002$, Cohen's $d_z = .55$) and Positive Urgency ($t(36) = 3.98, p < .001$, Cohen's $d_z = .65$) decreased significantly from baseline to post-training, whereas Reflexive Reaction to Feelings showed a non-significant decrease, $t(36) = 1.73, p = .09$, Cohen's $d_z = .28$. During the two-week follow-up, Urgency scores continued to decrease, $t(31) = 2.15, p = .04$, Cohen's $d_z = .38$, as did Reflexive Reaction to Feelings scores, $t(31) = 2.19, p = .04$, Cohen's $d_z = .39$. Positive Urgency decreased non-significantly, $t(31) = .78, p = .44$, Cohen's $d_z = .14$.

In contrast, there was no significant change on the Pervasive Influence of Feelings scale from pre-training to post-training, $t(36) = 1.29, p = .21$, Cohen's $d_z = .21$; this measure also did not significantly change from post-training to follow-up, $t(30) = .08, p = 0.94$, Cohen's $d_z = .01$. Similarly, Lack of Follow-Through did not significantly change from pre- to post-training, $t(36)$

= 1.97, $p = .06$, Cohen's $d_z = .32$; nor from post-training to follow-up, $t(30) = 0.48$, $p = 0.63$; Cohen's $d_z = .09$.

Analyses of individual subscales showed that scores on the Lack of Self-Control scale decreased from pre-training to post-training ($p = .01$), while none of the other measures encompassing Pervasive Influence of Feelings or Lack of Follow-Through changed during this time (all $ps > .08$). During the follow-up period, there was no change in the subscales of Emotions Color Worldview, Sadness Paralysis, or Lack of Perseverance (all $ps > 0.39$); however, participants reported decreases in Distractibility ($p = .04$), Inability to Overcome Lethargy, ($p = .03$), Lack of Self-Control ($p = .01$), and Negative Generalization ($p < .01$).

Discussion

There is mounting evidence for the importance of emotion-relevant impulsivity across many forms of psychopathology, and for other important consequences associated with this trait. To the best of our knowledge, this study represents the first test of a combined cognitive training intervention, focused on working memory and response inhibition that specifically targets emotion-relevant impulsivity. Results provided initial evidence that cognitive control training is both feasible and efficacious in reducing emotion-relevant impulsivity, and that the training is associated with gains in working memory and response inhibition, as well as improvements in emotion regulation.

Discussion of Primary Findings

Most participants enrolled in this study completed the intervention, and most completed the full training protocol. This suggests that the “dose” of cognitive training used in the present study—35 minutes, in person, six times over two weeks—is a feasible and generally acceptable intervention. Though more data are clearly needed, these results indicate that a frequent and relatively demanding cognitive training program, delivered in person, is generally well-tolerated by people prone to impulsive reactivity to emotion. However, analyses of predictors of attrition showed that people who did not complete the study were generally more symptomatic than those who completed the intervention. Previous cognitive training studies using similar methods have been implemented in the context of clinical care (e.g., Siegle et al., 2007; 2014) or delivered remotely via the internet (e.g., Hoorelbeke & Koster, 2016). This study demonstrates that cognitive training for impulsivity is feasible in a format that is less structured than integration into clinical practice and less flexible than delivery via the internet, which introduces the possibility that the frequency and type of cognitive training tested here could be expanded into new delivery formats in future studies. Integration of cognitive training with other treatments may be necessary to prevent the high level of attrition seen in individuals with higher symptom levels.

Beyond feasibility, participants who completed the intervention reported a significant decrease in emotion-relevant impulsivity corresponding to a large effect size. In contrast, emotion-relevant impulsivity scores did not significantly decline during the waitlist period, suggesting that some component of the cognitive training intervention influenced the observed decrease in impulsivity. However, the absence of an active control condition limits our ability to conclude that the cognitive training program contributed to the decrease in self-reported impulsivity. The possibility that demand characteristics influenced outcome cannot be excluded, given that participants were recruited on the basis of problematic emotion-relevant impulsivity and were not deceived about the study's focus on cognitive training for impulsivity. Belief that

the training would improve one's self-control was marginally correlated with change in impulsivity, suggesting that attitudes about the intervention were responsible for some small degree of the observed change.

Despite these uncertainties, the primary finding of significantly decreased emotion-relevant impulsivity in the context of a two-week intervention is clinically significant. Momentarily leaving aside the question of mechanistic change, there are few targeted treatments for emotion-relevant impulsivity. Some psychosocial treatments provide strategies for managing impulsive responses to emotion, such as chain analysis in Dialectical Behavior Therapy (DBT; c.f. Linehan, 2014), and there is ample evidence that DBT effectively reduces a number of impulsive behaviors, such as non-suicidal self-injury (e.g., Linehan, Korslund, et al., 2015). Despite these impressive findings, DBT is a relatively long treatment (24 weeks or more), and dropout rates from DBT treatment are relatively high, with estimates of as many as 30% of individuals in treatment trials and up to 58% of patients in community settings (Landes, Chalker, & Comtois, 2016; Rizvi, 2011). The present study demonstrates that significant changes in emotion-triggered impulsivity are feasible within a two-week, low-intensity intervention period. For individuals who may be susceptible to treatment dropout due to emotional instability, the present study suggests that targeted cognitive training could be a feasible component of interventions.

A key goal of the study was to examine potential mechanisms guiding the beneficial outcomes. Surprisingly, although working memory and response inhibition have each been proposed as mechanisms driving emotion-relevant impulsivity, baseline performance on tasks in each of these domains was not correlated with FTA. Regarding changes in cognitive control, the intervention was associated with a large improvement in working memory performance on a near-transfer task (the non-adaptive PASAT), with no significant evidence of far transfer (the Digits task). The improvement on a non-adaptive PASAT task following training with the adaptive PASAT replicates several prior findings using similar study designs (Hoorelbeke & Koster, 2016; Siegle et al., 2007). In contrast, participants did not improve their response inhibition performance on a near-transfer task (the non-adaptive Go/NoGo), while performance on far transfer task of response inhibition (the antisaccade task) significantly increased. Several explanations for these somewhat discrepant patterns are plausible.

Regarding working memory effects, participants improved on a non-adaptive version of the training task, but did not show significant improvements on a test of far transfer using the Digit Span task. This may be due to the fact that the Digit Span task has relatively little room for improvement, in that participants remembered on average about five to seven digits at baseline, and the test has a maximum performance level of only eight digits. Given the well-studied limitations of working memory capacity (cf. Miller, 1956), it is possible that the Digit Span task simply lacked the sensitivity to register changes in working memory. Alternatively, as the PASAT taps multiple cognitive resources including addition, holding answers in short-term memory, executing a response, and flexibly updating memory to retain the last number presented, a better test of transfer may be a task that evaluates working memory capacity alongside these other complex demands. Finally, when considering the performance improvement on the non-adaptive PASAT, another explanation may be that participants improved on the PASAT due to becoming more acclimated to the task rather than due to an improvement in underlying working memory capacity. Previous studies have used the PASAT as a stress-inducing measure (e.g., Brown et al., 2002), and it is possible that participants simply improved in their ability to tolerate a challenging and distressing task. Overall, the results of this

study do not suggest that training on the PASAT improves basic working memory capacity, but do suggest that people with a high degree of impulsive reactivity to emotion can improve their ability to perform a demanding cognitive task that taps working memory resources.

Regarding response inhibition, participants improved their performance on the adaptive, training version of the Go/NoGo task, but showed a surprising decrement in performance on the non-adaptive task at post-training, compared to baseline scores. One possibility for this discrepancy could be that the non-adaptive Go/NoGo task was administered at the very end of the post-training session, so fatigue effects are a possible explanation for this finding, particularly given the sustained attentional demands of this task. However, participants improved their performance on a response inhibition transfer task, the antisaccade task. While practice effects may be a possible explanation for this improvement, it is notable that antisaccade task performance is thought to be relatively stable over time (Klein & Fischer, 2005). Other studies have trained participants specifically on an antisaccade task and demonstrated improvements in error rate over two weeks (Dyckman & McDowell, 2005), which suggests that the observed decrease in error rate in the present study is a plausible outcome of response inhibition training. In sum, this study demonstrated that highly impulsive individuals can improve their ability to inhibit prepotent responses on both an adaptive training task and on a conceptually similar oculomotor response inhibition task, despite showing a lack of improvement on a non-adaptive response inhibition task.

Despite changes in performance on the cognitive control tasks, post-training emotion-relevant impulsivity scores were not significantly correlated with changes in cognitive control task performance (changes in PASAT performance were moderately correlated with lower Feelings Trigger Action scores at post-training, but this effect was not statistically significant). This suggests that other factors aside from improvement in working memory and response inhibition contributed to the observed decrease in impulsivity. Beyond the expectancy effects discussed above, it is possible that improvement in working memory and/or response inhibition potentiated changes in cognitive control that were not measured in the present study. Importantly, cognitive control in the context of heightened emotional arousal was not directly measured in this study. An untested hypothesis is that practicing response inhibition and working memory strategies allowed some participants to better control their responses to emotion in daily life, and that this improved control over emotional reactivity is the active ingredient driving change in the Feelings Trigger Action measure. In other words, engaging in the intervention could have provided practice using skills that required further refinement in the context of actual situations where participants are at risk for impulsive reactivity to emotions. One hypothesis for future study is to test whether improvements in response inhibition and working memory capacity also lead to reductions in impulsivity during the experience of actual emotional arousal.

