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Predictive modeling of addiction lapses in a mobile health application ☆

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ABSTRACT

The chronically relapsing nature of alcoholism leads to substantial personal, family, and societal costs. Addiction-comprehensive health enhancement support system (A-CHESS) is a smartphone application that aims to reduce relapse. To offer targeted support to patients who are at risk of lapses within the coming week, a Bayesian network model to predict such events was constructed using responses on 2,934 weekly surveys (called the Weekly Check-in) from 152 alcohol-dependent individuals who recently completed residential treatment. The Weekly Check-in is a self-monitoring service, provided in A-CHESS, to track patients' recovery progress. The model showed good predictability, with the area under receiver operating characteristic curve of 0.829 in the 10-fold cross-validation and 0.912 in the external validation. The sensitivity/specificity table assists the tradeoff decisions necessary to apply the model in practice. This study moves us closer to the goal of providing lapse prediction so that patients might receive more targeted and timely support.

1. Introduction

In 2010, an estimated 22.1 million people (8.7% of the U.S. population aged 12 or older) in the U.S. were classified with alcohol dependence or abuse (Substance Abuse and Mental Health Services Administration, 2011). Patients striving to change problematic drinking behavior often experience an initial setback, a transitory state or so-called lapse, that can lead to a full return to their previous drinking behavior (known as a relapse) (Witkiewitz & Marlatt, 2004). Relapse reduces the quality of life for the drinking individuals and their families, and can place a huge burden on society through crime, accident, healthcare costs, and reduced productivity (Sullivan, Fiellin & O'Connor, 2005). To prevent relapse, researchers have called for more adaptive interventions that offer constant monitoring, a wide variety of services, and decision support for clinicians to help them adjust the services to meet the changing needs of patients (McKay, 2005, 2009).

To address this issue, the Center for Health Enhancement Systems Studies (CHESS) at the University of Wisconsin-Madison developed a smartphone-based, relapse-prevention program, addiction-comprehensive health enhancement support system (A-CHESS) (Gustafson, Boyle, et al., 2011). Various services were designed and included in A-CHESS to promote patients' autonomous motivation, coping competence, and relatedness, so that patients were prepared to face different challenges along their recovery journey (Gustafson, Shaw, et al., 2011; Marlatt & George, 1984; Ryan & Deci, 2000). For example, patients can connect with their peers and counselors at any time via these A-CHESS services: "discussions", "my messages", "team feed", and "support team". Patients can search the latest addiction-related news articles and access other credible Web resources in addiction recovery in "news" and "recovery info"; listen to the stories of other patients from "our stories" and "recovery podcasts"; find the nearest alcoholics (or narcotics) anonymous meetings from "meetings"; use "panic button" and "easing distress" to help them cope with their recovery; and track their progress in "surveys". More details on A-CHESS services can be found in other publications (Gustafson, Boyle, et al., 2011; Gustafson, Shaw, et al., 2011; McTavish, Chih, Shah, & Gustafson, 2012).

A randomized trial to test the efficacy of A-CHESS on patients with a diagnosis of DSM-IV alcohol dependence has recently been completed. Preliminary results suggest that the patients receiving the access to A-CHESS in the treatment group demonstrated significantly reduced heavy drinking days (i.e., the number of days during which a patient's drinking in a 2-hour period exceeded, for men, 4 standard drinks and for women, 3 standard drinks) compared to those receiving treatment as usual in the control group across an 8-month intervention period and a 4-month subsequent follow-up period (Gustafson et al., 2012). In addition, A-CHESS received long lasting usage—about 80% of patients still used A-CHESS weekly in the end of 4 months after intervention, as compared to 65% of asthma teenagers and 35% colon cancer survivors using respective smartphone applications at the same time period (McTavish et al., 2012). Nevertheless, despite the encouraging outcomes, the full potential of A-CHESS may not yet have been realized.

As a smartphone application that is accessible at 24/7, A-CHESS has the potential to offer instant support to patients and their counselors at the moment they most need it. A lapse often happens suddenly, but

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may be predictable (Collins et al., 1998; Högström Brandt, Thorburn, Hiltunen, & Borg, 1999; Witkiewitz & Masyn, 2008). Being able to predict that a patient may lapse would enable A-CHESS to offer proactive support to patients before a lapse actually occurs. However, at its inception, no such mechanism was available that would allow A-CHESS to know when to provide such proactive intervention. Thus, the task undertaken in this present study was to evaluate patients' data collected via A-CHESS and develop a prediction function to be implemented in A-CHESS.

The ongoing data collection (both self-reported and system generated) being done with A-CHESS offered a great opportunity to develop such an intelligent feedback function. One important source of data was the Weekly Check-in. Patients normally completed this brief survey instrument in A-CHESS, called Weekly Check-in, once every 7 days on their smartphones. A-CHESS then transmitted the collected data to a remote, secure server via the Internet.

