Development, feasibility, acceptability, and utility of using an expressive speech-enabled digital

health agent to deliver online brief motivational interviewing for alcohol misuse

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Abstract

Background: Digital health agents –- embodied conversational agents designed specifically for health interventions -- provide a promising alternative or supplement to behavioral health services by reducing barriers to access to care.

Objectives: Our goals were to (1) develop an expressive speech-enabled digital health agent operating in a 3-dimensional virtual environment to deliver a brief behavioral health intervention over the Internet to reduce alcohol use, and to (2) understand its acceptability, feasibility, and utility with its end-users.

Methods: We developed an expressive speech-enabled digital health agent with facial expressions and body gestures, operating in a 3-dimensional virtual office, able to deliver a brief behavioral health intervention over the Internet to reduce alcohol use. We then asked 51 alcohol users to report on the digital health agent acceptability, feasibility, and utility.

Results: The developed digital health agent uses speech recognition and a model of empathetic verbal and nonverbal behaviors to engage the user, and its performance enabled it to successfully deliver a brief behavioral health intervention over the Internet to reduce alcohol. Descriptive statistics indicate that participants had overwhelmingly positive experiences with the digital health agent, including engagement with the technology, acceptance, perceived utility and intent to use the technology. Illustrative qualitative quotes provide further insight about the potential reach and impact of digital health agents in behavioral health care.

Conclusions: Web-delivered interventions delivered by expressive speech-enabled digital health agents may provide an exciting complement or alternative to traditional one-on-one treatment.

They may be especially helpful for hard-to-reach communities with behavioral workforce

shortages.

Introduction

Alcohol Use Disorder (AUD) affects 10% to 20% of males and 5% to 10% of females over their lifetime, and 26.4% of adults engage in binge drinking. AUD is the third leading preventable cause of death (1), with driving under the influence accounting for 31% of driving fatalities. In addition to personal costs associated with AUD, alcohol abuse costs the US economy an average of 249 billion dollars per year. Motivational Interviewing (MI) (2) is an effective and scalable intervention for AUD (3). It is as a client-centered counseling style that is directive and elicits behavior change by helping clients explore ambivalence and resolve it in order to develop *intrinsic* motivation to change. Adaptations of MI have bourgeoned to meet the need for motivational interventions that are brief and thus compatible within primary care settings (5). Brief motivational interviewing interventions (BMIs) include MI's style of communication (communicating empathy, increasing discrepancy, rolling with resistance, and supporting self-efficacy) with the common underlying elements of effective brief interventions (e.g. feedback, menus of options for changing respectful of current readiness to change, supportive advice). BMI can be delivered in multiple settings, as both a stand-alone intervention or in combination with other strategies for substance use disorders, such as Cognitive-Behavioral Therapy, and has been found to be effective across meta-analyses (3-5). Despite the high rates of alcohol use and availability of these effective interventions, only 1 in 10 individuals with AUD receive care (6, 7).

Barriers to Care

A number of barriers prevent individuals from accessing the treatment they need, including acknowledging the need for treatment (8), availability of trained providers (9), proximity of

providers, access to transportation, affordability, insurance coverage, scheduling, and stigma (10). Individuals living in rural settings or in poverty – where alcohol abuse is more prominent - are disproportionately impacted by these barriers (9). In rural settings in particular, anonymity is more difficult (11) and increases stigma around help-seeking. Lack of flexible scheduling options for individuals who work full-time further exacerbate barriers to treatment (9). Finally, when individuals do access treatment, it is not always an evidence-based treatment – further complicating issues around access to quality care.

Digital Health Interventions

Digital health interventions (DHI) are interventions that are delivered via digital platforms (applications, websites, mobile devices, etc.). Unlike telehealth (where a live provider meets with a consumer via a video chat), DHIs do not rely on a human provider to deliver services. As such, they have the potential to reduce a number of barriers associated with location (can be accessed from anywhere), scheduling (can be accessed at any time), stigma (can be accessed anonymously from the privacy of one's home), and cost (most are affordable or free). Past research indicates that consumers tend to be more truthful when disclosing possibly stigmatizing information such as drug or alcohol disorder to a computer versus a human (12-16) – providing another advantage to DHIs as they can be more informed about consumers' at-risk behaviors than a human provider.

A review of DHIs (17) indicates that these interventions range from brief screening tools to several months of structured activities. Content includes screening and self-monitoring, personalized normative feedback, goal-setting activities, and interactive journaling. Benefits include reductions in alcohol consumption, and consequences of heavy drinking. Despite all the benefits associated

with DHIs, they are associated with high dropout rates (18). For instance, a systematic review of the use of mental health support smartphone applications indicate that only 4% of users engage daily with the applications (19). Researchers suggest that the use of digital health interventions without the support or recommendation of a mental health professional may limit its use (19, 20). Mohr et al. (21) point out that improvement in mental health conditions tend to require continued behavior change over many weeks or months, yet mental health technologies are mainly didactic, thereby not ideal for supporting engagement and behavior change. Most behavioral health technologies require some human backing from a mental health professional to sustain engagement. Qualitative studies point to lack of motivation due to frustrating technology, inadequate content, competing priorities, and lack of face-to-face encounters (22, 23). This limits the promise of DHIs as a scalable solution to increase access to care, which our approach aims to improve.