Participants who completed the intervention also demonstrated significant improvements in two domains of emotion regulation: a decrease in rumination and an increase in use of cognitive reappraisal. The decrease in brooding rumination replicates and extends several previous findings, which have shown similar decreases in rumination following PASAT training in both clinical and non-clinical samples (Hoorelbeke & Koster, 2016; Hoorelbeke et al., 2015; Siegle et al., 2007; Siegle et al., 2014; Vanderhasselt et al., 2015). The present study adds to this growing list of citations documenting the efficacy of the adaptive PASAT training program for reducing rumination on negative affect, and extends these findings by illustrating how rumination robustly decreases in a heterogeneous sample of individuals with high levels of emotion-driven impulsivity.

Participants also reported a significant increase in use of reappraisal and perceived efficacy of reappraisal. Notably, one recent cognitive training study conducted in undergraduate students found no evidence of changes in reappraisal following training on the PASAT only (Hoorelbeke, Koster, Demeyer, Loeys, & Vanderhasselt, 2016), suggesting that working memory training alone is perhaps not sufficient to change use of reappraisal. Taken together with the present finding, it is possible that the additional training in response inhibition provided in the current study contributed an important component necessary to increase use of reappraisal. Apart from working memory, inhibition has also been identified as an important mechanism underlying cognitive reappraisal (e.g., Goldin, McRae, Ramel, & Gross, 2008; Joormann & Vanderlind, 2014; Ochsner et al., 2004; Schmeichel & Tang, 2015). Findings of this study suggest that two weeks of training in response inhibition, together with the working memory intervention, were sufficient to significantly increase use of reappraisal. More studies are needed to examine how inhibition and working memory training might separately or jointly contribute to reappraisal improvement. Given the many psychological and health benefits associated with use of reappraisal (e.g., John & Gross, 2004; McRae et al., 2012), future studies of this cognitive training paradigm focused on adaptive emotion regulation strategies are warranted.

Despite the significant decrease in impulsivity and associated changes in cognitive control and emotion regulation, this study found little evidence that the intervention was associated with change in psychopathology symptoms or with decreases in behaviors relevant to impulsivity. Post-hoc analyses found that externalizing symptoms of psychopathology were somewhat more responsive, albeit at a non-significant trend level, to the cognitive training intervention than internalizing symptoms. This finding is consistent with recent evidence showing that the Feelings Trigger Action measure is particularly relevant to impulsive external behavior, whereas another dimension of impulsivity on the same scale—Pervasive Influence of Feelings—is more relevant to internalizing syndromes (Johnson et al., submitted).

One possibility for the lack of significant effects on most psychopathology measures may be due to the selection of a very heterogeneous sample, which included a mixture of undergraduate students, individuals with extensive mental health diagnosis histories, and individuals receiving varying levels of psychiatric care. This diversity in the sample resulted in a relatively small number of individuals with elevated symptoms of psychopathology, leaving little room to test hypotheses about symptom change. Impulsivity within any particular individual may influence a broad range of outcomes, and this study was certainly limited by the small number of participants with impulsivity-related symptoms of psychopathology. However, the relatively low level of psychopathology in study participants could not be fully explained by heterogeneity, as participants from the community did not significantly differ from undergraduate students on psychopathology measures, and participants with past mental health diagnoses generally reported the same level of psychopathology as those without a history of diagnosis. This suggests that future research would benefit from studying additional moderators that could influence the pathway between impulsivity and psychopathology.

For some measures, including those of borderline personality traits and suicidal ideation, hypotheses about symptom change could not be tested at all given a lack of participants meeting the threshold for clinically elevated syndromes. Similarly, very few participants reported clinically elevated symptoms of anxiety or depression. Fewer than half of study participants endorsed current problems with binge eating, drug use, binge drinking, or urges to engage in NSSI, and even fewer participants endorsed other impulsive behaviors such as frequent or risk-taking or recent NSSI. Where symptoms or impulsive behaviors were present at baseline, there

was some post-hoc evidence that participants who completed the intervention showed non-significant, modest decreases in these behaviors, though power was severely limited for such analyses. Although about three quarters of participants at baseline reported at least one clinical elevation or recent impulsive behavior on self-report measures, many participants with more elevated scores did not finish the study. More research is clearly needed to assess the extent to which cognitive training for impulsivity is beneficial for people with more significant mental health challenges.

There was also no evidence that the cognitive training intervention influenced risk-taking as measured by the BART task, and in fact, participants showed an increase in risk-taking (number of balloons popped) on this task after the intervention. One explanation of this unexpected result could be that changes in cognitive control and in emotion-relevant impulsivity do not share a common mechanism with the type of financial risk-taking assessed via the BART. This is consistent with other recent findings showing no relationship between BART outcomes and emotion-relevant impulsivity (Johnson, Tharp, et al., 2016; Yau, Potenza, Mayes, & Crowley, 2015). The form of risk-taking assessed in the present study was relatively mild and was not tied to significant consequences, and participants may have felt emboldened to take more risks on the task after having already completed it previously at the baseline session. More research is needed to understand how emotion-relevant impulsivity relates to risk-taking in real-world, emotionally evocative environments.

Limitations

Findings of this study should be interpreted in the context of several important limitations. First, although there were no significant changes in emotion-relevant impulsivity during the waitlist period, and a robust drop in impulsivity during the intervention, the reasons for this change in impulsivity are not entirely clear without the inclusion of an active control training condition. It is possible that some of this effect could be explained by repeated interactions with research team members, rather than effects of the intervention itself. Second, study findings may have been influenced by expectancy effects, as participants were recruited and fully informed of the purpose of the study before beginning training, and belief that the training would influence self-control was marginally correlated with the primary outcome variable. Future studies could probe this possibility by testing the same intervention marketed in different ways, for example, to “improve self control” or to “improve cognitive abilities. Third, this study contained a heterogeneous sample of individuals with a wide range of symptoms and level of functioning and from various referral sources. Emotion-relevant impulsivity, though elevated for all participants, may lead to different types of consequences for high-functioning college students as compared to older adults with chronic psychiatric disorders. Emotion-relevant impulsivity is broadly linked to many impulsive behaviors and psychopathology, but within this study’s heterogeneous sample, few study completers showed clinically significant problems that are typically linked to impulsivity. Borderline personality disorder is robustly linked to emotion-relevant impulsivity, but no participants recruited for this study endorsed high levels of such traits. Future studies could test effects of training in more carefully targeted subgroups of individuals. Fourth, power analyses suggested that the study was slightly underpowered to detect changes in cognitive control. A priori power analyses, conducted using G*Power (version 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007), indicated that a sample of at least 46 completed participants were required for planned 2 x 2 ANOVA tests to achieve a medium effect size (Cohen’s $f = 0.25$), or a sample size of at least 44 participants to achieve a medium effect size (Cohen’s $d_z = 0.50$) for paired t -tests. The final sample of 39 completers fell short of these

targets, although the large effect size observed for the change in impulsivity suggests that this primary finding was not greatly influenced by power limitations. Finally, the training tasks in this study were chosen in order to enhance prefrontal cortical functioning, but without a measurement of cognitive control at the neural level, the degree to which underlying cognitive control networks were engaged by the training program is unknown. Future studies could make use of EEG technology or similar methods that would allow in-vivo exploration of changes in cognitive control occurring during training.

Implications

Despite these limitations, this study demonstrated that emotion-relevant impulsivity is modifiable in the context of a brief cognitive training intervention aimed at enhancing cognitive control. Emotion-relevant impulsivity is a transdiagnostic feature that is associated with a number of significant symptoms and problematic behaviors, yet few if any existing treatments target this specific aspect of psychopathology. The findings that cognitive control training also was linked to increased reappraisal, reduced rumination, and improvements on working memory and response inhibition tasks all suggest that the training program offered in the present study could have benefits extending beyond the reduction in emotion-triggered impulsivity.

Another primary finding of this study was that improvement in cognitive control was not a large predictor of improvement in impulsivity. Although the findings suggest that the training targets of both working memory and response inhibition were engaged, changes in these domains did not strongly correlate with post-training level of impulsivity. This would imply that other mechanisms, either within the domain of cognitive control or more broadly, could be important and as yet unknown determinants of change in impulsivity.

One important future direction will be test the extent to which this training program could be delivered in naturalistic settings, and whether the gains demonstrated here are observable in environments with a lesser degree of control. The findings presented in this study were obtained in a laboratory setting that maintained maximal control over data collection, and a frequent question from participants was whether they could take the intervention home at the end of the study. Reducing the problems that are associated with emotion-relevant impulsivity is a process that can only occur in individuals' lives outside the laboratory, and the extent to which a cognitive control training program such as this could be integrated into naturalistic treatment delivery settings is an important goal for future research.

