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Short communication

# Executive function fails to predict smoking outcomes in a clinical trial to motivate smokers to quit

Andrew T. Fox[a,*], Laura E. Martin[a,h], Jared Bruce[b], Jose L. Moreno[c], Vincent S. Staggs[d,e], Hyoung S. Lee[f], Kathy Goggin[d,e], Kari Jo Harris[g], Kimber Richter[h], Christi Patten[i], Delwyn Catley[j]

[a] Hoglund Brain Imaging Center, University of Kansas Medical Center, Kansas City, KS 66160, USA
[b] Department of Psychology, University of Missouri – Kansas City, 5030 Cherry Hall, Room 313, Kansas City, MO, 64110, USA
[c] Department of Psychiatry, University of Texas Health Science Center – San Antonio,7703 Floyd Curl Drive, San Antonio, TX 78229-3900, USA
[d] Health Services and Outcomes Research, Children's Mercy Kansas City,2401 Gillham Road, Kansas City, MO 64108, USA
[e] School of Medicine, University of Missouri – Kansas City,2411 Holmes Street Kansas City, MO 64108, USA
[f] Interdisciplinary Arts and Sciences, University of Washington Tacoma, 1900 Commerce St, Tacoma, WA 98402-3100, USA
[g] School of Public and Community Health Sciences, University of Montana,Skaggs Building Room 352, Missoula, MT 59812, USA
[h] Department of Preventive Medicine and Public Health, University of Kansas Medical Center, Kansas City, KS 66160, USA
[i] Department of Psychology and Psychiatry, Mayo Clinic, 200 First St SW, Rochester, MN 55905, USA
[j] Center for Children's Healthy Lifestyles and Nutrition, Children's Mercy Kansas City,2401 Gillham Rd., Kansas City, MO 64108, USA

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ABSTRACT

*Background:* Executive function (EF) is considered an important mediator of health outcomes. It is hypothesized that those with better EF are more likely to succeed in turning their intentions into actual health behaviors. Prior studies indicate EF is associated with smoking cessation. Experimental and longitudinal studies, however, have yielded mixed results. Few studies have examined whether EF predicts post-treatment smoking behavior. Fewer still have done so *prospectively* in a large trial. We sought to determine if EF predicts quit attempts and cessation among community smokers in a large randomized trial evaluating the efficacy of motivational interventions for encouraging cessation.

*Methods:* Participants (N = 255) completed a baseline assessment that included a cognitive battery to assess EF (Oral Trail Making Test B, Stroop, Controlled Oral Word Association Test). Participants were then randomized to 4 sessions of Motivational Interviewing or Health Education or one session of Brief Advice to quit. Quit attempts and cessation were assessed at weeks 12 and 26.

*Results:* In regression analyses, none of the EF measures were statistically significant predictors of quit attempts or cessation (all *ps* > 0.20).

*Conclusions:* Our data did not support models of health behavior that emphasize EF as a mediator of health outcomes. Methodological shortcomings weaken the existing support for an association between EF and smoking behavior. We suggest methodological improvements that could help move this potentially important area of research forward.

## 1. Introduction

Executive function (EF), which comprises cognitive processes like working memory, attention, and inhibition along with higher-order processes like self-regulation and planning (Goldstein et al., 2014), is associated with improved health. EF contributes to dietary (Allan et al., 2010, 2011) and exercise (Hall et al., 2008) adherence, maintaining healthy weight (Menon et al., 2013), antiretroviral therapy adherence (Avants et al., 2001; Solomon and Halkitis, 2008), and non-smoking status (Brega et al., 2008; Menon et al., 2013; Moss et al., 2009).

Smokers show poorer EF than non-smokers and ex-smokers (Durazzo et al., 2012; Glass et al., 2009; Nestor et al., 2011; Sabia et al., 2012; Starr et al., 2007), which could be an effect of smoking or both a cause and an effect. The few studies with longitudinal or experimental designs better suited to establishing whether EF predicts smoking behavior have yielded mixed results. For example, EF deficits in children with ADHD did not predict later cigarette smoking (Wilens et al., 2011). In smokers with schizophrenia, one of three EF assessments predicted treatment success (Moss et al., 2009) while in a study of community smokers one of two EF measures was associated with

* Corresponding author at: Hoglund Brain Imaging Center, University of Kansas Medical Center, Mail Stop 1052, 3901 Rainbow Blvd, Kansas City, KS 66160, USA.
*E-mail addresses:* afox3@kumc.edu, andrewtfox112@gmail.com (A.T. Fox).

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success in a laboratory relapse model (Mueller et al., 2009). Taken together these studies involving different populations, measures, and outcomes provide limited evidence that EF predicts smoking behavior. Further examination of this relationship in prospective studies, especially in large, diverse samples of smokers, is warranted.

We conducted a randomized controlled trial of Motivational Interviewing (MI) for inducing quit attempts and cessation in smokers with low interest in quitting (Catley et al., 2016), which included baseline measures of EF. Because no study has prospectively examined the influence of EF on smoking outcomes in a large treatment trial among a diverse community sample, we conducted such an analysis using our data. We hypothesized that individuals with higher levels of EF at baseline would be more likely to attempt quitting and achieve abstinence because quitting smoking is a multi-step process (Lee et al., 2014) and both planning and executing plans are executive functions (Miller and Cohen, 2001).

## 2. Methods

Our data came from a clinical trial (ClinicalTrials.gov #NCT01188018) described in detail elsewhere (Catley et al., 2016; Catley et al., 2012). The study protocol was approved by the Institutional Review Board of the University of Missouri–Kansas City (#0978).

