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Virtual prognostication: When virtual alcohol choices predict change in alcohol consumption over 6-months

Liyuan Wang¹, John L. Christensen², David C. Jeong³, and Lynn C. Miller¹

¹Annenberg School for Communication and Journalism, University of Southern California, Los Angeles, CA, 90007

²Department of Communication, University of Connecticut, Storrs, CT, 06269

³College of Computer and Information Science, Northeastern University, Boston, MA, 02115

Abstract

Narrative games, in which users interact with virtual agents, are increasingly being used in health interventions to change targeted behaviors. In virtual social interactions, based on similar real-life contextual cues, past behavior can predict virtual choices. Here, based on theories in learning and interactivity, we examined the whether following a virtual intervention, choices in social interactions may be particularly diagnostic of future behavior changes. To test this, we needed to: (1) leverage a contextualized risk (e.g., involving alcohol consumption) scenario (e.g., having one more drink with my partner) given a target audience (e.g., sexually risky young men who have sex with men (YMSM)), (2) include within this context an evidence-based virtual intervention (e.g., promoting alcohol reduction), (3) instantiate and record a virtual choice (water or alcohol) in a virtual dating game scenario intervention with IA for that target audience, and (4) assess pre and 6-months post-intervention YMSM's alcohol use. Using a Socially Optimized Learning Environment (SOLVE) intervention game with IA and alcohol use measures, we found that virtual water choice (versus virtual alcohol choice) significantly predicted real-life alcohol consumption change. Furthermore, personality factors (e.g., Behavioral Approach System) predicted virtual choices and alcohol consumption change. Implications of these findings are discussed.

Keywords

Interactive narratives; SOLVE game; interventions; diagnostic assessments; alcohol; risky sexual behavior; men who have sex with men

Interactivity, especially in the form of interacting with a virtual social agent, can be the key to interventions that improve performance and induce behavioral changes in various domains. For example, in training simulation environments, pilots or would be pilots -guided

Corresponding Author: Liyuan Wang, Annenberg School for Communication and Journalism, University of Southern California, Los Angeles, CA, 90007, liyuanwa@usc.edu.

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by virtual agents embedded in virtual environments (VE) that mimic real-life similar controls and flight situations -learn procedural skills that allow them to subsequently successfully fly, respond to emergencies, and land a range of aircraft in real-life. Indeed, guided by learning theories (e.g. Vygotsky, 1987) including procedural learning with feedback and repetition and habituation or systematic desensitization (Rizzo et al., 2013), virtual interactions are also used as both a means to improve and assess performances. Interacting with virtual characters in *Second Life* in a reality (VR) environment, high functioning Autistic individuals have shown great improvement in recognizing social meanings of emotion and haptics (Kandalaf, Didehbani, Krawczyk, Allen, & Chapman, 2013). Meanwhile, improvement in interacting with virtual characters, such as scientific inquiry skills with a virtual classmate (Ketelhut, Nelson, Clarke, & Dede, 2010) or enhanced surgical skills on virtual patients (Grantcharov et al., 2003; Seymour et al., 2002), were also used to assess the (likely) real-life performance of targeted participants.

Although these interventions differ substantially in their specific theoretical underpinnings, what much of this work has in common - implicitly or explicitly - are a number of assumptions. First, new behavior can be learned (e.g., overgeneralization or over-sensitization to triggering cues can be mitigated by new response option learning that becomes pre-potent) in virtual environments (Rizzo et al., 2000; Stratou et al., 2015). Second, that new behavior (or change in behavior) can generalize to the real world. A third implicit assumption is that during the virtual behavior itself, the client's/participant's behavior is changing, and therefore the virtual behavior itself is potentially diagnostic of future behavior change. Indeed, rapid advancements in using virtual agents to communicate with and to guide behavioral changes suggest that interactivity is not just a special feature on the media interface (Sundar et al., 2013): It may mean much more. Game-based interventions that utilize interactive narratives that are similar to real-life behavioral risk cues and challenges (Miller et al., 2018), and then contextualize virtual interventions within those risk contexts, can take advantage of virtual game characters to access participants' virtual reactions to those virtual contextualized interventions. For such interactive narrative games, participants' virtual choices themselves may indicate current movement in behavior towards key intervention messages provided by a game character (e.g., a scaffolding tutor or guide) and thus be prognostic of future behavior change.

