

# Substance Use Screening using Virtual Agents

Towards Automated Screening, Brief Intervention, and Referral to Treatment (SBIRT)

Timothy Bickmore

Khoury College of Computer  
Sciences, Northeastern University  
Boston, MA, USA  
bickmore@ccs.neu.edu

Amy Rubin

Depts of Psychiatry and Medicine  
Boston University  
Boston, MA, USA  
rubina@bu.edu

Steven Simon

VA Greater Los Angeles  
Healthcare System  
Los Angeles, CA, USA  
Steven.Simon2@va.gov

## ABSTRACT

Alcohol, tobacco and illicit drug use cause significant loss quality of life, and represent a large economic burden on society. Standardized questionnaires have been developed to enable healthcare providers to screen individuals for substance misuse problems that may require intervention. Although routine use of these screeners is promoted in many healthcare organizations, their administration can be irregular and lack follow through. In addition, patients may be reluctant to report substance use. We report on the development and validation of a Virtual Agent designed to automate the administration of a standard substance use screening instrument. We report on two validation studies in which a total of 57 patients at a US Veterans Administration medical center were screened by the virtual agent, comparing first to a research assistant administering the standard screening questionnaire, and second to a standard computerized text-based implementation of the questionnaire. Assessment correlations between the agent and human administration were all significant, ranging from  $\rho=0.83$  to  $0.94$ , with more disclosure to the agent. Correlations were lower for Study 2 ( $0.56 - 0.88$ ), with participants significantly more satisfied with the Agent compared to the standard tool.

## CCS CONCEPTS

• **Human-Centered Computing** → Human Computer Interaction (HCI)

## KEYWORDS

Virtual Agent, Relational Agent, Embodied Conversational Agent, Alcohol, Cocaine, Cannabis, Tobacco, NMASSIST, VA, Veterans Administration

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## 1 Introduction

Over 150 million people worldwide have alcohol or drug use disorders, leading to over 3 millions deaths per year [1]. Alcohol and tobacco use alone cost society more than 250 billion disability-adjusted life years [2]. Treatment programs can be effective, once substance use problems are detected and individuals are enrolled. For example, an early program evaluation of primary-care based intervention projects nationwide funded by the Substance Abuse and Mental Health Services Administration (SAMHSA) indicated that Screening, Brief Intervention, and Referral to Treatment (SBIRT) reduced illicit drug use by almost 68% [3]. In addition, the World Health Organization's Alcohol, Smoking and Substance Involvement Screening Test (WHO ASSIST) project piloted a brief intervention that was effective. At three month follow-up, participants who received a brief intervention for any drug other than alcohol showed significantly less drug use (24% decrease) compared to participants who did not receive brief intervention (3% decrease) [4].

However, detecting substance use problems is difficult. Primary care represents an ideal setting in which individuals could be regularly screened during regular check-ups or other office visits, given the frequency of patient contact, the ready availability of treatment resources, and the high compliance of patients asked to conduct screening as part of their clinical encounter (many home-based, online interventions suffer from low rates of use and/or high dropout [5]). The efficacy of screening and brief intervention for unhealthy alcohol and tobacco use in primary care has been established over a 30-year period [6-9] and a number of institutions, including the US Veterans Health Administration (VA), have included these practices in routine care.

Unfortunately, screening, intervention, and/or referral for substance misuse is not as effective as it should be, even when performed in primary care. Within the VA, for example, Veterans often do not receive screening for substance misuse except when they have become dependent and their illness is obvious, or when they ask for help, despite screening being part of routine care [10, 11]. Several factors contribute to this situation. Clinicians have limited time to interact with patients [12, 13] and face competing

demands of managing complex acute and chronic health conditions [14-16]. Most primary care clinicians lack sufficient training to deliver high-quality care for unhealthy substance use [17-19]. Moreover, both patients and clinicians may be reluctant to initiate discussions about substance misuse because of the potential stigma and concerns about revealing illegal behavior [20]. Numerous studies of the efficacy of SBI for other substance use problems have shown little efficacy, likely due to concerns that substance abuse problems come to light in the doctor-patient interaction only when they are severe, and the appropriate response is referral to specialty care rather than a brief intervention [21, 22].