References

- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.
- American Psychiatric Association. (2013). DSM-5 Self-Rated Level 1 Cross-Cutting Symptom Measure—Adult. Retrieved from <https://www.psychiatry.org/psychiatrists/practice/dsm/dsm-5/online-assessment-measures>
- Anguera, J. A., Boccanfuso, J., Rintoul, J. L., Al-Hashimi, O., Faraji, F., Janowich, J., ... Gazzaley, A. (2013). Video game training enhances cognitive control in older adults. *Nature*, *501*, 97–101. doi:10.1038/nature12486
- Aron, A. R. (2012). From reactive to proactive and selective control: developing a richer model for stopping inappropriate responses. *Biological Psychiatry*, *69*, e55-e68. doi:10.1016/j.biopsych.2010.07.024
- Auerbach, R., Stewart, J.G., & Johnson, S.L. (2016). Impulsivity and suicidality in adolescent inpatients. *Journal of Abnormal Child Psychology*. E-pub ahead of print. doi:10.1007/s10802-016-0146-8
- Bagge, C. L., Littlefield, A. K., Rosellini, A. J., & Coffey, S. F. (2013). Relations among behavioral and questionnaire measures of impulsivity in a sample of suicide attempters. *Suicide and Life-Threatening Behavior*, *43*, 460–467. doi:10.1111/sltb.12030
- Bardone-Cone, A. M., Butler, R. M., Balk, M. R., & Koller, K. A. (2016). Dimensions of impulsivity in relation to eating disorder recovery. *The International Journal of Eating Disorders*. E-pub ahead of print. doi:10.1002/eat.22579
- Bari, A., & Robbins, T. W. (2013). Inhibition and impulsivity: Behavioral and neural basis of response control. *Progress in Neurobiology*, *108*, 44–79. doi:10.1016/j.pneurobio.2013.06.005
- Baskin-Sommers, A. R., Curtin, J. J., & Newman, J. P. (2015). Altering the cognitive-affective dysfunctions of psychopathic and externalizing offender subtypes with cognitive remediation. *Clinical Psychological Science*, *3*, 45–57. doi:10.1177/2167702614560744
- Bechara, A. (2005). Decision making, impulse control and loss of willpower to resist drugs: a neurocognitive perspective. *Nature Neuroscience*, *8*, 1458–1463. doi:10.1038/nn1584
- Beeli, G., Casutt, G., Baumgartner, T., & Jäncke, L. (2008). Modulating presence and impulsiveness by external stimulation of the brain. *Behavioral and Brain Functions*, *4*, 33. doi:10.1186/1744-9081-4-33
- Beeli, G., Koeneke, S., Gasser, K., & Jancke, L. (2008). Brain stimulation modulates driving behavior. *Behavioral and Brain Functions*, *4*, 34. doi:10.1186/1744-9081-4-34
- Benikos, N., Johnstone, S. J., & Roodenrys, S. J. (2013a). Short-term training in the Go/Nogo task: Behavioural and neural changes depend on task demands. *International Journal of Psychophysiology*, *87*, 301–312. doi:10.1016/j.ijpsycho.2012.12.001
- Benikos, N., Johnstone, S. J., & Roodenrys, S. J. (2013b). Varying task difficulty in the Go/Nogo task: The effects of inhibitory control, arousal, and perceived effort on ERP components. *International Journal of Psychophysiology*, *87*, 262–272. doi:10.1016/j.ijpsycho.2012.08.005
- Berg, J. M., Latzman, R. D., Bliwise, N. G., & Lilienfeld, S. O. (2015). Parsing the heterogeneity of impulsivity: A meta-analytic review of the behavioral implications of the UPPS for psychopathology. *Psychological Assessment*, *27*, 1129–1146. doi: 10.1037/pas0000111.

- Berkman, E. T., Kahn, L. E., & Merchant, J. S. (2014). Training-induced changes in inhibitory control network activity. *Journal of Neuroscience*, *34*, 149–157. doi:10.1523/JNEUROSCI.3564-13.2014
- Bickel, W. K., Jarmolowicz, D. P., Mueller, E. T., Gatchalian, K. M., & McClure, S. M. (2012). Are executive function and impulsivity antipodes? A conceptual reconstruction with special reference to addiction. *Psychopharmacology*, *221*, 361–387. doi:10.1007/s00213-012-2689-x
- Bohus, M., Kleindienst, N., Limberger, M. F., Stieglitz, R. D., Domsalla, M., Chapman, A. L., ... Wolf, M. (2009). The short version of the Borderline Symptom List (BSL-23): Development and initial data on psychometric properties. *Psychopathology*, *42*, 32–39. doi:10.1159/000173701
- Boschen, M. J., & Oei, T. P. S. (2007). Discriminant validity of the MASQ in a clinical sample. *Psychiatry Research*, *150*, 163–171. doi: 10.1016/j.psychres.2006.03.008
- Bourne, C., Aydemir, O., Balanzá-Martínez, V., Bora, E., Brissos, S., Cavanagh, J. T. O., ... Goodwin, G. M. (2013). Neuropsychological testing of cognitive impairment in euthymic bipolar disorder: An individual patient data meta-analysis. *Acta Psychiatrica Scandinavica*, *128*, 149–162. doi: 10.1111/acps.12133
- Bowley, C., Faricy, C., Hegarty, B., Johnstone, S. J., Smith, J. L., Kelly, P. J., & Rushby, J. A. (2013). The effects of inhibitory control training on alcohol. *International Journal of Psychophysiology*, *89*, 342–348. doi: 10.1016/j.ijpsycho.2013.04.011
- Brown, R. A., Lejuez, C. W., Kahler, C. W., & Strong, D. R. (2002). Distress tolerance and duration of past smoking cessation attempts. *Journal of Abnormal Psychology*, *111*, 180–185. doi:10.1037/0021-843X.111.1.180
- Buckholtz, J. W. (2015). Social norms, self-control, and the value of antisocial behavior. *Current Opinion in Behavioral Sciences*, *3*, 122–129. doi:10.1016/j.cobeha.2015.03.004
- Buhle, J. T., Silvers, J. A., Wager, T. D., Lopez, R., Onyemekwu, C., Kober, H., ... Ochsner, K. N. (2014). Cognitive reappraisal of emotion: A meta-analysis of human neuroimaging studies. *Cerebral Cortex*, *24*, 1–10. doi:10.1093/cercor/bht154
- Buitenweg, J. I. V., Murre, J. M. J., & Ridderinkhof, K. R. (2012). Brain training in progress: a review of trainability in healthy seniors. *Frontiers in Human Neuroscience*, *6*, 1–11. doi:10.3389/fnhum.2012.00183
- Burt, S. A., & Donnellan, M. B. (2009). Development and validation of the subtypes of antisocial behavior questionnaire. *Aggressive Behavior*, *35*, 376–398. doi:10.1002/ab.20314
- Burt, S. A., & Donnellan, M. B. (2010). Evidence that the Subtypes of Antisocial Behavior questionnaire (STAB) predicts momentary reports of acting-out behaviors. *Personality and Individual Differences*, *48*, 917–920. doi:10.1016/j.paid.2010.02.021
- Burton, C. M., Pedersen, S. L., & McCarthy, D. M. (2012). Impulsivity moderates the relationship between implicit associations about alcohol and alcohol use. *Psychology of Addictive Behaviors*, *26*, 766–772. doi:10.1037/a0028742
- Calkins, A. W., McMorran, K. E., Siegle, G. J., & Otto, M. W. (2014). The effects of computerized cognitive control training on community adults with depressed mood. *Behavioural and Cognitive Psychotherapy*, *43*, 578–589. doi:10.1017/S1352465814000046
- Carver, C.S., Johnson, S.L., & Joermann, J. (2008). Serotonergic function, two-mode models of self-regulation, and vulnerability to depression: What depression has in common with impulsive aggression. *Psychological Bulletin*, *134*, 912–943. doi: 10.1037/a0013740

- Carver, C. S., Johnson, S. L., & Joormann, J. (2009). Two-mode models of self-regulation as a tool for conceptualizing effects of the serotonin system in normal behavior and diverse disorders. *Current Directions in Psychological Science*, 18, 195–199. doi:10.1111/j.1467-8721.2009.01635.x
- Carver, C. S., Johnson, S. L., & Joormann, J. (2013). Major depressive disorder and impulsive reactivity to emotion: Toward a dual-process view of depression. *British Journal of Clinical Psychology*, 52, 285–299. doi:10.1111/bjc.12014
- Carver, C. S., Johnson, S. L., Joormann, J., Kim, Y., & Nam, J. Y. (2011). Serotonin transporter polymorphism interacts with childhood adversity to predict aspects of impulsivity. *Psychological Science*, 22, 589–595. doi:10.1177/0956797611404085
- Carver, C. S., Johnson, S. L., Joormann, J., & Scheier, M. F. (2015). An evolving view of the structure of self-regulation. In G. H. E. Gendolla, M. Tops, & S. L. Koole (Eds.), *Handbook of Biobehavioral Approaches to Self-Regulation* (pp. 9–23). New York: Springer-Verlag. doi:10.1007/978-1-4939-1236-0
- Carver, C. S., LeMoult, J., Johnson, S. L., & Joormann, J. (2014). Gene effects and GxE interactions in the differential prediction of three aspects of impulsiveness. *Social Psychological and Personality Science*, 5, 730–739. doi:10.1177/1948550614527116
- Chavan, C. F., Mouthon, M., Draganski, B., van der Zwaag, W., & Spierer, L. (2015). Differential patterns of functional and structural plasticity within and between inferior frontal gyri support training-induced improvements in inhibitory control proficiency. *Human Brain Mapping*, 36, 2527–2543. doi:10.1002/hbm.22789
- Chester, D. S., Lynam, D. R., Milich, R., Powell, D. K., Andersen, A. H., & DeWall, C. N. (2016). How do negative emotions impair self-control? A neural model of negative urgency. *NeuroImage*, 132, 43–50. doi: 10.1016/j.neuroimage.2016.02.024
- Cho, S. S., Ko, J. H., Pellecchia, G., Van Eimeren, T., Cilia, R., & Strafella, A. P. (2010). Continuous theta burst stimulation of right dorsolateral prefrontal cortex induces changes in impulsivity level. *Brain Stimulation*, 3, 170–176. doi:10.1016/j.clinph.2011.06.006.A
- Cohen, J. R., & Poldrack, R. A. (2008). Automaticity in motor sequence learning does not impair response inhibition. *Psychonomic Bulletin & Review*, 15, 108–115. doi:10.3758/PBR.15.1.108
- Cross, C. P., Copping, L. T., & Campbell, A. (2011). Sex differences in impulsivity: a meta-analysis. *Psychological Bulletin*, 137, 97–130. doi:10.1037/a0021591
- Curtis, C. E., & D'Esposito, M. (2003). Persistent activity in the prefrontal cortex during working memory. *Trends in Cognitive Sciences*, 7, 415–423. doi:10.1016/S1364-6613(03)00197-9
- Cyders, M. A., & Coskunpinar, A. (2011). Measurement of constructs using self-report and behavioral lab tasks: Is there overlap in nomothetic span and construct representation for impulsivity? *Clinical Psychology Review*, 31, 965–82. doi:10.1016/j.cpr.2011.06.001
- Cyders, M. A., Dzemidzic, M., Eiler, W. J., Coskunpinar, A., Karyadi, K. A., & Kareken, D. A. (2014). Negative urgency mediates the relationship between amygdala and orbitofrontal cortex activation to negative emotional stimuli and general risk-taking. *Cerebral Cortex*, 25, 4094–4102. doi:10.1093/cercor/bhu123
- Cyders, M. A., Smith, G. T., Spillane, N. S., Fischer, S., Annus, A. M., & Peterson, C. (2007). Integration of impulsivity and positive mood to predict risky behavior: development and validation of a measure of positive urgency. *Psychological Assessment*, 19, 107–118. doi:10.1037/1040-3590.19.1.107