Extending theories of learning (Vygotsky, 1987) and interactivity (Green & Jenkins, 2014; Sundar et al., 2013), this study evaluates the possibility of using virtual interactions as prognostic tools to predict real-life behavior changes in an intervention. We assessed the virtual interactions involving alcohol or water consumption during virtual dating scenarios within SOLVE (Socially Optimized Learning in Virtual Environments, Miller et al., 2017; Christensen et al., 2013), a 3D interactive game-based intervention that was designed for reducing risky behaviors (e.g., sexual, alcohol-use) among younger men who has sex with men (YMSM).

The goals in the current work were first to evaluate if virtual choices (e.g., water versus alcohol) within an interactive narrative with risk cues could be diagnostic of subsequent behavior changes (e.g., change in real-life alcohol use) given an embedded virtual agent intervention (e.g., for alcohol reduction). Moreover, this study also observed how

individuals' traits (e.g. BIS/BAS) are related to the virtual choices of interest (e.g., water, alcohol). Understanding how these traits might affect user behavior could help researchers to design more effective content and messages for interventions that might be better tailored to those most at risk.

1. Are virtual interactions and choices predictive of real-life behavior changes?

There are three aspects of virtual environments that might enable learning and behavior change. First, developmental theory suggests that social agents (e.g. tutors, peers) may play a fundamental role in learning.

1.1. Developmental and Learning Theory for Virtual Agents

The validity of using intelligent agents to guide and assess behaviors in VE is rooted in a variety of literatures in developmental psychology and learning theory. Learning of new behaviors, according to the educational psychologist Vygotsky (1962), is usually first dependent on the social level, then the individual level. That is, new behaviors/skills are usually learned through social interactions with expert guides or peers before one can master the skill by themselves. Vygotsky (1978) also identified the zone of proximal distance, defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). Virtual characters, especially in narrative games, can facilitate behavioral changes by acting as the guide in simulated scenarios thus scaffolding the participants over the zone of proximal distance (Bloom, 1964; Honey, Connor, Veltman, Bodily, & Diener, 2012). In digital media interventions based on the SOLVE framework, for example, there is a user-chosen avatar that represents one's Virtual Future Self (VFS). The VFS character serves as an expert, guiding and scaffolding behavior change throughout the course of the interactive narrative. The VFS character is programmed to interrupt, challenge, and accept/acknowledge the user's emotions and goals - while modeling (Bandura, 1990) alternative behavioral choices that enable the user to safely achieve their goals.

Another type of social agent that users may interact with are peers (e.g., in negotiating safer sex). By interacting with a virtual character, participants - partially through observational learning and feedback (Read et al., 2006)- can develop the critical skills and improve interpersonal performance. In the case of reducing risky sexual behaviors with SOLVE, through interactions with one's virtual character and virtual partner characters (e.g., hot dates), users can learn new skills and practice avoiding obstacles to safe sex, with additional guidance and feedback from the avatar to help them through difficult situations. That is, engaging in a simulated scenario, users can be guided through difficult social scenarios such as negotiating condom use or simply ordering water as opposed to alcohol when on a virtual date. Therefore, virtual characters can be the key to providing the necessary scaffolding for desirable behaviors.

A plethora of studies has shown that virtual behaviors (or change in behaviors) acquired by interacting with virtual characters can generalize to the real world. For example, reviews (Cant & Cooper, 2014) have shown the parallels regarding the effects of using virtual instructors and patients and face-to-face teaching for nursing students, such that knowledge and skills (e.g. communication, patient management, etc.) acquired within the VE can be indicative of learning outcomes in real life. Researchers can even make use of the parallel between the virtual and real world to preempt problematic behaviors. Indeed, communicating with a virtual agent has also been identified as a potential means to predict problematic behaviors. Lucas and colleagues (2014) found when communicating with a likeable virtual agent, individuals are more likely to self-disclose. Indeed, virtual agents, who can directly capture problematic communications of the participant to diagnosis and predict problematic behaviors, have already been used as a prognostic agent that can predict psychological stress (Stratou et al., 2015).