Computerized approaches to automating substance misuse screening in general, and in primary care in particular, may address these shortcomings. An automated system alleviates the time demand on clinicians, and delivers screening with perfect fidelity, obviating the need for clinician training. Automated systems can also remove the awkwardness of bringing up the topic of substance misuse in the course of a routine clinical encounter. Finally, there is significant evidence that patients not only feel more comfortable discussing these topics with a computer, but that they are more likely to disclose socially undesirable behaviors, such as substance misuse, to a computer compared to other screening modalities. Studies have confirmed that people perceive paper and computer-administered assessments to be more anonymous than human-administered questions, which can lead to greater disclosure [23, 24]. Computers are also seen as being more anonymous than humans, but more confidential than paper-based methods, again leading to a greater disclosure advantage to computers [25]. A meta-analysis of 48 studies involving 125,672 subjects demonstrated that people exhibit stronger social desirability bias when reporting behaviors via paper questionnaire vs. computer-administered questionnaire, and that the effect was strongest for highly sensitive behaviors such as substance misuse [26].

Virtual agents represent an ideal medium for screening and brief intervention for substance misuse. In addition to all of the benefits described above for computerized approaches, virtual agents provide an intuitive conversational interface that is more accessible to individuals with a wide range of health, reading, and computer literacy [27]. Agents can also use verbal and nonverbal relationship-building skills to improve adherence to and retention in substance use interventions [28, 29]. Finally, agents may be particularly effective at eliciting potentially stigmatizing information from patients, such as substance misuse, compared to primary care providers or other humans [30].

In this work, we report the design and validation of a virtual agent that screens primary care patients for substance misuse. In order to validate the accuracy of the screening, we designed the agent to administer a standard screening questionnaire (the NIDA-Modified Alcohol, Smoking, and Substance Involvement Screener (NM-ASSIST [31])) and compare it to either a human administration or a text-based computer administration of the instrument.

## 2 Related Work

Significant prior work has now been done on computerized screening and virtual agents in healthcare.

### 2.1 Health Counseling by Virtual Agents

Virtual agents have demonstrated efficacy in many health interventions to date. For example, in a clinical trial promoting physical activity in sedentary older adults, 263 participants (mean age 71.3, 61% female, 40% inadequate health literacy) were randomized to either a relational agent exercise coach or a pedometer-only control condition, with the agent group significantly outperforming the controls at two months [32]. Agents have also been used in chronic disease management. For example, a smartphone-based agent that counseled patients with atrial fibrillation on self-care management was evaluated in a clinical trial in which 120 patients with the condition were either provided with smartphones with the Agent and a heart rhythm monitor installed, or standard care, for 30 days. Compared to patients undergoing standard of care, patients using the Agent reported significantly higher quality of life at the end of the intervention period, based on a standard measure for patients with atrial fibrillation [33].

### 2.2 Substance Use Counseling by Virtual Agents

A few agents have also been developed that provide brief health interventions for individuals with substance misuse problems. For example, Yasavur, et al, developed a virtual agent that provides brief intervention for individuals with alcohol use disorder [34]. However, the system has yet to be evaluated in a clinical trial for actual impact on alcohol consumption behavior. An, et al, report a virtual agent-based smoking cessation intervention, demonstrating significant improvement in 30-day smoking abstinence rates compared to a control group [35].

### 2.3 Screener Administration by Virtual Agents

Most closely related to the current effort are a few recent projects aimed at the design and validation of virtual agent-based administration of standard health screener questionnaires. Pontier and Siddiqui report a virtual agent that administers the Beck Depression Inventory [36]. However, they do not report results of any studies to validate this agent-based instrument.