### 2.1. Participants

Participants (N = 255, 110 women) were recruited from the community. The sample was predominantly Black (65%), low-income (58% < $1000/mo.), and high school educated or less (84%) (see Catley et al. (2016) for full demographics). Primary inclusion criteria were: age ≥18 (mean 45.8), self-reported smoking of ≥1 cigarette per day (mean 17.1), not using cessation medication, and low desire to quit (≤6 on a 10-point scale; mean 1.9).

### 2.2. Study arms

Participants were randomized in a 2:2:1 ratio to MI, Health Education (HE), or Brief Advice (BA). In MI and HE, participants received four 20-min sessions of in-person (baseline, week 12) or over-the-phone (weeks 6, 18) cessation counseling. In BA participants experienced one 5-min session of direct advice to quit smoking.

### 2.3. Psychological assessments

Baseline measures were assessed via computer or trained research staff and included demographics, smoking characteristics, and psychological variables. Nicotine dependence was assessed with the Heavy Smoking Index (HSI) (Kozlowski et al., 1994). EF measures were chosen for efficient administration and coverage of several facets of EF. We chose the Oral Trail Making Test (OTMT) (Ricker and Axelrod, 1994; Ricker et al., 1996) for general executive function, the "Victoria" Stroop task (Troyer et al., 2006) for response inhibition, and the Controlled Oral Word Association Test (COWAT-FAS) (Reitan and Wolfson, 1985) for verbal fluency. Detailed description and validation of these tests are available (Reitan and Wolfson, 1985; Ricker and Axelrod, 1994; Ricker et al., 1996; Troyer et al., 2006). OTMT score was defined as time to complete "B" section, Stroop as the interference score (color word sheet time/color dots sheet time), and COWAT-FAS as total valid words spoken.

### 2.4. Other assessments

Other assessments included the Wechsler Test of Adult Reading (WTAR; proxy for IQ) (The Psychological Corporation, 2001); the Center for Epidemiologic Studies – Depression scale (CES-D) (Radloff, 1977); the Neuroticism and Extroversion components of the Eysenck Personality Questionnaire—Brief Version (EPQ) (Sato, 2005); and the Symbol Digit Modalities Test (SDMT) (Smith, 2002).

### 2.5. Outcome variables

Main outcomes were quit attempts at baseline, 12 weeks, and 26 weeks defined as a self-reported quit attempt of at least 24 h (Boardman et al., 2005; Zhou et al., 2009) within the past 3 months and smoking cessation, defined as self-reported abstinence at 12 weeks and cotinine-verified 7-day point-prevalence abstinence at 26 weeks (Benowitz et al., 2002; Hughes et al., 2003). Readiness to quit ["Contemplation Ladder" (Biener and Abrams, 1991)], measured at baseline and weeks 12 and 26 was a secondary outcome.

### 2.6. Data analysis

Results of preliminary factor analysis of the EF measures did not justify creating an EF composite; this approach was not pursued further. To avoid multicollinearity among the EF measures, we fit separate models for each EF variable-outcome combination.

Odds of a quit attempt were modeled using mixed logistic regression. For each explanatory EF variable (Stroop, OTMT-B, COWAT-FAS), we fit the following four models and compared them using the Bayesian Information Criterion (BIC): A base model (predictors: arm, week, arm*week), a base + EF predictor model (predictors: arm, week, arm*week, EF predictor), a base + EF + EF*arm model, and finally a full model which added seven covariates (age, HSI, CES-D, WTAR, SDMT, EPQ Neuroticism, EPQ Extroversion) to the best-fitting (i.e., lowest-BIC) of the previous three models.

Odds of quitting smoking (verified cessation) were modeled using Firth logistic regression. Due to few quitters, the only covariate included was study arm. We repeated this analysis limited to participants reporting a quit attempt to determine if effects of EF on cessation differ between those who do and do not make a quit attempt.

Contemplation Ladder was modeled in the same way as quit attempts except with Gaussian rather than logistic mixed models.

## 3. Results

Control variables were mostly similar between quit attempters and non-quit attempters (Table 1). Mean differences on the EF measures were < 0.3 SD apart and not statistically significant (Wilcoxon test $ps > 0.3$). The same was true when comparing quitters versus non-quitters (Table 1). Bivariate correlations between the EF measures and outcome variables were uniformly small ($|r| < 0.14$; Table 2).

In the quit attempt modeling, the best model per BIC for all three EF variables was the full model including the 7 covariates and the EF predictor, but not the EF*arm interaction. We found no statistically significant relation between odds of making a quit attempt and Stroop (aOR = 1.07, 95% CI [0.70, 1.63], $p = 0.761$), OTMT-B (aOR = 1.26, 95% CI [0.77, 2.07], $p = 0.356$), or COWAT-FAS (aOR = 1.29, 95% CI [0.77, 2.17], $p = 0.331$).

Similarly, we did not find significant associations between smoking cessation and Stroop (aOR = 1.43, 95% CI [0.81, 2.51], $p = 0.217$), OTMT-B (aOR = 0.83, 95% CI [0.44, 1.60], $p = 0.584$), or COWAT-FAS (aOR = 0.84, 95% CI [0.47, 1.49], $p = 0.539$). Limiting the analysis to only those reporting a quit attempt yielded similar, non-significant results (aORs 1.44, 0.82, and 0.77 for Stroop, OTMT-B, and COWAT-FAS, respectively).

For the models predicting Contemplation Ladder the full model was not selected for any EF variable. COWAT-FAS was a significant predictor of Contemplation Ladder ($ß = 0.38$, 95% CI [0.09, 0.66], $p = 0.010$), but neither Stroop ($ß = 0.10$, 95% CI [−0.21, 0.40], $p = 0.532$) nor OTMT-B ($ß = 0.08$, 95% CI [−0.26, 0.41], $p = 0.659$) were significant.

The BIC indicated improved likelihood-based fit when the EF