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Carbon monoxide feedback in a motivational decision support system for nicotine dependence among smokers with severe mental illnesses

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ABSTRACT

Health concerns are common reasons for wanting to quit smoking among smokers with mental illnesses. Motivational interventions have used feedback from a carbon monoxide monitor to increase awareness of health concerns, but this device is not commonly available. Whether brief motivational interventions can be effective without this feedback is unknown. Using a randomized controlled trial, this study tested the effect of carbon monoxide feedback within a brief, multi-component, computerized motivational intervention among 124 smokers with schizophrenia or mood disorders. The main outcome was initiating cessation treatment over two months. Although participants in the carbon monoxide group increased their knowledge about the carbon monoxide, ($\chi^2 = 6.97$, df = 1, p = .008), the main and secondary outcomes did not differ significantly between groups. Overall, 32% of participants initiated treatment. This study suggests that a computerized motivational decision support system can lead users to initiate cessation treatment, and that carbon monoxide feedback is not a necessary component.

1. Introduction

Among smokers in the general population and smokers with mental illnesses, a commonly cited reason for wanting to quit smoking is a health concern (McCaul et al., 2006; Morris, Waxmonsky, May, & Giese, 2009; Nawaz, Frounfelker, Ferron, Carpenter-Song, & Brunette, 2012). Negative health events such as a diagnosis of emphysema often lead to smoking cessation (Sloan, Smith, & Taylor, 2003; Wray, Herzog, & Willis, 1998). People with severe mental illnesses such as schizophrenia and severe mood disorders experience high rates of health consequences (Birkenaes et al., 2007; Dickey, Normand, Weiss, Drake, & Azeni, 2002; Himelhoch et al., 2004) and early mortality (Brown, Inskip, & Barraclough, 2000) due in part to very high rates of smoking. But, they tend to have low awareness of the relationship between specific common health problems, such as hypertension, and smoking (Lucksted, McGuire, Postrado, Kreyenbuhl, & Dixon, 2004; Morris et al., 2009). Motivational interventions for smoking cessation typically attempt to increase awareness of the health risks of smoking in order to encourage people to quit. One study of motivational interviewing for smokers with schizophrenia used feedback from a health problem checklist and from a carbon monoxide monitor to increase awareness and motivation. This study found that 28% of those who received the intervention attended a first session of cessation treatment compared to 0% of controls who received no intervention (Steinberg, Ziedonis, Krejci, & Brandon, 2004).

The carbon monoxide monitor provides a quantitative measure of the level of carbon monoxide, a cigarette smoke toxin, in the breath. This reading may serve to personalize and heighten awareness of the negative health effects of smoking on the body. Heightening the focus on health effects by giving feedback may particularly benefit people with schizophrenia and severe mood disorders given that attention impairments are associated with these disorders (Reichenberg et al., 2009). Although carbon monoxide monitor feedback has been a component of motivational interventions for smokers with severe mental illnesses (Cather et al., 2010; Steinberg et al., 2004; Williams et al., 2010; Williams, Ziedonis, Vreeland, & Speelman-Edwards, 2009), including a computerized motivational decision support system we developed (Brunette, Ferron, McHugo, et al., 2011), research on the effect of carbon monoxide monitor feedback as a stand-alone intervention on smoking outcomes in the general population has been equivocal (Bize, Burnand, Mueller, & Cornuz, 2009; McClure, Ludman, Grothaus, Pabiniak, & Richards, 2009). Further, this type of feedback has not been used in many of the motivational interventions used in the general population (Lai, Cahill, Qin, & Tang, 2010). These monitors are expensive (the Smokerlyzer

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from Bedfont Scientific costs about $1300) and, according to clinic administrators, they are technically difficult to implement in real-world settings, in part due to the limited resources (Levit et al., 2008; Truffer et al., 2010) typical of public mental health care settings.