- Cyders, M. A., & Coskunpinar, A. (2012). The relationship between self-report and lab task conceptualizations of impulsivity. *Journal of Research in Personality*, 46, 121–124. doi:10.1016/j.jrp.2011.11.005
- Cyders, M. A., Flory, K., Rainer, S., & Smith, G. T. (2009). The role of personality dispositions to risky behavior in predicting first year college drinking. *Addiction*, 104, 193–202. doi:10.1111/j.1360-0443.2008.02434.x
- Cyders, M. A., Zanolini, T. C. B., Combs, J. L., Settles, R. F., Fillmore, M. T., & Smith, G. T. (2010). Experimental effect of positive urgency on negative outcomes from risk taking and on increased alcohol consumption. *Psychology of Addictive Behaviors*, 24, 367–375. <http://doi.org/10.1037/a0019494>
- Disner, S. G., Beevers, C. G., Haigh, E. A. P., & Beck, A. T. (2011). Neural mechanisms of the cognitive model of depression. *Nature Reviews Neuroscience*, 12, 467–77. doi:10.1038/nrn3027
- Dolan, S. L., Bechara, A., & Nathan, P. E. (2008). Executive dysfunction as a risk marker for substance abuse: The role of impulsive personality traits. *Behavioral Sciences & the Law*, 26, 799–822. <http://dx.doi.org/10.1002/bsl.845>
- Dyckman, K. A., & McDowell, J. E. (2005). Behavioral plasticity of antisaccade performance following daily practice. *Experimental Brain Research*, 162, 63–69. doi:10.1007/s00221-004-2105-9
- Endres, M. J., Rickert, M. E., Bogg, T., Lucas, J., & Finn, P. R. (2011). Externalizing psychopathology and behavioral disinhibition: working memory mediates signal discriminability and reinforcement moderates response bias in approach-avoidance learning. *Journal of Abnormal Psychology*, 120, 336–351. doi:10.1037/a0022501
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods*, 39, 175–191. doi:10.3758/BF03193146
- Fecteau, S., Pascual-Leone, A., Zald, D. H., Liguori, P., Théoret, H., Boggio, P. S., & Fregni, F. (2007). Activation of prefrontal cortex by transcranial direct current stimulation reduces appetite for risk during ambiguous decision making. *Journal of Neuroscience*, 27, 6212–6218. doi:10.1523/JNEUROSCI.0314-07.2007
- Figner, B., Knoch, D., Johnson, E. J., Krosch, A. R., Lisanby, S. H., Fehr, E., & Weber, E. U. (2010). Lateral prefrontal cortex and self-control in intertemporal choice. *Nature Neuroscience*, 13, 538–539. doi:10.1038/nn.2516
- Finn, P. R., Gunn, R. L., & Gerst, K. R. (2014). The effects of a working memory load on delay discounting in those with externalizing psychopathology. *Clinical Psychological Science*, 3, 202–214. doi:10.1177/2167702614542279
- Finn, P. R., Mazas, C., Justus, A., & Steinmetz, J. E. (2002). Early-onset alcoholism with conduct disorder: Go/NoGo learning deficits, working memory capacity, and personality. *Alcoholism: Clinical and Experimental Research*, 26, 186–206. doi:10.1111/j.1530-0277.2002.tb02524.x
- Fischer, S., Anderson, K. G., & Smith, G. T. (2004). Coping with distress by eating or drinking: role of trait urgency and expectancies. *Psychology of Addictive Behaviors*, 18, 269–274. doi:10.1037/0893-164X.18.3.269
- Fischer, S., Smith, G. T., & Cyders, M. A. (2008). Another look at impulsivity: A meta-analytic review comparing specific dispositions to rash action in their relationship to bulimic

- symptoms. *Clinical Psychology Review*, 28, 1413–1425.
doi:10.1016/j.cpr.2008.09.001.
- Another
- Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General*, 133, 101–135. doi:10.1037/0096-3445.133.1.101
- Garavan, H., Ross, T. J., & Stein, E. A. (1999). Right hemispheric dominance of inhibitory control: an event-related functional MRI study. *Proceedings of the National Academy of Sciences of the United States of America*, 96, 8301–8306. doi:10.1073/pnas.96.14.8301
- Gay, P., Rochat, L., Billieux, J., d'Acremont, M., & Van der Linden, M. (2008). Heterogeneous inhibition processes involved in different facets of self-reported impulsivity: evidence from a community sample. *Acta Psychologica*, 129, 332–9. doi:10.1016/j.actpsy.2008.08.010
- Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: reappraisal and suppression of negative emotion. *Biological Psychiatry*, 63, 577–86. doi:10.1016/j.biopsych.2007.05.031
- Goldin, P. R., Ziv, M., Jazaieri, H., Werner, K., Kraemer, H., Heimberg, R. G., & Gross, J. J. (2012). Cognitive reappraisal self-efficacy mediates the effects of individual cognitive-behavioral therapy for social anxiety disorder. *Journal of Consulting and Clinical Psychology*, 80, 1034–1040. doi: 10.1037/a0028555
- Grenard, J. L., Ames, S. L., Wiers, R. W., Thush, C., Sussman, S., & Stacy, A. W. (2008). Working memory capacity moderates the predictive effects of drug-related associations on substance use. *Psychology of Addictive Behaviors*, 22, 426–432. doi:10.1037/0893-164X.22.3.426
- Gronwall, D.M.A. (1977). Paced auditory serial addition task: A measure of recovery from concussion. *Perceptual and Motor Skills*, 44, 367–373. doi: 10.2466/pms.1977.44.2.367
- Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, 85, 348–362. doi:10.1037/0022-3514.85.2.348
- Gunn, R. L., & Finn, P. R. (2015). Applying a dual process model of self-regulation: The association between executive working memory capacity, negative urgency, and negative mood induction on pre-potent response inhibition. *Personality and Individual Differences*, 75, 210–215. doi:10.1016/j.paid.2014.11.033
- Hallett, P. E. (1978). Primary and secondary saccades to goals defined by instructions. *Vision Research*, 18, 1279–1296. doi:10.1016/0042-6989(78)90218-3
- Hamza, C. A., Willoughby, T., & Heffer, T. (2015). Impulsivity and nonsuicidal self-injury: A review and meta-analysis. *Clinical Psychology Review*, 38, 13–24.
doi:10.1016/j.cpr.2015.02.010
- Hofmann, W., Gschwendner, T., Friese, M., Wiers, R. W., & Schmitt, M. (2008). Working memory capacity and self-regulatory behavior: toward an individual differences perspective on behavior determination by automatic versus controlled processes. *Journal of Personality and Social Psychology*, 95, 962–977. doi:10.1037/a0012705
- Hoorelbeke, K., Faelens, L., Behiels, J., & Koster, E. H. W. (2015). Internet-delivered cognitive control training as a preventive intervention for remitted depressed patients: Protocol for a randomized controlled trial. *BMC Psychiatry*, 15, 125. doi:10.1186/s12888-015-0511-0
- Hoorelbeke, K., & Koster, E. H. W. (2016). Internet-delivered cognitive control training as a preventive intervention for remitted depressed patients: Evidence from a double-blind