The questions used in the Weekly Check-in were adopted from a multi-dimensional instrument, the brief addiction monitor (BAM), developed in 2008 (Cacciola, Alterman, Oslin, & McKay, 2008). Two BAM items related to the status of drinking or taking drugs were combined into a single item in the Weekly Check-in to assess patients' substance use activities during the week. This substance use item was used as the indicator of patient lapse status. Five other BAM items (i.e., sleeping problems, depression, urge, risky situation, and relationship troubles) were conceptualized as risk related items. Five additional BAM items (i.e., confidence, AA meeting attendance, religious activities, other activities and time with family) were considered as protection related items (Cacciola et al., 2008). Factors very similar to these 10 protective and risk items outlined above have been found in the literature to be strongly associated with substance use behavior (Baker, Piper, McCarthy, Majeskie, & Fiore, 2004; Hunter-Reel, McCrady, & Hildebrandt, 2009; Laffaye, McKellar, Ilgen, & Moos, 2008; Moos & Moos, 2007; Oslin, Cary, Slaymaker, Colleran, & Blow, 2009; Robinson, Krentzman, Webb, & Brower, 2011; Witkiewitz & Marlatt, 2004).

Because the data in the Weekly Check-in were provided by patients on a weekly basis, it is possible that the recovery progress status of a patient (based on the risk and protection items in the current Weekly Check-in) may be predictive of the substance use status reported by the same patient in the next Weekly Check-in. This paper introduces a predictive model that was developed using the data collected in the A-CHESS Weekly Check-in and reports results of its evaluation. While this study was not intended to validate a certain theoretical framework or set of predictors, those concepts were presented as a prelude to describing the construction of the predictive model.

2. Materials and methods

2.1. Participants

A total of 170 patients were recruited and randomized into the intervention group in a randomized controlled trial designed to test A-CHESS (McTavish et al., 2012). Only the patients in the intervention group were included in this predictive modeling study because they were the only group given access to A-CHESS in the trial. The patients were recruited from two residential treatment organizations—one in the midwestern and the other in the northeastern U.S.—from February, 2010 through November, 2011. Participants had to be at least 18 years old, meet the criteria for DSM-IV alcohol dependence upon entering treatment, and provide two backup contacts for follow-up. Patients were excluded if they had a history of suicidality, a significant developmental or cognitive impairment that would limit the ability to use A-CHESS, or vision problems. Self-report data from the pretest survey of these 170 patients, revealed a mean age of 38 years old, mostly Caucasian (81%), and mostly male (61%). About 42% had some college education or greater. About 20% were employed. More than half (62%) reported at pretest that they had abused drugs beyond alcohol (39.4% using cocaine along with other drugs and 22.4% using drugs other than cocaine) at some point, and 49% reported mental health problems.

2.2. Procedures

An onsite project coordinator at each clinic identified eligible patients from the clinic's administrative database. About 2 weeks before an eligible patient left residential treatment, the coordinator discussed the study with the patient, including procedures, benefits and risks of participating, and data to be collected. Patients were told that A-CHESS was an intervention geared around (but not limited to) alcohol addiction. If the patient was willing to take part, written informed consent was then obtained. The study was conducted according to the Declaration of Helsinki of 1975 and approved by the institutional review board at the University of Wisconsin-Madison.

Before leaving the residential facilities, patients in the intervention group received training on how to use A-CHESS and the smartphones with a mobile broadband connection provided as part of the trial. During the 8-month intervention period, patients were expected to submit the Weekly Check-in (i.e. an ongoing patient monitoring instrument) in A-CHESS once every 7 days. To complete a Weekly Check-in, patients turned on the Weekly Check-in page in A-CHESS and selected the answers for the questions. After patients clicked the "submit" button in the end of the survey, the Weekly Check-in immediately verified completeness and prompted patients to fill in unanswered items before the survey could be submitted. Once submitted, the Weekly Check-in data were sent to a secure server at the University of Wisconsin-Madison. Seven days following the prior Weekly Check-in submission, patients would receive a message via A-CHESS as a reminder for another Weekly Check-in submission. To be included in the trial, patients must agree to receive such a prompt. However, completion of the Weekly Check-in was not required to remain in the trial. Therefore, it is possible that substantially more than 7 days could elapse between submissions. More details about the randomized controlled trial can be found in prior publications (McTavish et al., 2012).

2.3. Weekly Check-in instrument

The Weekly Check-in contains an instrument presented across three screens (Fig. 1). On the first screen, patients were asked to report their substance use status in the last 7 days in a dichotomized form (i.e., yes/no). On the second screen, patients reported their perceived level of risk related items (i.e., sleeping problems, depression, urge, risky situation, and relationship troubles) in the past week on a scale from 0 (thumbs up at the green zone) to 7 (thumbs down at the red zone). On the third screen, they reported their perceived level of protection related items (i.e., confidence, AA meeting, religious activities, other activities, and time with family) in the past week on a scale from 0 (thumbs down at the red zone) to 7 (thumbs up at the green zone).

2.4. Measures

2.4.1. Lapse status

In this study, the substance use item from the first screen in the Weekly Check-in was used as the indicator of a patient's lapse status. A lapse was defined to have occurred when a patient indicated that he/she used alcohol or took drugs in the past week. "Lapse" only indicated whether a participant reported that they drank or took drugs in the prior week and did not provide information about the amount or the frequency of use during the lapse. Determining if