Another strategy to personalize the health effects of smoking is a health problem checklist with feedback. This type of intervention has been shown to reduce other substance use (e.g. problem drinking (Riper et al., 2009)) and is expected to lead to heightened awareness of the health consequences of smoking. Checklists are easy to use and free. Further, health checklists with feedback have been used in combination with carbon monoxide monitor feedback in studies of motivational interventions for severely mentally ill (Steinberg et al., 2004) and non-psychiatrically ill (McClure et al., 2009) smokers.

The purpose of this randomized clinical trial among severely mentally ill smokers was to assess whether a single session of a computerized motivational decision support system *with carbon monoxide and health checklist feedback* would lead to higher rates of initiating smoking cessation treatment than a version of the system *with health checklist feedback alone* (no carbon monoxide feedback). We hypothesized that the version with carbon monoxide feedback would lead to higher rates of cessation treatment initiation. However, if the two versions of the decision support system produced equivalent outcomes, the lesser expense and complexity of the checklist alone version could enhance uptake of this intervention in real world treatment settings. We also explored several secondary hypotheses (see statistical analysis section).

2. Materials and methods

2.1. Participants

Participants were identified at Thresholds, a large mental health treatment organization in Chicago. Eligibility criteria were: adult, English speaking, daily smoker, in treatment for severe mental illness (defined as mood or psychotic disorder with persisting functional disability) at the mental health program, and without current other substance dependence. Participants who had used smoking cessation treatment to try to quit in the past month were not eligible, as they were already motivated to use cessation treatment to quit smoking. Of 279 referred participants, 142 were eligible and gave written informed consent to participate, 135 were assessed at baseline, 11 were lost before randomization, and 124 entered the study. Three participants did not return for the two-month follow-up assessment.

2.2. Measures

Participants reported demographics, history of computer use, lifetime psychiatric hospitalizations, smoking history, knowledge about the effects of smoking (five multiple choice questions) and reasons for quitting ("What is most important to you about quitting smoking?"). Clinic records provided current psychiatric and substance use disorder diagnoses. Trained interviewers assessed participants for nicotine dependence with the five-item Fagerstrom Test for Nicotine Dependence (FTND) (Fagerström, 1978), with scores ranging from 0 to 10. The FTND has high internal consistency and adequate test retest reliability in people with schizophrenia (Weinberger et al., 2007). They also assessed participants for overall psychiatric symptoms with the Modified Colorado Symptom Index (Shern, Wilson, & Coen, 1994), a 14-item questionnaire with scores ranging from 0 to 56 that has been found to be reliable and valid in people with mental illness and/or substance use disorder (Conrad et al., 2001). Its content is similar to the Brief Psychiatric Rating Scale, and it has high internal consistency and good test–retest reliability (Boothroyd & Chen, 2008). Interviewers assessed participants' cognitive functioning with the Brief Assessment of Cognition in Schizophrenia (BACS) (Keefe et al., 2004) at baseline. The BACS includes brief assessments of reasoning and problem solving, verbal fluency, attention, verbal memory, working memory, and motor speed. It takes 30 min to complete and is comparable to a lengthier, standard cognitive battery (Keefe et al., 2004). Population norms have been established (Keefe et al., 2008), and the BACS has been shown to be reliable and sensitive to the deficits experienced by people with severe psychiatric disorders, whose scores are typically one to two standard deviations below those of normal controls (Keefe et al., 2004). The Wide Range Achievement Test (WRAT), a brief screening test of reading comprehension, was also completed at baseline. The test has extensive age-based population norms. Alternate forms reliability were above .89, and test–retest reliability was .91 or better (Wilkinson, Robertson, & Lutz, 2006).