A review of DHIs designed specifically for MI (24), further points out that given the important emphasis on the interpersonal therapeutic communication style that is a core aspect of MI, delivering MI through these different modalities is difficult. For instance, can the "MI spirit", or relational aspects, happen digitally? Therefore, comprehending the type of technology used to deliver relationally focused treatments provides an understanding of how technology may be used to replace face-to-face contact. The study found that DHIs for MI vary greatly in terms of technology and richness of the media used, ranging from text-only, to audio files, to video files, to interactive animated characters, and that the most common feature of these technologies was personalized feedback to the participant, based on their input. Only a subset of few programs used videos (e.g. a "video-doctor" actor playing a doctor's responses in MI style) or animations (e.g. a robot's head with facial expressions supporting participants during

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intervention). These media were always developed with the aim to mirror interpersonal communication. Our current focus on developing and evaluating 3-dimensional virtual characters able to deliver a BMI, with appropriate facial expressions, body gestures, speech synthesis, and speech recognition in real-time aims at providing awareness into how technology may be used to replace face-to-face contact.

Shingleton and Palfai's review also found that, while surveyed articles explained methods for some aspects (e.g. automatic computer prompts, chat rooms, emails, videos, animated characters) to deliver MI, most articles did not explain how they translated MI principles into the DHI, nor whether or how the relational components were resolved (24). Translating aspects that require the MI spirit such as "expressing empathy" or "collaboration" to technology– versus consolidating commitment to change and developing discrepancy which most studies focused on – is particularly difficult to implement in a piece of software. One conclusion was that future researchers need to detail both, not only how the technical (e.g. chat rooms, emails) are delivered, but also how the relational aspects (e.g. emoticons, videos of talking narrators) are delivered in order to increase the human-like discourse with the DHI. Asking questions to help understand how participants felt about and during the interaction were also encouraged as important 'soft' outcomes to uncover ways to increase the 'spirit' of MI within technology. As highlighted by Mohr (21), while usability testing has increased in recent years, the design of DHIs has generally not included input from end users. Our focus on technology outcomes in this article aims at providing insight into these 'soft' outcomes, by explicitly asking users of our DHI specific survey questions about their experience with an expressive animated ECA in order to inform the impact of our DHI current design, our future redesigns, and other researchers' DHIs.

Embodied Conversational Agents

Embodied Conversational Agents (ECAs) (also known as virtual intelligent agents, or virtual humans) are simulated human characters that may have the potential to increase consumer engagement in DHIs (25). Unlike avatars – which are virtual entities that represent and are controlled by the user (popular in video gaming) – ECAs are virtual entities of their own that interact with a consumer autonomously, and anonymously. They are developed with the aim to look, sound, and behave as closely to humans as possible. Their ability to hold conversations is still limited (26) but advancements in natural language processing and artificial intelligence hold promise in the future of ECAs as an alternative solution to traditional therapy for mental health and substance abuse concerns (27). ECAs have the ability to use sophisticated multimodal communication to build rapport (28-41), communicate empathically (32-35, 38), and engage in social talk (42-46). Despite the promise of ECAs, research around the acceptability, feasibility, and utility of such technology by consumers of behavioral health interventions is limited. Exceptions can be found in a few studies using 3-dimensional (3D) ECAs with realistic animated facial expressions and mirroring of the users' facial expressions exist (25), a study including an ECA with a dialog management system allowing users to answer freely to the ECA (albeit without full robustness for broad dissemination without synchronous human support) (26), and a few others using simple ECAs (43, 47-50).

In spite of their success, however, ECA development did not scale with the now abundant internet devices (smart phones, laptops) and the latest progress in 3D graphics. Some attempts have been made to build web-based 3D ECAs (51-53). However, their implementation is still very basic, and they do not offer an integrated framework for web-based ECA development, including

the ability to recognize and synthesized social cues in real time during spoken dialog, which is a significant technical challenge and which our ECA provides.

Current Study

The current study aims to fill the gap in knowledge of using ECAs in behavioral health contexts by establishing acceptability, feasibility, and utility of using ECAs by consumers receiving a Brief Motivational Interviewing intervention for alcohol abuse. MIs are highly structured (*assessment* of followed by normative *feedback*, then *menu* of change options), making them amenable to delivery via DHI (22), particularly if the "MI spirit", or relational components, can be captured without face-to-face contact. One such BMI, namely the *Drinker's Check-Up (DCU)* (2) is the intervention used for our current work. DCU has been computerized as a menu-based text-only program delivered online that targets alcohol abuse, reducing drinking by an average of 50% at a 12-month follow-up (50).   The DCU is one of the two English-language web-based DHIs designed for the public that have been tested in randomized controlled trials (7). We therefore chose to study how the delivery of the DCU by an ECA will be perceived by its users, given that its nonverbal and other media features aim to address the observed limitations of the use of avatars in DHIs for MI that do not strengthen the social relationship with the user (50).