1.2. Interactivity and Virtual Interactions

Examining virtual interactions could be meaningful in predicting, in real time, the efficacy of the intervention in producing future behavior changes. Indeed, extant theories on interactive narratives have also suggested that, during the virtual interaction, participants may already be changing their behavior and therefore the virtual behavior itself is potentially diagnostic of future real-world behavior change. This predictive nature of virtual behaviors can be especially prominent in VEs that are story based. That is, virtual interactivity, when embedded in narratives plots, takes the form of an active media experience in which the viewer can “choose their own adventure” (Green & Jenkins, 2014). Especially, in an interactive narrative game, people choose the characteristics of their avatar; they can customize their avatars’ hair color, clothes, and even voice. In this way, people can increasingly feel a sense of control and involvement by being an active part of the story. Such interactive features, although they may appear to be trivial, allow audiences to develop an affinity with their game character (Green & Jenkins, 2014; Walter, T. Murphy, & Gillig, 2018). This process of allowing people to be transported in the virtual world by assuming the perspective and status of the character (e.g. hero of the story, avatar, virtual agent) could apparently make them more likely to make informed decisions and advantageous choices on their characters’ behalf (Calleja, 2007; Green & Jenkins, 2014; Peng, Lee, & Heeter, 2010; Sangalang, Johnson, & Ciancio, 2013). That is, by identifying with the story character, viewers become transported to the story world through psychological mechanisms such as *narrative engagement* (Moyer-Gusé, 2008; Slater & Rouner, 2002), *identification* (Cohen, 2001), or *transportation* (M. Green & C. Brock, 2000). The unique narrative experience of the story world may compel audiences to change their subsequent attitudes and behaviors. For example, within the context of a health intervention, “informed decisions” (e.g., the choices one made through interactivity) are already the product of being an active part of a developing storyline with the intention to persuade or otherwise change behavior. Assuming that those virtual storylines and their associated cues are also similar to those in real life, the user’s learning is contextualized with the cues in the virtual environment that are similar to those in real-life (Miller et al., 2018). Thus, if a viewer makes desirable virtual decisions after being exposed to persuasive and other relevant framed contextualized messages, such decisions should largely be diagnostic of subsequent real-life behaviors.

Such parallels between one's behavior in the real world and the story world have long been examined. For instance, to understand the relationships between one's self-reported behaviors and virtual behaviors, Godoy and colleagues (2008) proposed the importance of examining *virtual validity*, the correlation between one's self-reported behaviors in the real-world and their subsequent virtual behaviors in a video game. In their study, virtual validity coefficients were quite high regarding participants' past behaviors such as substance use and sexual patterns. Similarly, researchers have used choices with virtual characters to provide indicators that are diagnostic of problematic behaviors difficult to observe in real life (Faraone et al, 2016; Rizzo et al., 2000). For example, Faraone et al. (2016) assessed ADHD children's virtual behaviors (e.g., joint attention and attention seeking), finding that virtual behaviors may provide more effective diagnosis of ADHD than that of parental self-reports. We should note that these coefficients between past and virtual behaviors were higher for behaviors that were not the target of behavior change, such as sexual position preferences, compared to those virtual choices involving behaviors that were also targeted (Godoy et al., 2013). This suggests that behaviors that are the target of interventions might be indicating more than past behavior: Rather they may already be indicative of change.

As such, virtual choices in interactive narratives, where the behavior has been targeted for change in virtual interventions, can have the potential to be accurate in-the-moment predictors of subsequent behavior changes of the intervention, such that researchers can immediately predict the post-intervention behavior changes by observing how participants interacted with game characters and what relevant virtual choices they made. This could happen if, during the intervention, participants started exhibiting virtual choices that were not merely mirroring "old habits" in response to social cues, but rather exhibiting new intervention-consistent virtual choices due to the intervention. Following this logic, virtual interactions can also be used to diagnostically assess why the intervention backfired or failed to achieve a certain level of success. Imagine if a participant did not make the desirable virtual decision intended by our persuasive messages, those virtual decisions are then indicators of the lack of message efficacy and low probability of subsequent behavior changes. Therefore, virtual interactions, offered in interactive narratives, can have the potential to be accurate in-the-moment predictors of subsequent behavior changes of the intervention, such that researchers can immediately predict the post-intervention behavioral changes by looking at how participants interacted with game characters.