As recommended by tobacco research experts (Baker et al., 2011), we chose a proximal behavior, initiation of cessation treatment, as the primary outcome. We selected a behavioral rather than psychological measure of motivation because initiation of treatment is a stronger predictor of successful smoking cessation (Culhane et al., 2008) than assessments of intention or other psychological measures. Initiation of cessation treatment was assessed by blinded research staff at baseline and two-month follow-up with the Behavioral Motivation Index (Brunette, Ferron, McHugo, et al., 2011). This checklist assessed initiation of cessation medication and attendance at behavioral treatment for smoking cessation, as well as other clinician contact regarding smoking cessation. Treatment initiation was a binary measure, included starting any evidence-based medication (nicotine replacement therapies, bupropion, varenicline) and/or individual or group cessation counseling, thereby allowing for shared decision making that involves patient choice and clinical tailoring of treatment. This self-report of treatment initiation was verified by medical record review and clinician report.

Two secondary outcomes were also assessed. First, amount and frequency of smoking over the past two months were assessed with quantity/frequency questions. Second, satisfaction with the decision support system was assessed with three items from the Perceived Usefulness and Ease of Use Scale, which asked about overall satisfaction with the program, satisfaction with how the information was presented, and satisfaction with the usefulness of the program (Davis, 1989). Third, stage of change (readiness) for quitting was assessed with a single question about when the subject was thinking about quitting (four point scale from now to not thinking of quitting) (DiClemente et al., 1991).

2.3. Interventions

The web-based motivational decision support system was designed and tailored for smokers with severe mental illnesses (Brunette, Ferron, McHugo, et al., 2011). Similar to in-person interventions for this population, the system provides information and exercises that aim to increase awareness of the pros and cons of smoking, including its' health risks, via education, assessment, and feedback. The carbon monoxide monitor feedback section provides information about carbon monoxide, then provides a reading of the level of carbon monoxide in the user's breath after he or she breaths into a carbon monoxide monitor (hereafter referred to as 'carbon monoxide feedback'), and a very brief interpretation of the reading. This component of the intervention utilized three computer screens (less than 5% of the program). The system also provides decision support for cessation treatments, including videos of personal testimonials about quitting with treatment and information about each evidence-based cessation treatment. The system has been extensively tested and tailored for usability among the smokers with severe mental illnesses (Ferron et al., 2011), who typically have low cognition (Keefe & Eesley, 2006). Preliminary testing demonstrated promising efficacy: 35% of users initiated smoking cessation

treatment compared to 10% of controls (Brunette, Ferron, Devitt, et al., 2011). Two versions of the system were used in this study: one with carbon monoxide feedback, one without.

2.4. Procedures

After providing informed consent and completing baseline assessments, participants met with a trained research assistant to use one of the decision support systems. The research assistant logged on to the decision support system website via a pre-assigned passcode. A computer-based randomization program (using blocks of 10) assigned participants to use the multi-component decision support system with or without the carbon monoxide feedback. The participant interacted with the program over the next 30 to 90 min. Using a specified protocol, the research staff assisted participants if they needed help using the system, helped them print out reports if needed, and encouraged users to complete the program, but did not deliver verbal counseling or other intervention. All participants who began viewing the decision support system completed it. Research assistant adherence to the decision support system study visit protocol was assessed with a 10-item checklist. Adherence to the visit protocol was high (mean score 9.6 out of 10) and not different between treatment groups.

Because lack of health insurance and cost can impede use of cessation treatments, the study and a local foundation paid for smoking cessation medication and smoking cessation group counseling for participants who wanted treatment but lacked insurance coverage. Cognitive behavioral smoking cessation group or individual treatment was available at the center, and prescribers were trained to provide smoking cessation pharmacotherapy in conjunction with pharmacotherapy for mental illnesses.

Research interviewers, blinded to condition, assessed participants for all outcomes 2 months after participants used the decision support system. We chose a 2-month follow-up period after using the program because this is the amount of time during which people with severe mental illnesses are typically able to access a physician visit and counseling in real world treatment settings.

The study was approved and monitored by the Dartmouth and Thresholds Institutional Review Boards. The study was conducted in accordance with the ethical standards of the Helsinki Declaration of 1975.

2.5. Statistical Analyses

With SAS 9.2, we used chi-square tests and two-tailed t-tests to evaluate between-group differences in baseline characteristics. A logistic regression model was used to test the main hypothesis, whether participants who used the system with the carbon monoxide feedback were more likely to initiate treatment (cessation medication or counseling) than those who used the system without it.