Using Davis' technology acceptance model (TAM) (54, 55) to guide our work, this study will enable us to determine if the ECA designed by our team using the eEVA (Empathic Embodied Virtual Agent, see Figures 1 and 2) framework for building digital health agents (56) has enough personal characteristics and social abilities (e.g., open-mindedness, supportive, respectful, friendly) to give users a positive experience (acceptability).

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Figure 1. Our empathic Embodied Virtual Agent (eEVA) delivering a Brief Motivational Interviewing behavior change session

The TAM stipulates that user acceptance can be predicted by the perceived usefulness (utility) and perceived ease of use (feasibility) of the technology. As such, we are interested in learning more about consumers' perceived positive experience (acceptability), usefulness of eEVA (utility), and ease of use (feasibility) to better understand acceptability and potential for adoption of the technology. Having technology that consumers like, find easy to use and helpful increases the potential for adoption, which, in turn, increases access to care. Increases in access to care have the potential to improve health outcomes for alcohol users. Prior studies have found that MI for alcohol use (including online delivery via textual interface) improves health outcomes (57).

Methods

Intervention

The intervention is based on the Drinker's Checkup (DCU) - an evidence-based intervention that uses strategies from Motivational Interviewing (57). *First*, users provide detailed information about their drinking (e.g. own drinking patterns or issues, family history of alcohol use). *Next*, they receive individualized feedback about their drinking habits, including information about risk factors and consequences (58). *Finally*, they resolve their ambivalence about whether to change their drinking, to plan for a change, and to set goals for change. The intervention provides resources to help users with changing their drinking (59). However, the DCU does not tell the clients what to do or not to do – it is up to the user whether or not they want to change their alcohol use. The DCU has been studied extensively and leads to reductions in the quantity and frequency of drinking by 50% throughout a 12-month follow-up period, when compared to a waitlist control group (57). The DCU is one of the two web-based DHIs that have the strongest evidence supporting their efficacy based on randomized controlled trials(7).

In this study, the DCU was delivered via an ECA (namely eEVA: an empathic Embodied Virtual Agent) rather than via its traditional textual interface. As a BMI, the eEVA intervention combines MI style of communication with the common underlying elements of effective brief interventions characterized by the acronym *FRAMES* (2): *Feedback* about client's individual status is personalized and stored in a user model database, keeping a record of users' answers for the next session(s); *Responsibility* for changing is left with the individual, and the language used throughout the intervention reflect this (e.g. "I will not pressure you in any way"); *Advice* is provided in a supportive manner, with empathic choice of words and supportive body gestures (see ; *Menus* of different options for changing that respect individual's readiness to change are

offered; *Empathic* style of communication is central to the individual-clinician relationship, and it is conveyed by the ECA's verbal utterances (e.g. spoken reflections) and nonverbal behavior (e.g. smiling facial expressions, lean forwards, hand flips, nodding at appropriate times), and empathic choice of wording (e.g. "It might be surprising to you to know that you are in the top percentile in drinking compared to people of your gender and age; you might want to review your answers again …") ; and *Self-efficacy* is nurtured and emphasized throughout, including with choice of words, and positive facial expressions (e.g. various head nods, and smiling facial expressions).

Technical Implementation of the Intervention

Our EEVA framework (shown in Figure 2) provides: 1) a realistic 3D WebGL graphics virtual environment with a realistic virtual office environment, that can be 'inhabited' by one of the 25 available racially diverse ECAs (shown in Figure 3), each with physiologically realistic FACS-validated facial expression animations, and full body animations), and 2) realtime speech recognition of user's answers; 3) text and multiple choice input; 4) voice synthesis for the ECA's spoken utterances; 5) ECA's lip synchronization between phonemes and visemes; 6) ECA's adaptive non-verbal responses such as head nods or leaning forward depending upon the utterance dialog act; 7) configurable dialogue content; and 8) ability to capture and process users' social cues such as facial expression recognition (which will be enabled in a future study).