1.2.1. Can Virtual Water Reduce the Alcohol Consumption and Risky Sexual Behavior Link?—In this study, using the SOLVE intervention framework, we evaluate whether the virtual choices of accepting water -- rather than beer -- from a virtual agent could be prognostic of a reduction in alcohol intake among YMSM. Results of this study could provide further support for using VE to reduce alcohol use and the link between alcohol consumption and risky sexual behaviors.

Multiple studies over the past decades suggest that MSM are likely to frequent bars and other social events such as house parties for socialization and meeting new sexual partners, suggesting a strong need for interventions to reduce alcohol consumption among MSM (Charlebois, Plenty, Lin, Ayala, & Hecht, 2017). This is especially necessary because a proliferation of studies have observed the strong link between alcohol consumption and

unsafe sexual behavior. Indeed, with the increasing amount of alcohol intake, the awareness of negotiating safe sex and condom use decreases such that MSM become vulnerable to HIV acquisition and transmission (e.g. Bruce, Kahana, Harper, Fernández, & ATN, 2013; Colfax et al., 2004; Gerbi, Habtemariam, Tameru, Nganwa, & Robnett, 2009; Santos, Jin, & Raymond, 2015). While extant interventions targeting alcohol consumption and its link to risky sexual behavior showed that altering the social environment (i.e., making the choice of water available in gay bars) could reduce alcohol intake (Charlebois et al., 2017), such interventions are still costly in terms of both time and effort. Such interventions must rely on (1) constantly providing messages that remind MSM of the availability and their desired choice of water, and (2) successfully negotiating with social venues (e.g., gay bars) to offer such messages.

Virtual game interventions may offer a promising alternative approach that may address some of these aforementioned obstacles, namely the cost in time and effort (Baranowski et al., 2008; Blascovich et al., 2002; Christensen et al., 2013; Read et al., 2006). Indeed, game interventions like SOLVE, are easily accessible (downloadable) and resourceful. Specifically, SOLVE can guide MSM through virtual scenarios that simulate social drinking, while effectively affording them self-control or enhanced self-regulation in favor of water. As such, MSM do not have to be reminded by constant messages around them while in real-life social events. Rather, the idea is that they would have already formed their own regulatory control involving avoiding risky decisions such as excessive drinking -- virtually.

1.2.2. Virtual Choices as A Prognostic Tool in SOLVE—While the SOLVE intervention targeted multiple social aspects (e.g., to reduce risky sexual behaviors; to reduce alcohol use), the current study focuses on its potential to create a virtual social drinking scenario. SOLVE uses a neuroscience-supported approach to reduce risky behaviors (Christensen et al., 2013), specifically designed for YMSM. The SOLVE intervention involves a virtual dating game in which users choose their characters and those characters are then aged to create an avatar that guides the user as the user makes a series of risky or safe choices in interacting with potential sexual partners in an animated intervention game. The design of the guide avatar is grounded in targeting participants' self-regulatory circuitry such that the avatar interrupts and challenges risky choices, focuses on acknowledging emotions/desires that might undermine safer sex and suggest alternative behavioral options (e.g., achieve safe sex by using condoms; satisfy thirst with water rather than beer). That is, by creating an avatar (Virtual Future Self or VFS) that represent the ideal future self, participants might be more likely to be reminded of their future. Participants of this intervention, using their own avatar, attend social activities (i.e. gay bars, house parties) where they met their potential sexual partner. While interacting with their virtual sexual partners, they were offered virtual choices of water and beer. During this process, feedback in terms of their virtual drinking choices (e.g., it is good to know that you are taking less drinks from your friends.) are offered by other virtual characters.