Jaiswal, et al, evaluated virtual agent-based administration of standard psychological assessment instruments, including PHQ-9 for depressive symptoms and GAD-7 for generalized anxiety, finding that agent-based administration, face-to-face administration by a human, and administration by a human over a video link yielded essentially equivalent results [37].

Of most relevance to the current work, Auriacombe, et al, used a virtual agent to screen patients on alcohol and tobacco use disorders. In a validation study involving 139 patients of an outpatient sleep clinic, they demonstrated significant agreement for the Cigarette Dependence Scale-5 (CDS-5) for tobacco use disorder, and the "Cut Down, Annoyed, Guilty, Eye-opener" (CAGE) for alcohol use disorder, between agent-based administration and standard paper-based administration [38]. However, their work did not screen for the wide range of

substances covered in the NM-ASSIST, nor include patients from substance use treatment programs to ensure wide coverage.

There have also been projects that use virtual agents to interview users and attempt to diagnose health conditions based on user verbal and nonverbal behavior. For example, SimSensei Kiosk was intended to be used to diagnose PTSD and depression in this manner, but it never progressed past demonstration stage and was not validated in a trial [39].

### 3 Virtual Agent for Substance Use Screening

We developed a Virtual Agent to administer the NIDA-Modified Alcohol, Smoking, and Substance Involvement Screener (NMASSIST [31]), as a first step towards the development of a fully-automated Agent-based system that could perform Screening, Brief Intervention, and Referral to Treatment (SBIRT) for alcohol misuse (Figure 1).



Figure 1: Virtual Agent NM-ASSIST Screener

Developed using a game engine, our agent is a humanoid character that communicates with the user through synthetic speech and synchronized nonverbal behavior. To enact simulated face-to-face conversation, the animated agent can display a variety of non-verbal behavior, including: facial display of affect; head nods; eyebrow raises, directional gazes for signaling turn-taking; a range of hand gestures (e.g., beat gestures for emphasis, contrastive gestures for comparisons), and posture shifts to mark topic boundaries. In addition, the agent's lip-sync is controlled by an animation subsystem that takes phoneme timings generated by the text-to-speech engine and converts them into viseme animations.

Agent dialogue is designed using a custom scripting language based on hierarchical state transition network. User responses are mainly in the form of multiple-choice selections to avoid safety issues with unconstrained natural language input [40]. Dialogue scripts are compiled using a text-to-embodied-speech translation engine [41], which automatically generates the agent's non-verbal behavior based on a linguistic analysis of the agent's utterances.

In addition, agent utterances can be tailored at runtime using template-based text generation.

We designed the screener administration dialogue to reproduce the language that a primary care physician would use in verbally administering the NM-ASSIST, including options for repeating and clarifying questions, and dialog flow to minimize the number of questions asked and maintain topic coherence (e.g., discussing all questions related to one substance before starting discussion of another).

The Agent-based screener was deployed on a touch screen tablet computer, designed for use in primary care. The system outputs a printable report that mirrors the one produced by NIDA's online NM-ASSIST [42].

### 4 Validation Studies

We conducted two human subjects studies to validate agent-based administration of the NMASSIST screener for substance use. The two studies each used a mixed-methods, one-time, counterbalanced, within-subjects design. Participants were randomized into receiving either the Virtual Agent or the human Research Assistant assessment first for Study 1, and the Virtual Agent or a standard computer text-based online assessment (VA's CPRS Mental Health Assistant [43]) for Study 2.

#### 4.1 Participants

For each study we recruited 30 Veterans; 20 Veterans from primary care, and 10 Veterans from a residential substance abuse treatment program. We recruited specifically from the substance abuse program to ensure that we interviewed Veterans with substance abuse problems. It is estimated that approximately 4% of Veterans in VA may have substance abuse problems other than alcohol, and most Veterans in the Substance Abuse Residential and Rehabilitation Treatment Program (SARRTP) or Ambulatory Drug Treatment Program (ADTP) get their primary care at Boston VA. We believed this ensured a more representative sample of the level and types of substances misused.