- randomized controlled trial study. *Journal of Consulting and Clinical Psychology*. E-pub ahead of print. doi: 10.1037/ccp0000128
- Hoorelbeke, K., Koster, E. H. W., Demeyer, I., Loeys, T., & Vanderhasselt, M.-A. (2013). Effects of cognitive control training on the dynamics of (mal)adaptive emotion regulation in daily life. *Emotion*, *13*, 1689–1699. doi: 10.1017/CBO9781107415324.004
- Hoorelbeke, K., Koster, E. H. W., Vanderhasselt, M., Callewaert, S., & Demeyer, I. (2015). The influence of cognitive control training on stress reactivity and rumination in response to a lab stressor and naturalistic stress. *Behaviour Research and Therapy*, *69*, 1-10. doi:10.1016/j.brat.2015.03.010
- Hoptman, M. J., Antonius, D., Mauro, C. J., Parker, E. M., & Javitt, D. C. (2014). Cortical thinning, functional connectivity, and mood-related impulsivity in schizophrenia: Relationship to aggressive attitudes and behavior. *American Journal of Psychiatry*, *171*, 939–948. doi: 10.1176/appi.ajp.2014.13111553
- Houben, K., Havermans, R. C., Nederkoorn, C., & Jansen, A. (2012). Beer à no-go: Learning to stop responding to alcohol cues reduces alcohol intake via reduced affective associations rather than increased response inhibition. *Addiction*, *107*, 1280–1287. doi:10.1111/j.1360-0443.2012.03827.x
- Houben, K., & Jansen, A. (2011). Training inhibitory control: a recipe for resisting sweet temptations. *Appetite*, *56*, 345–349. doi:10.1016/j.appet.2010.12.017
- Houben, K., Nederkoorn, C., Wiers, R. W., & Jansen, A. (2011). Resisting temptation: Decreasing alcohol-related affect and drinking behavior by training response inhibition. *Drug and Alcohol Dependence*, *116*, 132–136. doi:10.1016/j.drugalcdep.2010.12.011
- Houben, K., Wiers, R. W., & Jansen, A. (2011). Getting a grip on drinking behavior: training working memory to reduce alcohol abuse. *Psychological Science*, *22*, 968–975. doi:10.1177/0956797611412392
- Insel, T., Cuthbert, B., Garvey, M., Heinssen, R., Pine, D. S., Quinn, K., ... Wang, P. (2010). Research domain criteria (RDoC): toward a new classification framework for research on mental disorders. *American Journal of Psychiatry*, *167*, 748–51. doi:10.1176/appi.ajp.2010.09091379
- Jacob, G. A., Gutz, L., Bader, K., Lieb, K., Tüscher, O., & Stahl, C. (2010). Impulsivity in borderline personality disorder: Impairment in self-report measures, but not behavioral inhibition. *Psychopathology*, *43*, 180–188. doi:10.1159/000304174
- John, O. P., & Gross, J. J. (2004). Healthy and unhealthy emotion regulation: personality processes, individual differences, and life span development. *Journal of Personality*, *72*, 1301–33. <http://doi.org/10.1111/j.1467-6494.2004.00298.x>
- Johnson, S. L., Carver, C. S., & Joormann, J. (2013). Impulsive responses to emotion as a transdiagnostic vulnerability to internalizing and externalizing symptoms. *Journal of Affective Disorders*, *150*, 872–878. doi:10.1016/j.jad.2013.05.004
- Johnson, S.L., Tharp, J., Peckham, A.D., Carver, C.S, & Haase, C.M. (submitted). A path model of different forms of impulsivity with externalizing and internalizing psychopathology: towards greater specificity.
- Johnson, S.L., Tharp, J., Peckham, A.D., Sanchez, A.H, & Carver, C.S. (2016). Positive urgency is related to difficulty inhibiting prepotent responses. *Emotion*, *16*, 750-759. doi: 10.1037/emo0000182

- Johnstone, S. J., Roodenrys, S., Blackman, R., Johnston, E., Loveday, K., Mantz, S., & Barratt, M. F. (2012). Neurocognitive training for children with and without AD/HD. *ADHD Attention Deficit and Hyperactivity Disorders*, 4, 11–23. doi:10.1007/s12402-011-0069-8
- Johnstone, S. J., Roodenrys, S., Phillips, E., Watt, A. J., & Mantz, S. (2010). A pilot study of combined working memory and inhibition training for children with AD/HD. *ADHD Attention Deficit and Hyperactivity Disorders*, 2, 31–42. doi:10.1007/s12402-009-0017-z
- Jones, A., & Field, M. (2013). The effects of cue-specific inhibition training on alcohol consumption in heavy social drinkers. *Experimental and Clinical Psychopharmacology*, 21, 8–16. doi:10.1037/a0030683
- Jones, A., Guerrieri, R., Fernie, G., Cole, J., Goudie, A., & Field, M. (2011). The effects of priming restrained versus disinhibited behaviour on alcohol-seeking in social drinkers. *Drug and Alcohol Dependence*, 113, 55–61. doi:10.1016/j.drugalcdep.2010.07.006
- Joormann, J., & Gotlib, I. H. (2008). Updating the contents of working memory in depression: interference from irrelevant negative material. *Journal of Abnormal Psychology*, 117, 182–92. <http://doi.org/10.1037/0021-843X.117.1.182>
- Joormann, J., & Vanderlind, W. M. (2014). Emotion regulation in depression: The role of biased cognition and reduced cognitive control. *Clinical Psychological Science*, 2, 402–421. <http://doi.org/10.1177/2167702614536163>
- Joseph, J. E., Liu, X., Jiang, Y., Lynam, D., & Kelly, T. H. (2009). Neural correlates of emotional reactivity in sensation seeking. *Psychological Science*, 20, 215–223. doi:10.1111/j.1467-9280.2009.02283.x
- Khurana, A., Romer, D., Betancourt, L. M., Brodsky, N. L., Giannetta, J. M., & Hurt, H. (2013). Working memory ability predicts trajectories of early alcohol use in adolescents: The mediational role of impulsivity. *Addiction*, 108, 506–515. doi:10.1111/add.12001
- Kim, S., & Lee, D. (2011). Prefrontal cortex and impulsive decision making. *Biological Psychiatry*, 69, 1140–1146. doi:10.1016/j.biopsych.2010.07.005
- Kircanski, K., Joormann, J., & Gotlib, I. H. (2012). Cognitive aspects of depression. *Wiley Interdisciplinary Review of Cognitive Science*, 3, 301–313. doi: 10.1002/wcs.1177
- Klein, C., & Fischer, B. (2005). Instrumental and test-retest reliability of saccadic measures. *Biological Psychology*, 68, 201–213. doi:10.1016/j.biopsycho.2004.06.005
- Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlstrom, K., ... Westerberg, H. (2005). Computerized training of working memory in children with ADHD: A randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry*, 44, 177–186. doi:10.1016/S0084-3970(08)70044-6
- Knoch, D., Gianotti, L. R. R., Pascual-Leone, A., Treyer, V., Regard, M., Hohmann, M., & Brugger, P. (2006). Disruption of right prefrontal cortex by low-frequency repetitive transcranial magnetic stimulation induces risk-taking behavior. *Journal of Neuroscience*, 26, 6469–6472. doi:10.1523/JNEUROSCI.0804-06.2006
- Krämer, U. M., Solbakk, A.-K., Funderud, I., Løvstad, M., Endestad, T., & Knight, R. T. (2013). The role of the lateral prefrontal cortex in inhibitory motor control. *Cortex*, 49, 837–849. doi:10.1016/j.cortex.2012.05.003
- Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, 4, 1–12. doi:10.3389/fpsyg.2013.00863
- Landes, S. J., Chalker, S. A., & Comtois, K. A. (2016). Predicting dropout in outpatient dialectical behavior therapy with patients with borderline personality disorder receiving

- psychiatric disability. *Borderline Personality Disorder and Emotion Dysregulation*, 3, 9. <http://doi.org/10.1186/s40479-016-0043-3>
- Lejuez, C.W., Read, J.P., Kahler, C.W., Richards, J.B., Ramsey, S.E., Stuart, G.L...Brown, R.A. (2002). Evaluation of a behavioral measure of risk taking: The Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied*, 8, 75–84. doi: 10.1037//1076-898x.8.2.75
- Linehan, M.M. (2014). *DBT skills training manual* (2nd Ed). New York, NY: Guilford Press.
- Linehan, M. M., Korslund, K. E., Harned, M. S., Gallop, R. J., Lungu, A., Neacsiu, A. D., ... Murray-Gregory, A. M. (2015). Dialectical behavior therapy for high suicide risk in individuals with borderline personality disorder. *JAMA Psychiatry*, 72, 475–482. doi:10.1001/jamapsychiatry.2014.3039
- Lipszyc, J., & Schachar, R. (2010). Inhibitory control and psychopathology: a meta-analysis of studies using the stop signal task. *Journal of the International Neuropsychological Society*, 16, 1064–1076. doi:10.1017/S1355617710000895
- Lozano, J. H. (2015). Are impulsivity and intelligence truly related constructs? Evidence based on the fixed-links model. *Personality and Individual Differences*, 85, 192–198. doi:10.1016/j.paid.2015.04.049
- Manuel, A. L., Bernasconi, F., & Spierer, L. (2013). Plastic modifications within inhibitory control networks induced by practicing a stop-signal task: An electrical neuroimaging study. *Cortex*, 49, 1141–1147. doi:10.1016/j.cortex.2012.12.009
- Manuel, A. L., Grivel, J., Bernasconi, F., Murray, M. M., & Spierer, L. (2010). Brain dynamics underlying training-induced improvement in suppressing inappropriate action. *Journal of Neuroscience*, 30, 13670–13678. doi:10.1523/JNEUROSCI.2064-10.2010
- McRae, K., Jacobs, S. E., Ray, R. D., John, O. P., & Gross, J. J. (2012). Individual differences in reappraisal ability: Links to reappraisal frequency, well-being, and cognitive control. *Journal of Research in Personality*, 46, 2–7. <http://doi.org/10.1016/j.jrp.2011.10.003>
- Miller, G.A. (1956). The magical number seven, plus-or-minus two: Some limits on our capacity for processing information. *Psychological Review*, 63, 81–97. doi: 10.1037/0033-295X.101.2.343
- Minamoto, T., Osaka, M., & Osaka, N. (2010). Individual differences in working memory capacity and distractor processing: Possible contribution of top-down inhibitory control. *Brain Research*, 1335, 63–73. doi:10.1016/j.brainres.2010.03.088
- Mishra, J., & Gazzaley, A. (2014). Harnessing the neuroplastic potential of the human brain & the future of cognitive rehabilitation. *Frontiers in Human Neuroscience*, 8, 218. doi:10.3389/fnhum.2014.00218
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, a H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: a latent variable analysis. *Cognitive Psychology*, 41, 49–100. doi:10.1006/cogp.1999.0734
- Muhtadie, L., Johnson, S. L., Carver, C. S., Gotlib, I. H., & Ketter, T. A. (2014). A profile approach to impulsivity in bipolar disorder: The key role of strong emotions. *Acta Psychiatrica Scandinavica*, 129, 100–108. doi:10.1111/acps.12136
- Noack, H., Lövdén, M., & Schmiedek, F. (2014). On the validity and generality of transfer effects in cognitive training research. *Psychological Research*, 78, 773–789. doi:10.1007/s00426-014-0564-6