In this work, we evaluate the efficacy of SOLVE in reducing alcohol intake by using a novel prognostic tool: participants' virtual choices. Recall that in the previous sections, findings on virtual validity (Godoy, 2007, 2013) suggested the high correlation between virtual and real-life behaviors such that virtual behaviors could be prognostic of subsequent behaviors: This

was the case especially for behaviors the intention was *not trying to change*. What about the behaviors the intervention is specifically targeting? In an intervention game, the participant's virtual behaviors relevant to the intervention's targeted behavior change goals may already reflect behavior change and therefore might be prognostic of real-life subsequent behavioral changes (pre and post the virtual intervention).

That is, taking advantage of the virtual choices that are recorded by SOLVE, we can examine the relationship between virtual interactions with a digital agent and the subsequent behavior changes. By accessing individuals' virtual interactions with a digital agent, we will be able to know whether and to what extent can a virtual choice of water within the SOLVE game bring about behavior change in individuals' subsequent real-life alcohol choices. Here, virtual choices can also reveal whether undesired virtual behaviors (i.e. virtual choice of beer) were predicted by relevant personality characteristics of these men.

H_f : MSM's virtual alcohol choices will be prognostic of the extent to which they reduced (or increased) their alcohol use assessed at 6 months, such that (H_{fa}) greater amount of virtual choice of water is prognostic of a decrease in alcohol intake and (H_{fb}) greater amount of virtual choice of beer is prognostic of an increase in alcohol intake.

2. BAS and Drinking Behaviors

Individual differences in two major behavioral systems may matter for conversational response choices. The Behavioral Inhibition System (BIS) and the Behavioral Activation System (BAS) have been known as important factors that can affect how people establish social bonds and interpersonal relationships (Elliot & Thrash, 2002; Gable, 2006; Impett et al., 2010). Reinforcement sensitivity theory (RST) in motivation and behavioral regulation (Fowles, 1994; Franken, Muris, & Georgieva, 2006; Gray, 1976, 1987) posits that individual motives and goals are based on BIS and BAS, two motivational systems. The BAS activates behaviors in response to appetitive, rewarding signals. The BIS inhibits behaviors in response to signals of uncertainty (e.g. novelty and punishment).

In this study, we focus on BAS rather than BIS as a main predictor of virtual choice of drinks because studies have consistently shown the association of BAS and alcohol intake (Booth & Hasking, 2009; Franken et al., 2006, 2006; Hundt, Kimbrel, Mitchell, & Nelson-Gray, 2008; O'Connor & Colder, 2005). BAS is comprised of three factors: drive (consistent pursuit of an appetitive goal), reward responsiveness (positively expectance towards the rewards from an appetitive goal), and fun-seeking (eagerly seeking and pursuit of rewarding events). BAS sensitive individual, due to their stronger subjective, physiological and behavioral reactivity towards incentive cues, are posited to be more likely to be drawn to additive behaviors such as alcohol and other substance use (Diaz, Ayala, Bein, Henne, & Marin, 2001; Fowles, 1994; Franken, 2002). Indeed, all dimensions of BAS have been found to be, to a great extent, associated with various aspects of alcohol consumption (Franken & Muris, 2006; Jorm et al., 1998; O'Connor & Colder, 2005). For example, individuals with high BAS drive demonstrated stronger desires towards cues that reminds them of drinking (Zelenski & Larsen, 1999, Franken, 2002). Especially, experiments have shown that this

cue-induced urge is even stronger among BAS sensitive social drinkers (Kambouropoulos & Staiger, 2001).

Driven by the same mechanism of seeking appetitive outcomes, BAS sensitive individuals may demonstrate heightened reactivity towards the virtual choices of drinks, such that their motivational propensity in general could affect the efficacy of SOLVE. As such, assessing their virtual choices not only provides us an in-the-moment evaluation of the efficacy of the intervention, but also the information in evaluating the targeted population of the intervention, thus allowing us to create better tailored messages based on individual characteristics in the future. As such, we aim to explore the associations between BAS, virtual choice, and subsequent changes in alcohol consumption.

RQ1: How does (a) BAS drive, (b) reward responsiveness, and (c) fun-seeking sensitivity affect the outcome of the intervention?