We also examined several exploratory hypotheses with logistic regression models. We hypothesized that treatment initiation after using one of the programs would be associated with: 1) high reading comprehension, because understanding the relationship between breath carbon monoxide and disease could be easier for those with high reading comprehension; and 2) high nicotine dependence, because those with high dependence will have higher carbon monoxide levels, which could increase the impact of this type of feedback. With a similar logistic model, we also assessed whether treatment initiation after using one of the programs would be associated with stage of change (wanting to quit right now or within the next month) before and after using the program.

We used chi-square tests to assess whether users of the two versions of the decision support system differed in their ratings of satisfaction. Additionally, because the program was tailored for people with low reading comprehension and cognitive deficits, we were interested in whether satisfaction among those with higher reading comprehension and cognition scores (people in the upper quartile for comprehension and for cognition) was different than satisfaction ratings among users with lower comprehension and cognition scores. We chose to compare the upper quartile to the lower three quartiles because reading comprehension and cognition were close to population norms in the upper quartile only, and we hypothesized that the smokers in this group would not be satisfied with this simply designed system.

We powered this experiment to detect a medium effect for the difference between the two decision support system groups (with two groups of 60, the power was .78 to detect a 20% difference between the groups). We assumed that a medium or larger difference in favor of the carbon monoxide monitoring system would indicate its clinical significance.

3. Results

Study participants were primarily middle-aged, male, never-married smokers with schizophrenia-spectrum disorders (see Table 1). About half of the group was African American and one sixth of the group was Hispanic. They smoked an average of 15 cigarettes per day. Although mean Fagerström scores suggested low levels of dependence, most people smoked within 30 min of waking. No participant had used cessation treatment in the past month. On average, they had mild psychiatric symptoms, a low level of education, and substantial cognitive deficits (mean BACS scores were about 2 standard deviations below the population mean). Mean reading comprehension scores were consistent with a 9th grade reading level. Demographics, diagnoses, symptoms, cognition and smoking characteristics (including health knowledge) did not differ between the two groups.

At the 2-month follow-up, participants in the carbon monoxide group were more likely to increase their knowledge about the impact of carbon monoxide, ($\chi^2 = 6.97$, df = 1, p = .008), but the main outcome, initiating cessation medication or counseling, did not differ between groups (rate difference = 15%, SE = 0.08, Confidence Interval = − 0.31 to 0.01).

Regarding secondary outcomes, basic knowledge about the health effects of smoking was fairly high and did not increase differentially between groups. When asked what reason they had to quit smoking, 75% of participants (93 of 124) answered “health” or a health-related term such as “breath better” at the two-month interview (also not significantly different between groups). Regression analyses with interactions between a) sentence comprehension and intervention type as well as b) baseline amount smoked and intervention type showed no relationship with the main outcome, initiation of cessation treatment. These findings indicate that the program with carbon monoxide feedback was not more effective than the program without carbon monoxide feedback for increasing cessation treatment initiation and other quit behaviors, and the program with the carbon monoxide feedback was not differentially effective among those with higher sentence comprehension or those with higher severity of dependence.

Cessation behaviors reported by study participants at 2 months are summarized in Table 2. Over 50% of participants engaged in at least one cessation behavior. Approximately one third used an evidence-based intervention, and a quarter tried to quit without any treatment. At the two month follow-up, amount smoked did not differ between groups and no participants had achieved abstinence.

We conducted regression models to evaluate whether stage of change (readiness) to quit impacted the main outcome. First, stage of change before and after use of the program was not related differentially to the main outcome based on version of the program (i.e. there were no interaction effects; OR = 3.3, 95% CI = 0.5–20.3, p = 0.21). In contrast, readiness to quit after using the decision

Table 1
Characteristics of study participants.