We recruited participants using flyers and posters in the VA Primary Care Clinic. Receptionists asked patients checking in if they were interested in participating in the study, and referred them to the interviewers. In the substance abuse treatment program, we were invited to a community meeting to describe the study and inform Veterans how to participate. We also posted a flyer on the community bulletin board.

Participants were required to speak English and pass the Callahan cognitive screening test. The studies were approved by the VA IRB, and participants were compensated for their time.

#### 4.2 Measures

**4.2.1 Demographics.** We collected demographic information, including sex, age, race/ethnicity, years of education, military service, previous treatment for substance abuse, experience with computers, and current employment status.

**4.2.2 NIDA-Modified Alcohol, Smoking and Substance Involvement Screening Test (NM-ASSIST).** This form modifies the

ASSIST, which was developed by the WHO [44] to screen for substance misuse in primary care. The full ASSIST can take 20-30 minutes to administer, while the NM-ASSIST takes about 15 minutes. The NIDA-modified ASSIST focuses on the current drugs of abuse rather than asking all questions about all substances ever used, while the ASSIST asks about lifetime use, and asks about alcohol and tobacco use in detail. Both instruments produce a Substance Involvement score, ranging from 0 for lowest risk to 36 for highest risk, for each of: cannabis, prescription stimulants, methamphetamines, inhalants, sedatives, hallucinogens, street opioids, and prescription opioids. We focused on these common elements when comparing results across instruments (Study 2).

The NM-ASSIST was used in Studies 1 and 2 by the Agent and the Research Assistant. The ASSIST was used in Study 2 by the text-based tool as that was already deployed and available as a standard tool in the VA.

**4.2.3 Satisfaction.** Satisfaction was assessed using single scale-measure self-report items to assess overall satisfaction (1="Very Unsatisfied" to 7="Very Satisfied"), the degree to which participants were comfortable with the assessment method and the degree to which they would use the assessment method again (1="Not at all" to 7="Very much").

**4.2.4 Callahan Screener.** Callahan et al [45], includes 6 items and is used as a cognitive screener.

**4.3 Procedure**

Participants assessed by the Virtual Agent were shown a tablet computer loaded with the Agent (Figure 1). The Research Assistant demonstrated how to navigate and interact with the computer. The Research Assistant remained close by to provide technical assistance or answer any questions. Participants assessed by the Research Assistant were administered the NM-ASSIST in the format of a one-on-one clinical interview in a private space.

Following the Agent and Research Assistant interaction, the Research Assistant administered the Satisfaction questionnaire to the participant, along with a manila envelope in which to seal it. Since the participant was rating the Research Assistant as well as the computer programs, we wanted them to feel as if they could rate the screening methods without any bias. At the end of each session of two substance use assessments in Study 1, the Research Assistant conducted a semi-structured interview with the participant, probing global perspectives of the Agent, and its potential usefulness in supporting individuals with substance misuse and related health problems.

We compared satisfaction with the screening experience, participant acceptance of the screening modality, and interrater agreement of scores on the substance abuse measure. Agreement of scores across the methods of substance misuse screening were assessed using Spearman's rho correlations for degree of agreement of Substance Involvement and on presence or absence of lifetime substance misuse. Spearman's rho was used instead of intraclass correlations for substance use score ranges because the distributions were highly skewed, with the majority of participants

reporting no use of stimulants, methamphetamines, inhalants, sedatives, street opioids, prescriptions opioids and "other" drugs.