3. Method

3.1. Study Design

Data for this analysis came from the SOLVE intervention. The original design randomly assigned participants to the game or a waitlist control condition. Participants were recruited nationwide in the United States through banner advertisements placed on Craigslist, blogs, and gay interest websites between February and November 2012. Participants were recruited nationwide in the United States. Once recruited, they were entered into a lottery with a 1:40 chance of winning a \$100 gift card. They were then redirected to a project website to complete a screening survey to determine eligibility for inclusion. Additional details regarding the design and methods of this parent could be found in another paper (Christensen et al., 2013; Park et al., 2014).

3.2. Ethical Considerations

This study was approved by the institutional review board (IRB). Participants were only identified by email address to ensure confidentiality. Email addresses were subsequently deleted upon study completion.

3.3. Participants

The data for this study comes from a sample of young men who were very risky for contacting HIV. Our criterion for inclusion are (1) receiving a prior HIV-negative test result to fit into the scope of the study (2) living in the United States because the game contents were in English; (3) being 18 to 24 years of age, as according to CDC (2016), this age group has the highest HIV diagnosis; and (4) engaging in CAI with a non-primary male partner during the three-month period (i.e. risky status) prior to enrollment in the study. “Non-primary partner” refers to a male partner with whom the participant was not, at the time, engaged in a romantic relationship. We used data from longitudinal 6-month study, thus only participants available for 6 months were eligible and only findings from the initial baseline portion of the data-collection were analyzed here. Of the 934 participants who were enrolled in baseline, only 579 participants returned at 6-month follow-up. Of these 579 MSM who

returned at follow-up, there were 252 MSM in the experimental group and 357 MSM in the control group (who did not receive the intervention and for whom we had no virtual choice data). Participants usually play two levels of the game, each level takes around 30 minutes to finish. Those who played more than two levels were not included for analysis. Thus, data from 213 of the 252 MSM in the SOLVE experimental group were analyzed. This is because the 213 MSM's virtual choices were fully recorded.

3.3.1. Alcohol Intake: Alcohol intake is a self-report measure asking participants how many days in the past 90 days that they have used alcohol. This variable was also measured three times: baseline, 90 days, and 180 days after participating the intervention.

3.3.2. Drinking Choices.—Virtual drinking behaviors were operationalized in terms of the amount of beer/water our participants chose during their virtual date. The amount of alcohol or water could vary across participants from 1 to 6 since each participant participated in one to two levels (i.e. the house party and the bar scene) of the game.

3.3.3. BAS.—Carver and White's (1994) 20-item measure of BIS/BAS was used. BAS is a 12-item measure, participants rated on a Likert-type scale (1=not like me at all, 4=a lot like me). BAS items can be decomposed into three sub-scales with 4-items-each. BAS tendencies including drive ($M=3.08$, $SD=0.59$, $\alpha=0.76$), reward responsiveness ($M=3.25$, $SD=0.57$, $\alpha=0.70$), and fun seeking ($M=3.02$, $SD=0.57$, $\alpha=0.68$). The alpha was consistent with the BAS/BIS scale at the time of its publication by Carver and White (ranging from 0.73 to 0.66).

3.4. Data analysis.

We used residualized change scores in order to eliminate dependency between simple difference scores and baseline values (Muthén & Muthén, 2012) and potential problems with reliability of measurement ((McFarland & Ryan, 2000; Rogosa, Brandt, & Zimowski, 1982; Tisak & Smith, 1994). Using linear regression in SPSS 24, residuals for drinking behaviors were calculated by regressing immediate post-test values (Y) on baseline values (X): This afforded estimates of predicted values (Y') that were then subtracted from Y (and saved as unstandardized residuals). Change in drinking behaviors was computed by regressing six-month follow-up values on baseline values. Positive values represent an increase in alcohol consumption, negative values represent a decrease in alcohol consumption. With residualized change scores we are already controlling for previous drinking behaviors in the analysis: Any correlations between virtual drink choices and past alcohol behaviors have already been removed from residualized change score measures.

Linear regression examined whether changes in alcohol intake in the past 90 days (compared to baseline) at 6-months were related to relevant virtual choices. Reported tests are two-tailed and a p-value of 0.05 indicates statistical significance and 95% confidence intervals are provided: If they do not contain 0, this indicates that the effect was significant. To test the proposed mediation models, as shown in figure 1., we used ordinary least squares (OLS) regression provided by the SPSS macro PROCESS (Hayes, 2013; Preacher, Curran, & Bauer, 2006) using model 4 (parallel mediation). For each mediational analysis bias-

corrected 95% confidence intervals were generated using 10,000 bootstrap samples. An indirect effect is significant if the confidence interval does not include 0.