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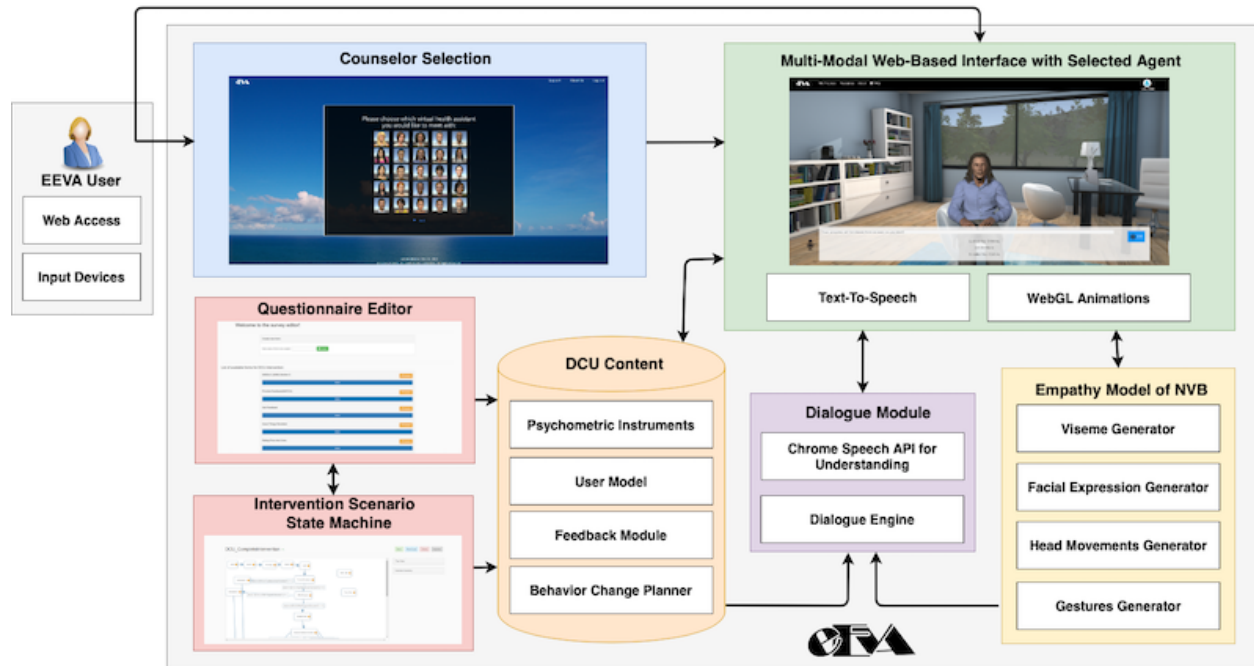

Figure 2: **eEVA system overview**

Technically speaking, the framework consists of three main components. First, the application layer consists in a modular client-side JavaScript mainframe which controls the multi-modal user interface, audio and video input, graphical user interface (GUI) interaction and services such as speech recognition and speech synthesis. Secondly, the JavaScript mainframe handles execution of a scenario (the content of the DCU in this study) – a collection of state-machines that are created by developers. Third, the scenario states can be constructed to pull information (e.g. the ECA's speech, graphics to show) from the data layer – a database of content.

The backbone of the client-side application is a JavaScript framework that handles the formation of a group of modules and the communication between them. Each module then implements various functionalities, including:

      • gaining feedback from the user (e.g., asking to access microphone and camera),

processing input information (e.g. analyzing users' responses, extracting facial expressions if

desired);

      • determining how to answer the user (e.g. words agent should say, non-verbal

behaviors);

      • answering to the user through a multi-modal 3D embodied ECA, with speech synthesis,

non-verbal behaviors and multimedia content (e.g. text, images and videos).

This results in an interactive online application which can run on numerous platforms such as

desktop, cell phone, autonomous robotic agent, and potentially smart watch integrations (Figure

4).

Figure 4: eEVA running on different platforms: desktop (a), mobile phone (b), autonomous robot (c), smartwatch concept (d).

In addition, the user can also choose between a collection of 3D virtual characters to interact

with – of different gender, races, and appearances. To personalize the eEVA system further,

favorite chosen characters are remembered and displayed after login during the next interaction

with the system. Distributing the framework core (3D character, perception, behavior, etc.) to

consumer devices makes this technology scalable, with little to no overhead with additional

users. Computer-intensive functionality such as speech and face recognition is asynchronous via

web services or with built-in functionalities in the browser.

Unlike traditional ECAs, EEVA's design follows common modularity patterns found in robotics platforms such as ROS (60), allowing us to generate collections of modules to cover a diversity of application use-cases, such as various browsers, many internet bandwidth limitations, and interaction capabilities. For instance, when using speech recognition, in order to provide the transcript of the user's spoken utterances to be used by the ECA application, based on browser capabilities, a specialized module can be used to either interface with the Web Speech API or to use another service such as the Watson Speech to Text. The advantage of this design is the seamless passing from one module implementation to another, including at runtime, without affecting the rest of the application.

Three main categories of module functionality are necessary for modeling social interaction, namely: *input/sensing modules* (for perceiving social cues from the user in real time); *social interaction decision-making modules,* including an ECA behavior module, vocal command interpretation, and the scenario controller; and *output/actuator modules* for actually expressing verbal and non-verbal cues to the user. The functionalities of the main modules used in the current version of eEVA are listed in Table 1. Most modules have simple functions to retrieve or display information from and to the user or call functions from libraries (3rd party or in-house) or services.

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Table 1: Listing of most significant modules used in eEVA for our Health Agent.