- Nolen-Hoeksema, S. (1991). Responses to depression and their effects on the duration of depressive episodes. *Journal of Abnormal Psychology, 100*, 569–582. doi: 10.1037/0021-843X.100.4.569
- Norman, A. L., Pulido, C., Squeglia, L. M., Spadoni, A. D., Paulus, M. P., & Tapert, S. F. (2011). Neural activation during inhibition predicts initiation of substance use in adolescence. *Drug and Alcohol Dependence, 119*, 216–223. doi:10.1016/j.drugalcdep.2011.06.019
- Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. E., & Gross, J. J. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage, 23*, 483–499. doi:10.1016/j.neuroimage.2004.06.030
- Oken, B. S. (2008). Placebo effects: Clinical aspects and neurobiology. *Brain, 131*, 2812–2823. doi:10.1093/brain/awn116
- Peeters, M., Janssen, T., Monshouwer, K., Boendemaker, W., Pronk, T., Wiers, R., & Vollebergh, W. (2015). Weaknesses in executive functioning predict the initiating of adolescents' alcohol use. *Developmental Cognitive Neuroscience, 16*, 139–146. doi:10.1016/j.dcn.2015.04.003
- Price, R. B., Paul, B., Schneider, W., & Siegle, G. J. (2013). Neural correlates of three neurocognitive intervention strategies: A preliminary step towards personalized treatment for psychological disorders. *Cognitive Therapy and Research, 37*, 657–672. doi:10.1007/s10608-012-9508-x
- Redick, T. S., Calvo, A., Gay, C. E., & Engle, R. W. (2011). Working memory capacity and go/no-go task performance: selective effects of updating, maintenance, and inhibition. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 37*, 308–324. doi:10.1037/a0022216
- Riley, E. N., Combs, J. L., Jordan, C. E., & Smith, G. T. (2015). Negative urgency and lack of perseverance: Identification of differential pathways of onset and maintenance risk in the longitudinal prediction of non-suicidal self-injury. *Behavior Therapy, 46*, 439–448. doi:10.1016/j.beth.2015.03.002
- Rizvi, S. L. (2011). Treatment failure in dialectical behavior therapy. *Cognitive and Behavioral Practice, 18*, 403–412. doi: 10.1016/j.cbpra.2010.05.003
- Roberts, W., Fillmore, M. T., & Milich, R. (2011). Linking impulsivity and inhibitory control using manual and oculomotor response inhibition tasks. *Acta Psychologica, 138*, 419–428. doi:10.1016/j.actpsy.2011.09.002
- Rochat, L., Beni, C., Annoni, J.-M., Vuadens, P., & Van der Linden, M. (2013). How inhibition relates to impulsivity after moderate to severe traumatic brain injury. *Journal of the International Neuropsychological Society, 19*, 890–8. doi:10.1017/S1355617713000672
- Rubia, K., Russell, T., Overmeyer, S., Brammer, M. J., Bullmore, E. T., Sharma, T., ... Taylor, E. (2001). Mapping motor inhibition: conjunctive brain activations across different versions of go/no-go and stop tasks. *NeuroImage, 13*, 250–261. doi:10.1006/nimg.2000.0685
- Schmeichel, B. J., Volokhov, R. N., & Demaree, H. A. (2008). Working memory capacity and the self-regulation of emotional expression and experience. *Journal of Personality and Social Psychology, 95*, 1526–40. doi:10.1037/a0013345
- Sharbanee, J. M., Stritzke, W. G. K., Wiers, R. W., Young, P., Rinck, M., & MacLeod, C. (2013). The interaction of approach-alcohol action tendencies, working memory capacity,

- and current task goals predicts the inability to regulate drinking behavior. *Psychology of Addictive Behaviors*, 27, 649–661. doi:10.1037/a0029982
- Sharma, L., Kohl, K., Morgan, T. A., & Clark, L. A. (2013). “Impulsivity”: Relations between self-report and behavior. *Journal of Personality and Social Psychology*, 104, 559–575. doi:10.1037/a0031181
- Sharma, L., Markon, K. E., & Clark, L. A. (2014). Toward a theory of distinct types of “impulsive” behaviors: A meta-analysis of self-report and behavioral measures. *Psychological Bulletin*, 140, 374–408. doi:10.1037/a0034418
- Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Cogmed working memory training: Does the evidence support the claims? *Journal of Applied Research in Memory and Cognition*, 1, 185–193. doi:10.1016/j.jarmac.2012.06.003
- Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin*, 138, 628–54. doi:10.1037/a0027473
- Siegle, G. J., Ghinassi, F., & Thase, M. E. (2007). Neurobehavioral therapies in the 21st century: Summary of an emerging field and an extended example of cognitive control training for depression. *Cognitive Therapy and Research*, 31, 235–262. doi:10.1007/s10608-006-9118-6
- Siegle, G. J., Price, R. B., Jones, N. P., Ghinassi, F., Painter, T., & Thase, M. E. (2014). You gotta work at it: Pupillary indices of task focus are prognostic for response to a neurocognitive intervention for rumination in depression. *Clinical Psychological Science*, 2, 455–471. doi:10.1177/2167702614536160
- Simmonds, D. J., Pekar, J. J., & Mostofsky, S. H. (2008). Meta-analysis of Go/No-go tasks demonstrating that fMRI activation associated with response inhibition is task-dependent. *Neuropsychologia*, 46, 224–232. doi:10.1016/j.biotechadv.2011.08.021
- Snyder, H. R. (2013). Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: A meta-analysis and review. *Psychological Bulletin*, 139, 81–132. doi:10.1037/a0028727
- Snyder, H. R., Kaiser, R. H., Warren, S. L., & Heller, W. (2014). Obsessive-compulsive disorder is associated with broad impairments in executive function: A Meta-Analysis. *Clinical Psychological Science*, 3, 301–330. doi:10.1177/2167702614534210
- Snyder, H. R., Miyake, A., & Hankin, B. L. (2015). Advancing understanding of executive function impairments and psychopathology: bridging the gap between clinical and cognitive approaches. *Frontiers in Psychology*, 6, 328. doi:10.3389/fpsyg.2015.00328
- Spierer, L., Chavan, C. F., & Manuel, A. L. (2013). Training-induced behavioral and brain plasticity in inhibitory control. *Frontiers in Human Neuroscience*, 7, 427. doi:10.3389/fnhum.2013.00427
- Subramaniam, K., Luks, T. L., Fisher, M., Simpson, G. V., Nagarajan, S., & Vinogradov, S. (2012). Computerized cognitive training restores neural activity within the reality monitoring network in schizophrenia. *Neuron*, 73, 842–853. doi:10.1016/j.neuron.2011.12.024
- Subramaniam, K., & Vinogradov, S. (2013). Cognitive training for psychiatric disorders. *Neuropsychopharmacology Reviews*, 38, 242–3. doi:10.1038/npp.2012.177
- Svaldi, J., Dorn, C., Matthies, S., & Philippsen, A. (2012). Effects of suppression and acceptance of sadness on the urge for non-suicidal self-injury and self-punishment. *Psychiatry Research*, 200, 404–416. <http://doi.org/10.1016/j.psychres.2012.06.030>

- Thorell, L. B., Lindqvist, S., Nutley, S. B., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science*, 12, 106–113. doi:10.1111/j.1467-7687.2008.00745.x
- Thush, C., Wiers, R. W., Ames, S. L., Grenard, J. L., Sussman, S., & Stacy, A. W. (2008). Interactions between implicit and explicit cognition and working memory capacity in the prediction of alcohol use in at-risk adolescents. *Drug and Alcohol Dependence*, 94, 116–124. doi:10.1016/j.drugalcdep.2007.10.019
- Torres, A., Catena, A., Megías, A., Maldonado, A., Cándido, A., Verdejo-García, A., & Perales, J. C. (2013). Emotional and non-emotional pathways to impulsive behavior and addiction. *Frontiers in Human Neuroscience*, 7(February), 43. doi:10.3389/fnhum.2013.00043
- Treynor, W., Gonzalez, R., & Nolen-Hoeksema, S. (2003). Rumination reconsidered: A psychometric analysis. *Cognitive Therapy and Research*, 27, 247–259. doi: 10.1023/A:1023910315561
- Unsworth, N., Schrock, J. C., & Engle, R. W. (2004). Working memory capacity and the antisaccade task: individual differences in voluntary saccade control. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 30, 1302–21. doi: 10.1037/0278-7393.30.6.1302
- Vanderhasselt, M., Raedt, R. De, Namur, V., Lotufo, P. A., Bensenor, I. M., Boggio, P. S., & Brunoni, A. R. (2015). Transcranial electric stimulation and neurocognitive training in clinically depressed patients: A pilot study of the effects on rumination. *Progress in Neuropsychopharmacology & Biological Psychiatry*, 57, 93–99. doi:10.1016/j.pnpbp.2014.09.015
- Veling, H., Aarts, H., & Stroebe, W. (2013). Using stop signals to reduce impulsive choices for palatable unhealthy foods. *British Journal of Health Psychology*, 18, 354–368. doi:10.1111/j.2044-8287.2012.02092.x
- Verbruggen, F., Adams, R. C., & Chambers, C. D. (2012). Proactive motor control reduces monetary risk taking in gambling. *Psychological Science*, 23, 805–815. doi:10.1177/0956797611434538
- Washburn, J. J., Juzwin, K. R., Styer, D. M., & Aldridge, D. (2010). Measuring the urge to self-injure: Preliminary data from a clinical sample. *Psychiatry Research*, 178, 540–544. doi:10.1016/j.psychres.2010.05.018
- Watson, D., Weber, K., Assenheimer, J. S., Clark, L. A. Strauss, M. E., & McCormick, R. A. (1995). Testing a tripartite model: I. Evaluating the convergent and discriminant validity of anxiety and depression symptom scales. *Journal of Abnormal Psychology*, 104, 3–14. doi: 10.1037/0021-843X.104.1.3
- Wechsler, D. (2001). *Wechsler Test of Adult Reading*. San Antonio, TX: Psychological Corporation.
- Wesley, M. J., & Bickel, W. K. (2013). Remember the future II: Meta-analyses and functional overlap of working memory and delay discounting. *Biological Psychiatry*, 75, 435–448. doi:10.1016/j.biopsych.2013.08.008
- Whiteside, S. P., & Lynam, D. R. (2001). The five factor model and impulsivity: Using a structural model of personality to understand impulsivity. *Personality and Individual Differences*, 30, 669–689. doi:10.1016/S0191-8869(00)00064-7
- Whiteside, S. P., & Lynam, D. R. (2003). Understanding the role of impulsivity and externalizing psychopathology in alcohol abuse: application of the UPPS impulsive