**4.4 Results**

Participants in both studies were primarily in their 50's and 60's with an average age of 57 in Study 1 and 60 in Study 2 (Table 1). They had on average two years of school past high school, and were overwhelmingly male. They were about 70% Caucasian and around 25% African-American. 70% of participants in Study 1 had prior substance abuse treatment, while 56% in Study 2 had prior treatment. In both Studies, a majority of participants stated they used a computer regularly.

**Table 1: Participant Demographics**

	Study 1 (N= 30)	Study 2 (N=27)
Age, years, median (IQR)	56.5 (41-65)	60.0 (55-65)
Education, years (median, IQR)	14 (12-16)	14 (13-16)
Males, % (n)	100% (30)	92.6% (25)
Prior substance abuse treatment, % (n)	70% (21)	55.6% (15)
Race		
Caucasian	70% (21)	70.3% (19)
African-American	23% (7)	25.9% (7)
Computer Experience		
Never used one	10% (3)	3.7% (1)
Have tried one	26.7% (8)	40.7% (11)
Used one regularly	56.7% (17)	51.9% (14)
Experts	6.6% (2)	3.7% (1)

In both studies, every participant answered at least 4 out of 6 questions correctly on the Callahan Cognitive screening test.

**4.4.1 Interrater agreement between Agent and Research Assistant on risk of substance misuse (Study 1).** We calculated interrater agreement between the Agent and the Research Assistant Substance Involvement scores on all substance categories in which at least five participants reported use in the last three months (cannabis, cocaine, sedatives, and hallucinogens), and we report Spearman rho correlations for those four substances (Table 2). Interrater agreement was very good, ranging from rho=0.7 to 0.9, all tests p<.01.

**Table 2: Interrater Agreement on Substance Involvement Score**

	Study 1	Study 2
Cannabis	0.83**	0.91**
Cocaine	0.81**	0.77**
Sedatives	0.90**	0.44*
Hallucinogens	0.70**	0.69**

Spearman rho, \*\*p<0.01; \*p<0.05

We also calculated interrater agreement between the Agent and the Research Assistant on whether participants indicated any substance use over their lifetime (Table 3). Interrater agreement

was excellent, ranging from rho=0.86 to rho=1.0. Twenty of the 30 participants had completely identical responses on both methods of screening. Among the other 10 participants, there were a total of 16 discordant responses between Agent and Research Assistant; of these 12 (75%) were cases of the participant reporting substance use to the Agent but not to the Research Assistant.

**Table 3: Interrater Agreement on Any Lifetime Use**

	Study 1	Study 2
Cannabis	1.00*	0.69*
Cocaine	1.00*	0.92*
Sedatives	0.87*	0.26
Hallucinogens	0.86*	0.85*

Spearman rho, \*p<0.001

4.4.2 *Interrater agreement between Relational Agent and text-based online measure on risk of substance misuse (Study 2).* For Study 2, since the measures were slightly different between the Agent (NM-ASSIST) and text-based tool (ASSIST), we report interrater agreement on substances that had the exact same definitions in the two measures. Four of these substances had five or more participants reporting use, and we report those Spearman rho correlations on Substance Involvement scores for those four substances in Table 2. Interrater agreement ranged from rho=0.44 to rho=0.91, all p<.01.

We also calculated interrater agreement between the Agent and the text-based tool on whether participants indicated any substance use over their lifetime (Table 3). Interrater agreement was good on 3 of 4 substances (rho=0.69 to rho=0.92, p<.001), with only sedatives demonstrating poor agreement (rho=0.26, n.s.).

The Relational Agent and text-based tool agreed for all indicators for 16 of 24 participants. There were 10 discrepant measurements among 8 participants, evenly split between the Agent ascertaining higher risk (N=5) and the text-based tool ascertaining higher risk (N=5).

4.4.3 *Satisfaction.* Participants were significantly more satisfied with the human Research Assistant in Study 1 compared to the Agent, but were significantly more satisfied with the Agent than the text-based tool in Study 2 (Table 4). Other satisfaction ratings for all assessment methods were similar, except that participants in Study 1 expressed a significantly stronger desire to continue working with the human Research Assistant compared to the Agent (Table 4).