Module Function Description
- *Input/Sensing Modules* -
User microphone interface using WebRTC API
Speech recognition using Google Chrome API
Interface with CoreNLP
GUI for direct user input (text, buttons)
- *Social Interaction Decision-Making Modules* -
Vocal command interpretation
ECA's behavior (gesture and facial animations
Scenario controller (state machine execution)
- *Output/Actuator Modules* -
Speech synthesis
25 webGL eEVA 3D ethnically diverse characters

We tested two types of network connections: broadband and 4G mobile data. The majority of the launch time consists of loading the 3D character and surrounding virtual environment, which takes about 30 and 25 seconds on 4G and Broadband respectively. The experiments (Table 2) show that the main distributed functionalities of the eEVA framework allow real-time interaction and adequate loading times. This was echoed by users, as discussed later in our Results Section.

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Table 2: Average response time and standard deviation analysis for eEVA (in milliseconds); 4G/Broadband connections over the Internet between North America and Europe; caching disabled (first run).

Functionality	4G Mobile data	Broadband internet
Unity 3D character	30018 +/- 663	24626 +/- 1910
TTS (sentence)	939 +/- 381	551 +/- 141
TTS (word)	72 +/- 40	44 +/- 23
Speech recognition	~ 30 (offline processing	
Entire HTTP request	1124 +/- 166	784 +/- 66
DOM loading	2313 +/- 80	1635 +/- 224

Model of Empathic Verbal and Non-verbal Behavior

To simulate some of the communication psycho-linguistic signals of a counselor delivering a BMI, we first videotaped BMI sessions between a live licensed counselor and a client. Then, a clinical expert reviewed the videotapes to code verbal reflections and non-verbal behaviors (NVB). From these, the expert generated a set of rules for basal behaviors of the health agents. Based on the codes of verbal and NVBs, eEVA is implemented with the following verbal reflections: Ah., Alright., Okay., Good., Sounds Good., Oh, okay., Great! Thanks for letting me know., Oh, I see., Okay, thanks!.

In addition, the following NVBs animations were synthesized on the agent's face. smile, facial expressions, hand gestures (typing on computer at desk, hands resting on the agents' legs, formless-flick, two-handed flip, two-handed contrast gesture), body leans (forward), head

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gestures (nod, shake, non-shake), and eyebrow movements (up, neutral, and down), which our results (discussed later) show are conducive of a positive experience for the user with the agent, in the given healthcare context.

Since it was determined that head nods are critical to portraying (some level of) active listening, we sought to offer three variants depending on the users chosen responses. We created a set of nods using established emotional expressions governed by activation of specific individual facial movement animations. All three of the head nods included activation of head down and eyes down. However, depending on the type of reaction required, these also included facial expressions (e.g. smile, mild concern).

The patterns observed in the videotapes of the counselor-client session also directed us towards creating rules about when certain statements should be made, to ensure the counselor did not appear judgmental, and to make the interaction appear more natural. In all scenarios, the counselor began seated at the desk while typing on the computer, then looked up and moved to the chair closer to where the user perceives it is sitting during an initial greeting. Once seated, the counselor began with a greeting introduction and then moved on to delivering the DCU. Verbal responses to user responses were applied based on the "score" of each question to provide non-judgmental reactions for higher scores that might indicate a problem, and positive reactions for scores that might suggest healthy consumption levels. For example "Sounds good" was used in response to a user mentioning that [s/]he wanted to change.

In parallel, NVBs were applied using a set of states that were determined as appropriate given the context of the interaction as shown in Figure 5: Neutral, Explaining, Asking, and Listening.
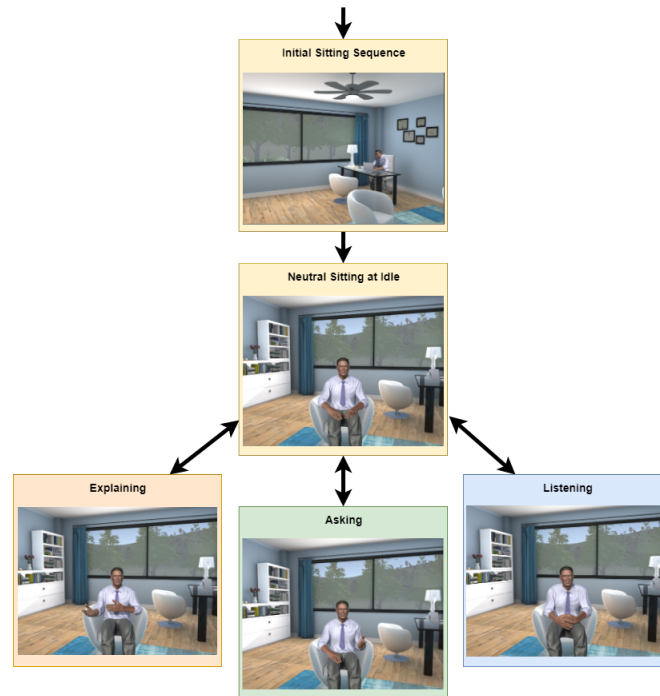
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Figure 5: Defining NVBs for virtual health agents. All undergo the initial sitting sequences and then assume a neural sitting at idle position. From here, the agent an enter either be explaining, asking, or listening loop