- behavior scale. *Experimental and Clinical Psychopharmacology*, *11*, 210–217.
doi:10.1037/1949-2715.S.1.69
- Whiteside, S. P., Lynam, D. R., Miller, J. D., & Reynolds, S. K. (2005). Validation of the UPPS impulsive behavior scale: A four factor model of impulsivity. *European Journal of Personality*, *19*, 559–574. doi: 10.1002/per.556
- Wiers, R. W., Gladwin, T. E., Hofmann, W., Salemink, E., & Ridderinkhof, K. R. (2013). Cognitive bias modification and cognitive control training in addiction and related psychopathology: Mechanisms, clinical perspectives, and ways forward. *Clinical Psychological Science*, *1*, 192–212. doi:10.1177/2167702612466547
- Wilbertz, T., Deserno, L., Horstmann, A., Neumann, J., Villringer, A., Heinze, H.-J., ... Schlagenhaut, F. (2014). Response inhibition and its relation to multidimensional impulsivity. *NeuroImage*, *103*, 241–248. doi:10.1016/j.neuroimage.2014.09.021
- Wright, L., Lipszyc, J., Dupuis, A., Thayapararajah, S. W., & Schachar, R. (2014). Response inhibition and psychopathology: A meta-analysis of go/no-go task performance. *Journal of Abnormal Psychology*, *123*, 429–439. doi:10.1037/a0036295
- Yau, Y.H.C., Potenza, M.N., Mayes, L.C., & Crowley, M.J. (2015). Blunted feedback processing during risk-taking in adolescents with problematic internet use. *Addictive Behaviors*, *45*, 156-163. doi : 10.1016/j.addbeh.2015.01.008
- Zapolski, T. C. B., Cyders, M. A., & Smith, G. T. (2009). Positive urgency predicts illegal drug use and risky sexual behavior. *Psychology of Addictive Behaviors*, *23*, 348–354.
doi:10.1037/a0014684.Positive
- Zheng, D., Oka, T., Bokura, H., & Yamaguchi, S. (2008). The key locus of common response inhibition network for no-go and stop signals. *Journal of Cognitive Neuroscience*, *20*, 1434–1442. doi:10.1162/jocn.2008.2010

Footnote:

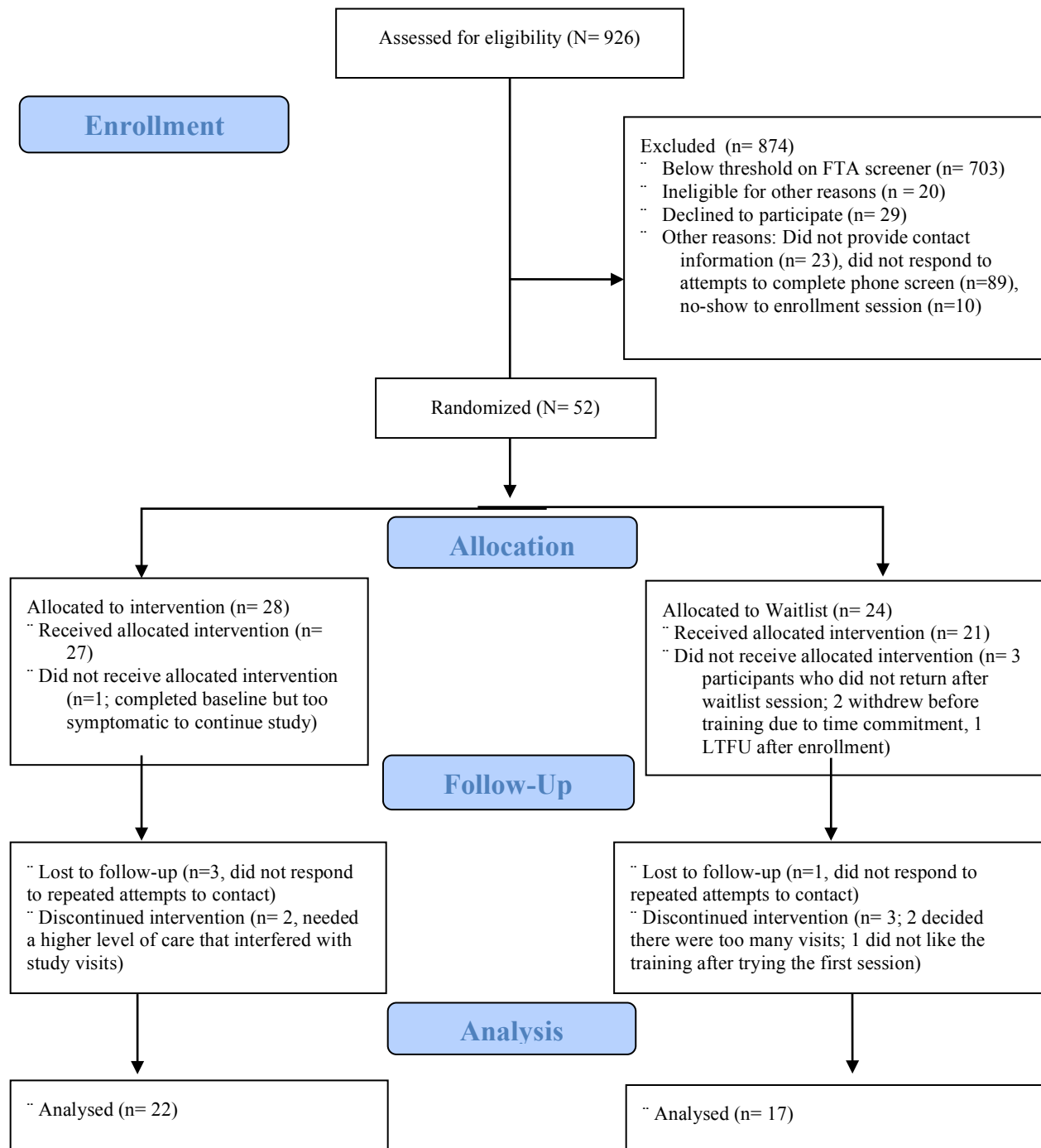
¹Analyses presented for the Feelings Trigger Action measure are based on average response to the 26 items on a 1 to 5 scale, in contrast to the factor scoring method reported in previous studies using this measure. This was done because the FTA measure was used as the primary screening measure, with cutoff scores for study enrollment based on total scores that did not account for factor loading.

²Sample size for waitlist questionnaire comparisons is 19. Of the 24 participants allocated to waitlist, 3 dropped out of the study without returning for their baseline/beginning of training visit. Two additional participants completed the waitlist questionnaires but did not complete baseline questionnaires due to experimenter error.

³The Three-Factor Impulsivity Scale also includes the subscale of Laziness, which was inadvertently not administered in the present study. Scale scores are presented without Laziness items.

