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# Improving substance use prevention efforts with executive function training

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ABSTRACT

*Background:* Executive function (EF) includes emotional regulation, planning and decision-making, and behavioral impulse control. Improving youth substance use (SU) prevention by targeting EF poses challenges including determining whether specific sub-domains of EF are more associated with SU than others, whether EF is related to some types of SU more than others, and whether EF programs might be enhanced by inclusion of mindfulness training.
*Methods:* Data were drawn from two studies from the Pathways to Health project: a randomized controlled trial of 4th–6th graders and a cross-sectional pilot study of the relationship of EF to specific types of SU in a sample of 7th graders. Survey measures included assessment of the EF subdomains of inhibitory control (IC), emotional control, working memory, organization/planning, lifetime SU (tobacco and alcohol use), and mindfulness. Analyses included multivariate and multiple group path analysis.
*Results:* Results suggested that the EF sub-domain of IC was the strongest and most consistent predictor of SU, particularly cigarette and e-cigarette use, though emotional control was predictive of alcohol use among late-elementary school students. In the 7th grade sample, IC was predictive of alcohol, cigarette, and e-cigarette use only among students in the low 75% of mindfulness.
*Conclusions:* Findings from the present studies suggest that improvements in SU prevention efforts may result from increased curricular emphasis on IC and its application to multiple substance use prevention, and systematically integrating mindfulness with EF skills training. Future research should examine whether EF–SU relationships vary across patterns of SU and types of measures used to assess EF.


## 1. Introduction

### 1.1. Incorporating executive function (EF) into substance use (SU) prevention programs

Most SU prevention programs for adolescents are school-based and include some variation of social skills training with the intent to teach adolescents how to recognize and avoid peer pressure, and to make good decisions about selecting alternatives to drug use (Pentz, 2009). Such programs typically assume that once presented with an array of alternatives, adolescents will make the appropriate plans and decisions required to stay drug free. However, planning and decision-making represent only some of the skills that enable adolescents to select healthier alternatives to SU. Others include, but are not limited to, emotion regulation and impulse control (Bardo and Pentz, 2015; Romer et al., 2009). Collectively, these skills represent executive function (EF), the neurocognitive processes which guide health behavior and development in general (Pentz, 2009; Riggs and Pentz, 2015, in press).

There is increasing recognition that emotion regulation, impulse control, and the more "planful" aspects of EF proceed through rapid phases of integration during adolescence [i.e., as the pre-frontal cortex becomes integrated with both the dopaminergic mesolimbic (reward) and amygdala-striatal (emotion) systems of the brain] and, if underdeveloped, pose significant risk for early adolescent SU (Kandel and Kandel, 2014; Riggs et al., 2012a,b). This integration also informs the dual processing model of implicit and explicit cognition as it relates to SU addiction (Giancola and Tarter, 1999; Gibbons et al., 2009; Henderson et al., 2015). Thus concentrating only on higher-order cognitive skills such as planning or healthy

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goal-setting in prevention programs, rather than integrating these skills with emotional regulation and impulse control training, may not provide the full picture in understanding what drives adolescent risk for SU and how to reduce this risk.

### 1.2. Examples of prevention programs focused on EF

Recently, a small number of programs, typically focusing on behavioral outcomes other than SU prevention, have been shown to effectively promote EF in children (Diamond and Lee, 2011). For example, Promoting Alternative Thinking Strategies (PATHS) is a social-emotional learning program that has shown effects on childhood behavioral conduct problems mediated by program effects on EF (Riggs et al., 2006). More recently, EF training has been applied directly to SU prevention in children and early adolescents in the Pathways to Health trial, which is described in this paper. The Pathways program is based on emotional regulation and behavioral impulse control skills training that are applied directly to situational and environmental contexts for SU, as well as obesity risk behaviors that have been similarly associated with emotional regulation and impulse control (Bardo and Pentz, 2015; Pentz, 2009; Riggs et al., 2006; Sakuma et al., 2012). Details of the Pathways program are published elsewhere (Pentz et al., 2015; Riggs et al., 2012a,b; Sakuma et al., 2012).

### 1.3. Remaining questions

It is not clear from current programs whether emotional regulation, behavioral impulse control (sometimes referred to as emotional control and inhibitory control in EF measurement), working memory, or higher order planning/organizational skills are driving most of the effect of EF skills training programs, nor whether EF competency is more closely linked to reduced risk for use of some substances vs. others., e.g. tobacco vs. alcohol use. Finally, there is increasing evidence to suggest that mindfulness can moderate the relationships of tobacco use intentions and distress to SU (Black et al., 2015a, 2012). However, little is known about whether mindfulness moderates the relationship of EF–SU, thereby potentially increasing the impact of EF training on SU.