In the *Neutral* state, the counselor spoke and used smile, gaze, facial expressions, head gestures and/or eyebrow movements. In the *Explaining* state, which was activated during long periods of speaking, the two-handed flip and two-handed contrast gesture were applied. When the counselor posited a question to the user, the *Asking* state was initiated, which included a single hand form- less flick. While the counselor waited for the user to respond to a question, the *Listening* mode was initiated, which included a leaning forward gesture. The leaning gesture remained in effect until a choice was made, at which point the body resumed an upright sitting position.

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Participants

Participants were alcohol users ages 21 to 55 recruited online to participate in the intervention. Participants had to have engaged in heavy drinking (consumed 5 drinks in one sitting at least once in the past year), not currently be receiving treatment for their alcohol use disorder, and not have a medical condition for which alcohol use would be contraindicated. Users were also screened for severe mental illness. We recruited 51 participants as part of a larger randomized controlled trial of the effectiveness of this program in reducing alcohol abuse. Participants were 62.2% male, 32.2% female; with a mean age of 28 (SD = 15.8). Participants reported their race as White (41.9%); Black (24.3%); Asian (6.8%); Other (2.7%); and no response (24.3%). Participants reported their ethnicity as Non-Hispanic (83.8%); Hispanic (14.9%); no response (1.4%). Marital status was married (45.9%), single (33.8%), divorced (6.8%), widowed (1.4%), no response (12.2%). Their education level was high school (14.1%), some college (25%), Associate Degree (18.8%), Bachelors Degree (35.9%), and Graduate Degree (6/3%).

Procedures

Participants were recruited online via targeted advertising on Facebook, offering free treatment for alcohol users and compensation for research participation. When users clicked on the ad, they were redirected to an online screener (on Qualtrics) to ensure they were eligible for the study. If they were eligible, users were randomly assigned to receive the same DCU Motivational Interviewing intervention delivered online either by an ECA (eEVA) or a textual interface. Participants in this study were those who were assigned to eEVA, since the control group assigned to the text-only interface could not comment on the ECA's social features which they did not see. Once randomized, participants were provided with a username and password to

enter the DHI platform eEVA. Participants had to log on, enter demographics information and begin the intervention. After completing the intervention (participants were given one week to complete), they were redirected to an online survey on Qualtrics to provide feedback about their experience with the intervention.

Measures

After completing the intervention, participants were asked to provide feedback on feasibility, acceptability, and utility of the technology. Specifically, we sought feedback regarding their engagement (acceptability), perceived utility and intent to use the technology (feasibility). Participants completed a questionnaire developed for this study. Since there does not exist to date a standardized instrument to evaluate interaction with ECAs of various levels of complexities, we used and adapted relevant existing questionnaires commonly used for the evaluation of human interaction with technologies involving some social cues, whether embodied with graphics or with robot technologies. Questions were based on a combination of O'Brien's engagement model (61), Heerink's Almere model (62), and Bartneck's 'Godspeed questionnaire' which has been widely used to evaluate human-technology interactions using five key concepts -- anthropomorphism, animacy, likability, perceived intelligence and safety – found useful for interacting with either ECAs or robots (63). All responses were on a seven-point Likert scale (1 = Strongly Agree; 7 = Strongly Disagree), with lower scores indicating more desirable findings. There was no cut-off as the measures were combined for the purpose of this study and were meant to provide descriptive feedback. In addition, each question included a blank space with a prompt "Comments" for participants to provide optional qualitative feedback to each question.

O'Brien's engagement model explores acceptability of the ECA via constructs of user engagement with technology. Six attributes of a technology make it more likely that a user will engage with it (challenge using the technology, interest, motivation to use the technology, and appeal of the technology; e.g. "I found the health assistant interesting"). Responses were on a 7-point Likert scale (Strongly agree - 1) to Strongly disagree - 7)

The Almere Model evaluates the users' acceptance of the digital health agent by relying on constructs from the Unified Theory of Acceptance and Use of Technology (12). Users replied to thirteen statements (e.g., "I enjoyed participating in this session with the health assistant") that map on to constructs that predict intent to use the technology and perceived usefulness of the technology. Responses were on a 7-point Likert scale (Strongly agree - 1) to Strongly disagree - 7)

Godspeed Questionnaire. This questionnaire consists of twelve questions that capture five constructs that measure human-like traits of robots, which we adapted for ECA (e.g., "The health agent seemed warm"): (1) Anthropomorphism (e.g., moving rigidly / moving elegantly); (2) Animacy (e.g., Mechanical / Organic); (3) Likeability (e.g., Unfriendly / Friendly); (4) Perceived Intelligence (e.g., Incompetent / Competent); and (5) Perceived Safety (e.g., Anxious / Calm). Each trait could be rated as being very human-like to very un-human like on a 7-point scale. All questions included a fill-in option for participants to expand on their numerical responses with qualitative feedback if they wanted to. We highlight some of those comments in the results.