Figure 1

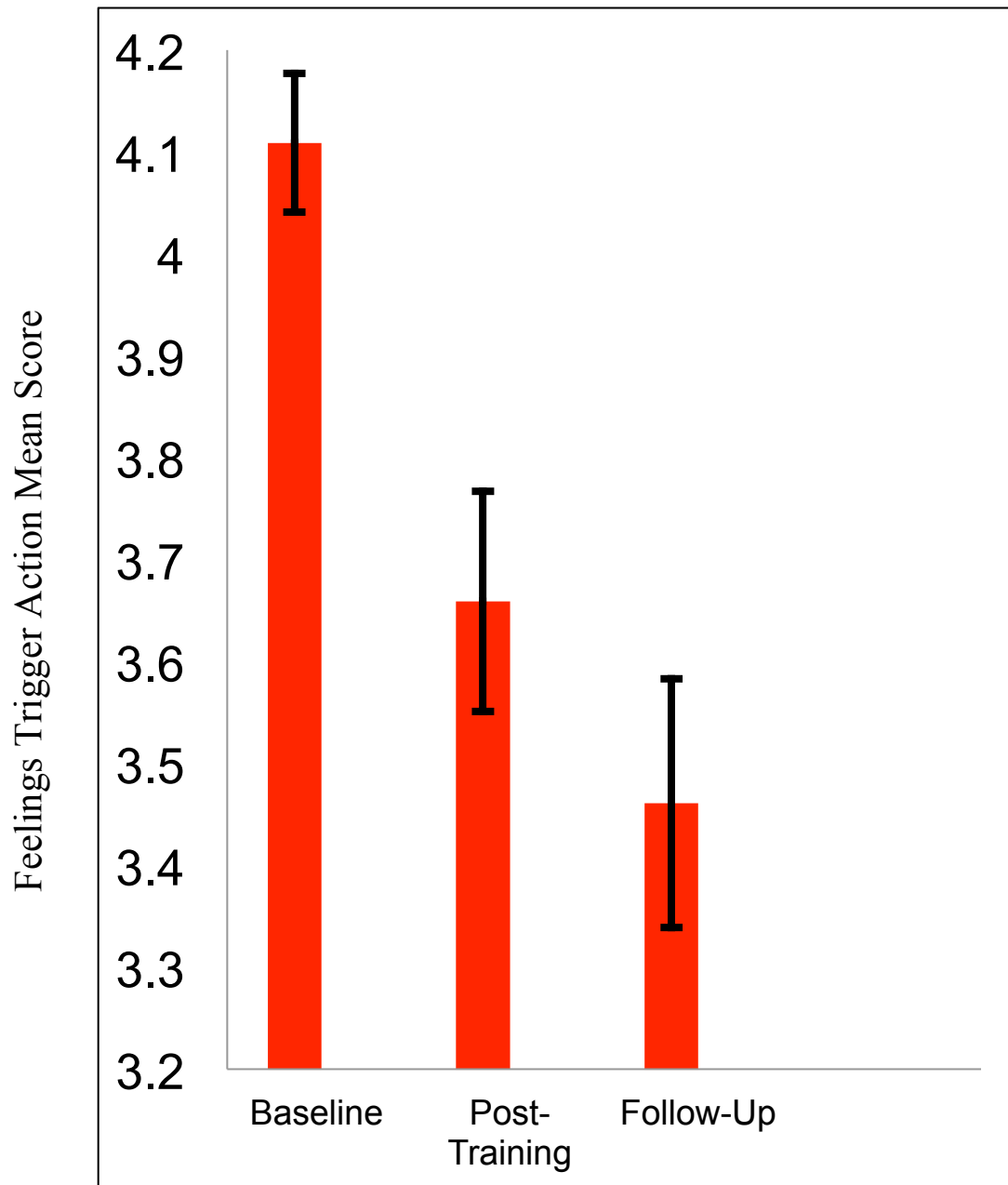
CONSORT Diagram of Study Enrollment



Note. “Received Intervention” indicates that participant completed at least one full training session. Not all participants completed the target dose of 6 sessions (see Results).

Figure 2

Change in Feelings Trigger Action Scores for Study Completers Including Follow-Up (n = 30)



Note. Error Bars = +/- 1 Standard Error.

Table 1

Timeline of Study Measures

Measure	Timepoint					
	Screening	Pre-Waitlist Session (Waitlist group only)*	Baseline	Training	Post-Training	2-Week Follow-Up
Demographic Interview		x	x			
WTAR		x	x			
Feelings Trigger Action	x		x		x	x
Impulsivity Scales: Pervasive Influence of Feelings/Lack of Follow-Through		x	x		x	x
PASAT			x		x	
Letters Go/NoGo			x		x	
Adaptive PASAT				x		
Adaptive Letters Go/NoGo				x		
Antisaccade			x		x	
Digit Span			x		x	
MASQ-SF		x	x			x
BSL-23/BSL Behavioral Supplement		x	x			x
STAB			x			x
ABUSI			x			x
DSM5 Substance			x			x
ERQ/ERQ-SE		x	x		x	x
Treatment Expectancy/ Credibility Ratings				x		
Balloon Analogue Risk Task			x		x	x
RRS: Brooding Subscale			x		x	x

Note. ABUSI=Alexian Brothers Urge to Self-Injure scale; BSL-23= Borderline Symptom Inventory; ERQ=Emotion Regulation Questionnaire; ERQSE=Emotion Regulation Questionnaire-Self Efficacy Scale; MASQ-SF = Mood and Anxiety Symptoms Questionnaire-Short Form; PASAT = Paced Auditory Serial Addition Task; RRS=Ruminative Responses Scale; STAB=Subtypes of Antisocial Behavior scale; WTAR = Wechsler Test of Adult Reading.

Table 2

Internal Consistency (Alpha Coefficients) for Self-Report Measures (n = 47)

Measure	Cronbach's alpha
Feelings Trigger Action	.86
RRS-Brooding Scale	.71
ERQ	
Reappraisal	.90
Suppression	.72
ERQ-SE	
Reappraisal	.85
Suppression	.78
BSL-23	.90
STAB	
Physical Aggression	.79
Social Aggression	.86
Rule-Breaking	.60
MASQ-SF	
General Distress-Anxiety	.78
General Distress-Depression	.94
Anhedonic Depression	.94
Anxious Arousal	.87
ABUSI	.94

Note. Baseline $n = 46$ for BSL, RRS, FTA, and MASQ.

Table 3

Baseline Sample Characteristics: Demographic, Clinical, and Task Data

Variable	Full Sample <i>N</i> = 52	Study Completers <i>n</i> = 39
	Mean (SD) or %	Mean (SD) or %
Age	32.17 (14.67)	31.97 (14.82)
Years of education	15.27 (1.44)	15.46 (1.34)
Percent female	67.3	69.2
Born in U.S.A.	84.6	87.2
Race		
Caucasian	57.7	64.1
African American	1.9	0
Asian American/Pacific Islander	21.1	20.5
More than one race	19.2	15.4
Percent Hispanic/Latino/a	11.5	12.8
Current undergraduate student	36.5	41
Full-time work or full-time student	73.1	74.4
Visited mental health treatment provider in past month	50	48.7
Taking psychiatric medication(s)	40.4	35.9
History of mental health treatment	82.7	79.5
History of psychiatric disorder	70.6	68.4
History of psychiatric hospitalization	25	17.9
Ever left school due to symptoms	44.2	41
Ever left work due to symptoms	29.4	26.3
Number of psychiatric hospitalizations	.79 (2.02)	.46 (1.39)
WTAR Standard Score	111.35 (12.04)	112.77 (11.94)
WAIS-IV LDSF	6.82 (1.17)	6.90 (1.12)
WAIS-IV LDSB	5.08 (1.21)	5.10 (1.19)
PASAT % Accurate Responses	55.86 (22.34)	57.37 (22.14)
Go/No-Go False Alarm Rate	13.40 (14.58)	12.22 (10.63)
Antisaccade Error Rate	36.75 (16.55)	35.91 (16.90)
BART % of Exploded Balloons	31.53 (13.79)	31.18 (13.47)
Treatment Expectancy: Self-Control	3.09 (.80)	3.08 (0.78)
Treatment Expectancy: Emo. Regulation	2.89 (.95)	2.95 (0.9)
# of Training Sessions	4.5 (2.03)	5.49 (0.91)

Note. LDSF = Longest Digit Span-Forward; LDSB = Longest Digit Span – Backwards; WTAR = Wechsler Test of Adult Reading. For full sample, *n* = 49 for Digit Span variables; *n* = 48 for PASAT and Go/NoGo; *n* = 47 and 46 for the two treatment expectancy questions; *n* = 44 for BART; *n* = 40 for antisaccade task.

Table 4

Pearson Correlation Matrix of Baseline Feelings Trigger Action Scores and Cognitive Variables

Variable	Age	WTAR Standard Score	PASAT Percentage Correct Answers	Go/NoGo False Alarm Rate	Longest Digit Span Forward	Longest Digit Span Backward	Antisaccade Failure proportion	BART Proportion of Balloons Popped
Feelings Trigger Action	.177	.030	.075	-.031	.120	-.116	.175	-.064
Age	-	.155	-.239	-.240	.061	-.051	-.102	-.019
WTAR Standard Score		-	.302*	-.170	.306*	.133	-.227	.073
PSAT Percentage Correct Answers			-	-.201	.218	.175	-.362*	-.052
Go/NoGo False Alarm Rate				-	-.088	-.116	.175	.427**
WAIS Longest Digit Span Forward					-	.292*	-.163	-.163
WAIS Longest Digit Span Backward						-	-.024	-.068
Antisaccade Failure proportion							-	.079

Note. BART = Balloon Analogue Risk Task; PASAT = Paced Auditory Serial Addition Task; WAIS = Wechsler Adult Intelligence Scale; WTAR = Wechsler Test of Adult Reading.

Table 5

Baseline Correlations of Feelings Trigger Action and Clinical Variables

Variable	ABUSI	BSL 23	Binge Eating Frequency (past week)	Induced vomiting (past week)	Binge Drinking (past 2 weeks)	Drugs Use (past 2 weeks)	MASQ GDA	MASQ GDD	STAB Phys Aggres	STAB Social Aggres	STAB Rule Breaking
Feelings Trigger Action	-.044	.116	-.115	-.037	-.015	-.141	.182	.151	.304*	.200	.347*
ABUSI	-	.460**	.125	.278	.265	.240	.310*	.431**	.096	.128	.119
BSL-23		-	.402**	.430**	.242	.282	.646**	.849**	.365*	.200	.373*
Binge eating (past week)			-	.095	.020	.017	.115	.409**	-.090	.034	.038
Induced vomiting (past week)				-	.004	.004	.149	.316*	.142	-.074	-.028
Binge drinking (past 2 weeks)					-	.244	.235	.280	.108	-.115	.040
Drug Use (past 2 weeks)						-	.248	.247	.163	.114	.182
MASQ GDA							-	.577**	.415**	.127	.339*
MASQ GDD								-	.239	.176	.355*
STAB Physical Aggression									-	.554**	.610**
STAB Social Aggression										-	.553**
STAB Rule Breaking											-

Note. ABUSI = Alexian Brothers Urge to Self-Injure Scale; MASQ GDA = General Distress Anxiety; MASQ GDD = General Distress Depression.

Table 6

Pearson Correlations of Emotion Regulation Variables and Baseline Feelings Trigger Action

Variable	ERQ Suppression	ERQ Reappraisal	ERQ-SE Suppression	ERQ-SE Reappraisal	RRS Brooding
Feelings Trigger Action	-.063	-.227	-.379**	-.280	.523**
ERQ Suppression	-	-.059	.561**	.089	-.123
ERQ Reappraisal		-	.286	.753**	-.316*
ERQ-SE Suppression			-	.464**	-.397**
ERQ-SE Reappraisal				-	-.447**

Note. ERQ = Emotion Regulation Questionnaire; ERQ-SE = Emotion Regulation Questionnaire –Self Efficacy; RRS = Ruminative Responses Scale.