**Table 4: Satisfaction Ratings**

	Study 1		Study 2	
	Agent	Human	Agent	Text Tool
Overall Satisfaction	5.5	6.7*	6.0	5.2*
Desire to work with again	5.1	6.0*	5.9	5.4

Comfort with assessment	6.0	6.2	6.3	6.1
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\*p <.05

4.4.4 *Qualitative Results.* More than three-fourths of the participants in Study 1 (23/30; 77%) rated their experience with the Agent as “positive,” including 9 of the 10 Veterans recruited from the Rehabilitation Treatment Program. Not surprisingly, nearly half of the participants (14/30; 47%) said they prefer the human Research Assistant to the Agent, while only a quarter (8/23; 27%) preferred the Agent. Despite the predictable preference for human contact, nearly all participants (27/30; 90%) indicated that the Agent could be used in clinical practice for evaluation of a wide range health topics. One participant noted that the Agent was “easier to understand, simple to use, and quick.” Participants also valued the Agent for conducting the screening in a non-judgmental, non-threatening manner. A participant commented, “I know for a fact the computer is not being judgmental...having a real person could be a little...intimidating...Regular people are not robots. You still get some facial expression and I’m really perceptive.” The participant concluded, “Even though people will see it later, being able to say it to something that is not immediately judging” was a valuable Agent feature. Almost half (40%, 12/30) of participants in Study 1 mentioned judgment as an inevitable part of interacting with a human.

## 6 Conclusion

We found that Veterans’ responses to the NM-ASSIST’s screening questions were similar when asked by the Virtual Agent and by the human Research Assistant in Study 1, with significantly more disclosure to the Agent in the discrepant cases. We also found generally good agreement between the Agent and the VA’s text-based assessment tool. Whereas participants preferred the human administration on the screener to the Agent, they preferred the Agent to the text-based tool.

These studies indicate that substance use screening by a Virtual Agent is a viable approach for rapid identification of primary care patients who may require treatment.

### 6.1 Limitations

There are several limitations to the validation studies, beyond the small, single-site, convenience sample of participants. The studies relied entirely on self-report, without using biological tests for ground truth on current substance use. They also used the same Research Assistant performing the substance use assessment and for running the validation study, which may bias participant assessments.

### 6.2 Future Work

We have developed a Virtual Agent to perform screening, brief intervention, and referral to specialty treatment, deployed on a touch screen tablet for use in primary care clinics in VA medical centers (Figure 2). The Agent is designed to first screen for alcohol problems then, if indicated, conducted a 15-minute

counseling session using techniques from Motivational Interviewing and cognitive behavioral therapy. A randomized clinical trial is currently underway.

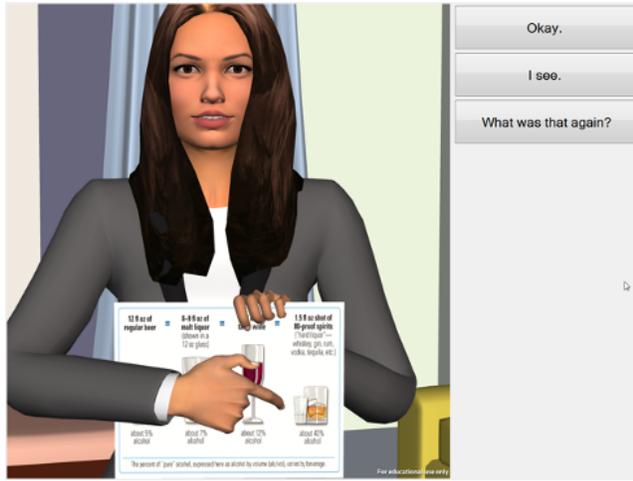


Figure 2: Alcohol Misuse SBIRT Virtual Agent

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