Results

Acceptability and Utility

Participants reported high acceptability and utility of the technology, as indicated by their scores on the Almere model questions (M = 2.31; SD = 1.05). Most participants reported enjoying their interaction with the agent (86.1%) stating "*The questions she asked me, no one had asked me before and helped recognize my drinking problem*". They thought the agent was both physically appealing (73.6%) and had a pleasant voice (81.9%), stating "*He is neat, he has a good haircut, he is well dressed*"; "*He appears wise, intelligent, and healthy*"; "*The voice was adequate, calm, and confident*".

Furthermore, participants indicated that they found it easy to interact with the health agent (88.9%) and they learned to do so quickly (88.9%) stating "*I just followed the instructions and voila!*"; "*I just waited and followed his instructions, it was easy*". Participants had more difficulty with the voice feature of the technology, with only 69.4% reporting that they felt like the agent understood them when they spoke into the microphone. Based on the qualitative feedback, this may have been due to issues with participants' microphone setting rather than the technology itself (e.g., "*I set my microphone up but it seems there is a problem with it*"; "*I tried to speak my answers but it never worked so I ended up typing them*").

Those who were able to get their microphones to work seemed to have no difficulty speaking to the agent as echoed by their qualitative feedback (e.g., "*I don't even repeat my answers, the agent understands me very well*"). Despite some difficulties with the microphone, 77.5% felt like they could have a conversation with the agent, stating "*I felt that he knows me, knows what I want*" and reported that they sometimes felt like they were talking to a real person (70.8%)

stating that *"his voice sounded quite real"* and *"the gestures he made, way he moved around"* and *"he answered me like a real person"*.

Participants further reported that the health assistant was friendly (88.9%) and they found it to be useful (87.5%) because *"he explained things that I did not know"*, *"it helped me recognize that I have a problem"*, and *"I learned a lot"*. Participants reported that they were comfortable disclosing information about their drinking to their digital health assistant (93.1%), with 83.3% reporting that they were *more* comfortable disclosing their drinking to the digital health assistant over their medical doctor. Indeed, participants highlighted *"The assistant gives me a level of trust that I don't have with other humans"* and *"it is more easy talking to (the health agent) than to a real person"* because *"I don't feel like they are judging me"*.

Finally, participants reported trusting the advice the health agent gave them (84.7%) and that they planned on following that advice (86.3%), stating *"I think she is sincere and wants to help me with my problems"* and *"because it is based on facts and studies and that is real and valid information for me"*. One participant noted *"I didn't feel like I was given advice, more like information to be able to make my own decision. I was the one with the power to give myself advice"* – perfectly capturing the intent of Motivational Interviewing.

Engagement

Participants were highly engaged with the digital health intervention, as indicated by their score on the O'Brien's engagement questions (M = 2.86; SD = -.96); indicating that the majority of participants agreed with statements around how engaged they were. Specifically, 68.5% were not worried about making mistakes while using the technology; stating "*At first it was a little bit intimidating, but then I felt confident*" and "*The assistant feels understanding, attentive, very friendly*".

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A majority (86.1%) thought it was a good idea to use the health assistant; reporting "*He is kind of like a home counselor who works with reliable information and statistics*" and "*It is practical, easy to use and guides the person on what to do without forcing us to make a final decision*". Participants felt that the system could be adaptive to their needs (90.3%) stating that "*it could be adapted to other health problems like smoking*".

Finally, 87.5% found the health assistant to be interesting indicating "*I was impressed by the way it converts my answers into figures and important information for my health*" and said they would interact with the agent again (84.7%): "*Setting a new exchange with the health assistant would help me to reach my goal*".

Impressions of digital health agent

Participants reported a high number of human-like traits on the Godspeed questions (M = 2.07; SD = 0.89). Participants reported that the agent moved appropriately (84.7%), seemed warm (90.3%), responsive (88.6%), knowledgeable (91.8%), relaxed (90.4%), flexible (83.3%), honest (90.3%), respectful (90.4%), confident (91.8%), interested (86.3%), open-minded / non-judgmental (83.6%), and supportive (89%).

Overall, participants' responses to the questionnaires and qualitative feedback indicate that they found the delivery of a Motivational Interviewing intervention by a digital health agent over the internet to be acceptable, engaging, with features that are close to human-like.

Discussion

Our goal with this study was to understand if the technology we developed was feasible (able to be implemented online), acceptable, useful and easy to use by consumers. As such, we focused largely on the technology aspects of the intervention.