Published studies on the Pathways program have thus far focused on development and effects of the Pathways program (Riggs et al., 2007; Sakuma et al., 2012), the relationship of EF to obesity risk behaviors and SU (Pentz and Riggs, 2013; Pentz et al., 2015; Riggs et al., 2012b), and whether the relationship of EF to SU is moderated by socioeconomic status (Riggs and Pentz, 2015, in press). Findings to date have raised several questions about how to improve subsequent substance use prevention programs. One is whether training on specific subdomains of EF might be differentially emphasized to increase program effectiveness. Pathways focused equally on all four domains of EF (global EF), without separation or emphasis on a particular domain. A second question is whether EF training might have a greater effect on certain types of SU than others, thereby informing which substance(s) might be the best targets for initial application and evaluation of EF training. A third question is whether including mindfulness enhances the practice of EF skills (Pentz, 2014). While Pathways incorporated some exercises which may have bolstered mindfulness among participants, such activities constituted less than 5% of the program and were not designed a priori to impact mindfulness. Furthermore, these exercises were applied only in the early stages of the program where emotion recognition and regulation were addressed. To examine these questions, the present paper draws on data from two studies that were part of the Pathways to Health Project: a prevention trial on 4th-6th graders, and a cross-sectional pilot study of 7th graders.

## 2. 4th–6th grade pathways to health prevention trial

The 4th–6th grade Pathways to Health prevention trial was a randomized controlled trial involving matching and randomization of 4th grade students from 28 elementary schools to either a 30 session teacher-delivered EF training program delivered over a three-year period, or a delayed intervention control group (2008–2014). Pathways was based on a theoretical model that included promoting EF skills related to both emotion regulation and behavior control as applied to multiple health risk behaviors that were developmentally sequenced so that dietary intake, sedentary, and physical activity behaviors were addressed in 4th and 5th grade, with tobacco and alcohol use behaviors introduced in 6th grade (Pentz 2009; Sakuma et al., 2012). Also sequenced were the EF skills, with affective feelings and emotion regulation skills first, followed by decision-making and behavioral choices, behavioral applications, and finally, simultaneous and reciprocal practice of both affective and "planful" cognitive skills.

### 2.1. Sample

Of the 1005 students who formed a parent- and self-consented panel followed for 4 measurement periods and 3 years, 185 moved out their districts, 18 declined participation after baseline, 29 were absent from measurement, and 64 were excluded from analysis due to switching intervention conditions following school closure (4 of 28 schools were closed). The resulting analysis sample size was 709. Analyses showed few differences between retained participants with complete vs. incomplete data, with the exception that slightly more Hispanic ($p < .05$) and lower SES ($p < .001$) participants had incomplete data.

### 2.2. Measures

The Pathways trial used a self-report survey including measures of EF and lifetime tobacco and alcohol use (SU; none to one or more). Since Pathways was a field-based universal prevention trial with applications of EF training to everyday contexts for behavior, the Behavior Rating Inventory of Executive Function-Self-Report version was used to measure EF (Guy et al., 2004). The BRIEF consists of 8 scales with items that measure the application of EF in everyday situations. Three versions have been standardized on youth as young as 4th grade: teacher, parent, and self-report. Following procedures used in our previous studies, the BRIEF self-report form was used and EF was analyzed both as a global EF competency score as well as four separate subscales (Riggs et al., 2012a) that have shown the strongest predictive relationships to SU, specifically the emotional control (EC, 9 of 10 items), inhibitory control (IC, 11 of 13 items), working memory (all 12 items), and organization of materials (all 7 items) subscales (Guy et al., 2004). For each item on each subscale, participants were asked "How often each of the following has been a problem in the last month?" BRIEF response choices were: 1 = Never, 2 = Sometimes, 3 = Often. An example item for the BRIEF EC subscale is "I have angry outbursts," and for the IC subscale is "I get out of control more than my friends." The BRIEF has shown acceptable internal consistency and concordance between subscales and global BRIEF scores (Riggs et al., 2007; Pentz and Riggs, 2013). Subscales are significantly correlated with one another (ranging from $r = 0.48$ to 0.64, $p$ values $< 0.001$). The BRIEF also demonstrates good ecological validity (Guy et al., 2004).

SU consisted of two items drawn from the Monitoring the Future national survey on adolescent substance use: lifetime tobacco use and lifetime alcohol use, asked as "Have you ever smoked a cigarette in your whole life? (1 = no, not even a puff to 4 = use, 1 or more cigarettes) and "Have you ever tried alcohol in whole life (beer, wine, liquor not for religious purposes; 1 = no, not even a sip to