	DSS with CO	DSS without CO	Total group
	N = 58	N = 66	N = 124
Mean (sd) age	46.7 (9.3)	46.3 (10.8)	46.5 (10.1)
Number (%) men	44 (75.9)	45 (68.2)	89 (71.8)
Number (%) African American[a]	30 (51.7)	30 (45.5)	60 (48.4)
Number (%) White[a]	26 (40.0)	16 (27.6)	42 (34)
Number (%) Hispanic[a]	6 (10.3)	12 (18.2)	18 (14.5)
Number (%) diagnosed with schizophrenia or schizoaffective disorders	38 (65.5)	46 (69.7)	84 (67.7)
Number (%) diagnosed with bipolar or depressive disorders	16 (24.2)	18 (31.0)	34 (27.4)
Number (%) diagnosed with other disorders	4 (6.1)	2 (3.4)	6 (4.8)
Mean (sd) years education	11.6 (2.5)	11.2 (2.4)	11.4 (2.4)
Number (%) ever married (vs never)	17.0 (29.3)	10.0 (15.2)	27.0 (21.2)
Fagerström Dependence Categories			
Number (%) Very Low Dependence (0–2)	8 (13.8)	19 (28.8)	27 (21.8)
Number (%) Low Dependence (2–4)	26 (44.8)	23 (34.9)	49 (39.5)
Number (%) Medium Dependence (5)	14 (24.1)	8 (12.1)	22 (17.7)
Number (%) High Dependence (6–7)	10 (17.2)	16 (24.2)	26 (21)
Number (%) who smoked within 30 min of waking	50 (86.2)	49 (74.2)	99 (79.8)
Mean (sd) cigarettes per day	15.0 (11.8)	15.1 (10.8)	15.0 (11.2)
Want to quit now or within next month	14 (24.1%)	21 (31.8%)	17 (28.2%)
Number (%) used computer < 5 times	20 (34.5)	29 (43.9)	49 (39.5)
Mean (sd) lifetime psych hospitalizations	8.4 (8.9)	14 (21.9)	11.6 (16.6)
Mean (sd) CSI symptom score (0–56)	17.5 (9.6)	14.9 (10.1)	16.1 (9.9)
Mean (sd) WRAT sentence comprehension score	34.0 (10.8)	32.8 (11.5)	33.8 (11.2)
Mean (sd) BACS composite z score	−2.2 (1.3)	−2.3 (1.4)	−2.2 (1.4)

DSS = Decision support system; CO = carbon monoxide monitor; CSI = Colorado Symptom Index schiz = schizophrenia/schizoaffective disorders; WRAT = Wide Range Achievement Test; BACS = Brief Assessment of Cognition in Schizophrenia.
[a] 4 participants identified as other race or multiple races.

support system was related to initiation of cessation treatment (controlling for baseline readiness to quit and version of the decision support system; OR = 3.9, 95% CI = 1.4–11.5, p = 0.01), indicating that stage of change for quitting after completing the decision support system was an important proximal outcome associated with treatment initiation.

Responses to the three satisfaction questions did not differ between the two groups. Participants reported high levels of satisfaction with both versions of the program: 75.0% were 'very satisfied' with the program ($\chi^2 = 0.14$, df = 1, p = 0.71); 98.0% agreed that the way the information was presented was 'good' (28.2%), 'very good' (28.2%), or 'excellent' (41.6%) (Fisher's exact F = 5, p = 0.45); and 81.7% agreed that the program was 'very useful for helping you think about smoking' (Fisher's exact F = 1, p = 0.50). Participants who were in the highest quartile of reading comprehension scores and cognition (total BACS score) were not less satisfied than users with scores in the lower three quartiles for reading comprehension ($\chi^2 = 1.4$, df = 1, p = .23) and cognition ($\chi^2 = 1.8$, df = 1, p = .18).