Principal Results

This study provides an optimistic outlook for the use of digital health agents to deliver brief online interventions in the future. Consumers overwhelmingly reported positive experiences in their interactions with the agent, with many reporting that they trusted the agent and felt that they could more comfortably disclose information that they may not have disclosed to a human provider. This echoes what has been found in the literature around disclosing to computers versus humans (12, 14, 64, 65).

Further, participants tended to attribute many human-like traits to their agent (e.g., friendly, trustworthy, kind) and commented positively on the physical appearance, voice and physical gestures of the agent. Our team engaged in coding of verbal reflections, hand gestures, and facial expressions of a real therapist to enhance the digital agent's nonverbal communication to resemble what a therapist might do in session (66).

Implications for this work are important. Given the shortage of mental health workforces in many locations, digital health agents may provide an acceptable complement to traditional face-to-face therapy, reducing demand for higher levels of care, where a digital health agent can act as a clinician 'extender' to deliver booster sessions. Similarly to telehealth services, digital health agents resolve a number of barriers to care such as transportation and scheduling.

In addition, digital health agents reduce stigma around mental health care, are less costly than one-on-one therapy, and can be scaled out and disseminated. For individuals with high levels of social anxiety, digital health agents may provide them with a unique opportunity to get help. Given the digital nature of the agent, it is possible to adjust the programming to make the agent able to speak in multiple languages, reducing language barriers for minority and refugee populations. Already, consumers can pick a digital health agent from a library of diverse options

of physical visual features (gender, age, race and ethnicity, see Figure 2), and vocal features (gender). This is an exciting development given the lack of a diverse mental health workforce (67, 68).

This study has provided the investigative team with valuable feedback to improve the technology, including improving the flow and tone of the voice, providing questions in text, and formatting the technology for use on mobile phone and with lower bandwidth.

Limitations

Despite these enthusiastic findings and implications, it is important to note a number of limitations. *First*, digital health agents cannot replace traditional therapy, and certainly cannot manage crisis situations. They are well suited for brief, structured interventions, but cannot replace the complex nature of a therapeutic relationship and complex therapeutic interventions such as family therapy, emotion-focused therapy, etc.   They were considered and studied in this article as clinician "extenders". *Second*, this study was conducted with participants in the United States only. It is unclear if technology acceptability would be as high in other countries. *Third*, the impact of the digital health intervention on actual alcohol outcomes remains unclear. A study is underway to better understand the effects of a digital health agent. *Fourth*, it is unclear whether ECAs are suitable for various health problems besides alcohol and for various other populations not studied here, such as the elderly or children. *Finally*, the access and cost to reliable internet necessary to use ECAs may limit access to some – potentially further increasing the digital divide.

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Conclusions

This type of intervention and research on digital health agents in virtual reality over the Internet is still in its infancy, and there is much work to be done. For instance, the same BMI intervention delivered in this study could be adjusted to other health behaviors (other substances, medication compliance, weight management, etc.). Other interventions could be delivered to screen or treat a variety of problems. Furthermore, our team is working on integrating natural language dialog management features such that the agent will respond to the consumer's answers without needing specific input to read from. We conducted preliminary work (26) for a speech-enabled ECA for BMI interventions with promising results. However, natural language understanding is still a very open research area of computer science, and its use in DHIs not robust enough to deploy with real users who need support and help, without the potential frustrations generated by unreliable agent's speech understanding. Our team has also worked on features based on artificial intelligence, that allow a PC-based agent (i.e. operating on PC only and not web-based) to pick up on the consumer's facial expressions in realtime (e.g., if the consumer smiles, the agent smiles back) which has been shown to improve users' engagement with digital health agents (25), and we plan to add this type of features to our web-based eEVA system.

Despite all these exciting potential developments, it is critical to evaluate DHIs with high levels of rigor before they can be deployed for the population at large. As pointed out by Carroll (7), very few of the many available Internet-based interventions have been carefully evaluated in well-controlled clinical trials, and the majority of those studies have been conducted on college populations, bringing into questions the generalization of the results to broader society. The conclusions that can be drawn from many studies are constrained by high levels of dropout, high

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attrition, and weak control conditions (e.g., waitlists). To that end, we will report on the results of the randomized controlled trial we conducted to assess the efficacy of the eEVA DHI compared to a text-only version of the intervention.

We furthermore consider that these digital health agents and digital health interventions can only *complement* the unique experience of psychosocial therapy, and serve as "clinician extenders" (7). As suggested by Mohr et al.(21), mental health technologies in general should be considered as socio-technical systems (or technology-enabled services rather than mere products) that must fit within an ecosystem of mental health services (involving human support and organizational factors). Our aim is to provide relief to a clogged mental health system, and provide online access to self-help to individuals who otherwise would not access traditional face-to-face care. Further research on whether DHIs increase access to care by removing the barriers identified earlier (e.g. availability and proximity of trained providers, affordability, stigma), or whether they increase the digital divide is needed (21). Digital health agents, even with integrated AI, will not replace human therapists, they should be considered therapist extenders.

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