4. Discussion

Several outcomes of this study have clinical implications. First, contrary to our hypothesis, feedback from a carbon monoxide monitor did not enhance the response to our multi-component, computerized, motivational decision support system for smokers with severe mental illnesses, despite an increase in knowledge about carbon monoxide. The intervention may have changed factors other than knowledge about carbon monoxide, such as knowledge, attitudes or social norms regarding treatment (Ajzen, 1991), that increased motivation and resulted in behavioral change. Because the study was powered to detect a moderate difference between the two groups, we infer that feedback related to the carbon monoxide monitor is not a necessary ingredient of the system, potentially easing its adoption by routine mental health centers.

Second, the study demonstrated that this technology-delivered motivational intervention was highly satisfactory to people with severe mental illnesses and motivated them to access evidence-based smoking cessation treatments. The outcomes reported here (a third of participants initiated cessation treatment) are similar to our previous study of this intervention (Brunette, Ferron, McHugo, et al., 2011) and also to the level of treatment engagement resulting from in-person motivational interventions for this population (Steinberg et al., 2004). Treatment was available to all participants regardless of ability to pay. In settings were treatment is requires payment, use of treatment would likely be lower.

Third, severely mentally ill smokers with all levels of reading comprehension and cognition were highly satisfied with both versions of the program. By comparison, smokers with severe mental illnesses have difficulty using other existing web-based smoking cessation programs (Brunette, Ferron, Devitt, et al., 2011). A usable web-based intervention has the potential to reach more people at a lower cost than in-person counseling.

We did not find a significant difference between groups in our analysis. Numerically, a lower proportion of people who received feedback from the carbon monoxide monitor initiated treatment. It is possible that, in the context of a single session, multi-component motivational intervention, this feedback could deter users from initiating cessation treatment. We have observed that some people who received carbon monoxide feedback within the program felt that the CO monitor number was incongruent with their perception of their smoking (e.g. a person who smoked 15 cigarettes a day had a medium carbon monoxide level, but the person felt very highly

Table 2
Cessation behaviors over 2 months following intervention.

Cessation behavior	N (%)[a]
Met with doctor to discuss cessation	44 (36.7)
Met with cessation specialist	38 (31.4)
Started cessation counseling without meds	10 (8.3)
Started cessation medication without counseling	13 (10.7)
Started both counseling and cessation medication	16 (13.2)
Started any treatment	39 (32.2)
Quit attempt without treatment	30 (24.8)
Any cessation behavior	64 (52.9)

[a] Numbers add up to more than total because many participants reported more than one cessation behavior.

dependant on tobacco). Without a clinician to process potential incongruencies between the computer program report and the user's perceptions, it is possible that this feedback detracted from the other motivational content.

Notably, stage of change, or readiness to quit, after using the program (but not at baseline) predicted whether an individual initiated cessation treatment. This finding indicates that a desire to quit smoking in general is one important factor associated with motivation to try cessation treatment.

A few limitations warrant mention. This study was conducted at one large, urban mental health center among severely mentally ill smokers. This study did not evaluate whether smokers with particular diagnoses were more or less likely to respond to the intervention. Whether smokers with severe mental illnesses in other settings would respond similarly is uncertain. Whether other disadvantaged smokers who do not have severe mental illnesses would respond similarly is also uncertain. The study did not test whether feedback and discussion related to carbon monoxide in the breath are important components of other interventions such as cognitive–behavioral therapy for smoking cessation or whether they are effective as a stand-alone intervention with this population. Further, the carbon monoxide feedback was given without controlling for the amount of time since the last cigarette. The variation in carbon monoxide levels resulting from varying recency of smoking could have diluted the effect of the feedback. The study included neither a placebo nor an attention control condition.

In summary, this study demonstrated that a brief, multi-component computerized motivational decision support system motivated a third of smokers with severe mental illnesses to initiate cessation treatment, and feedback from a carbon monoxide monitor was unnecessary to achieve this outcome. Technology offers promising strategies to deliver interventions for nicotine dependence, even among smokers with severe psychiatric illnesses, high nicotine dependence, and low reading comprehension and cognition. Our findings call for further controlled research to confirm the efficacy of web-based motivational interventions and to evaluate their impact on long-term abstinence among people with severe mental illnesses and other disparity groups.

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