4. Results

In this study, we only focused on those who made the virtual choices in the experimental condition. While previous studies have examined the efficacy of SOLVE in reducing risky sexual behaviors, no studies from the group have looked at the changes of alcohol intakes produces by SOLVE. Specifically, previous studies have already shown that comparing to waitlist control group, those we are in the SOLVE condition significantly reduced shame which then reduces risky sex (Christensen et al (2013). In other work using a different group of participants, we found that SOLVE, when incorporated into interactive videos, also reduced risky sexual behavior (Read et al., 2006). Furthermore, in another paper in preparation (for references, see Christensen et al., 2013), we found that the SOLVE intervention reduced alcohol consumption at 6-months post intervention. In this study, we only focused on those who made the virtual choices in the experimental condition. As such, those who were in the control condition were not part of the data analysis in this study. Furthermore, this is the only work where we have focused, or plan to focus, on virtual alcohol/water choices as prognostic of alcohol behavior change. As such, results of this study do not duplicate any previous publication regarding SOLVE projects.

First, we tested H_1 , that MSM's virtual alcohol choices would be prognostic of the extent to which they reduced (or increased) their alcohol use assessed at 6 months. As predicted, controlling for the total choice one could have in the game, (H_{1a}) virtual non-alcohol decisions (VNAD) as predictive residualized change at 6-months in drinking behavior, $\beta = -0.94$, $t(214) = -2.98$, $p < .01$, VNAD also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.04$; also, (H_{1b}) virtual alcohol decisions (VAD) in the game was predictive of residualized change at 6-months in drinking behavior, $\beta = 0.94$, $t(214) = 2.98$, $p < .01$, VAD also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.04$. Details for the results are shown in figure 2. That is, for those who chose alcohol during the game, there was less alcohol reduction at 6-months. And for those who chose water during the game, there was more alcohol reduction at 6-months. Thus, H_1 was supported.

Q_1 asked whether MSM's virtual drinking choices would be prognostic of the extent to which SOLVE efficacy affect BAS individuals, and our results indicated that, controlling for the total choice one could have in the game, shown in figure 3, (Q_{1a}) BAS drive significantly affected VAND (virtual non-alcohol decision) as indicated by the significant "a" path ($\beta = -0.46$, $SE = 0.16$, 95 % CI = $-0.76, -0.16$), and the significant 'b' path from VNAD to change in alcohol intake ($\beta = -0.80$, $SE = 0.06$, 95 % CI = $-1.43, -0.16$). The overall indirect effect c' (the multiplicative of a and b) was significant: $\beta = 0.37$, $SE = 0.24$, 95% CI: (0.04, 1.02). However, the direct effect c was not significant $\beta = 1.38$, $SE = 0.33$, 95% CI: ($-0.10, 2.85$), indicating full mediation. The model also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.05$. BAS drive significantly affected VAD (virtual alcohol decision) as indicated by the significant "a" path ($\beta = 0.46$, $SE = 0.16$, 95 % CI = $0.16, 0.76$), and the significant 'b' path from VAD to change in alcohol intake ($\beta = 0.80$,

SE = 0.32, 95 % CI = 0.16, 1.44). The overall indirect effect c' (the multiplicative of a and b) was significant: $\beta = 0.37$, SE = 0.24, 95% CI: (0.04, 1.05). However, the direct effect c was not significant $\beta = 1.38$, SE = 0.75, 95% CI: (-0.10, 2.85), indicating full mediation. The model also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.05$.

(Q_{1b}) BAS reward responsiveness significantly affect VAND (virtual non-alcohol decision) as indicated by the s" path ($\beta = -0.35$, SE = 0.16, 95 % CI = -0.67, -0.02), there is also the significant 'b' path from VNAD to change in alcohol intake ($\beta = -0.85$, SE = 0.32, 95 % CI = -1.48, -0.22). The overall indirect effect c' (the multiplicative of a and b) was significant: $\beta = 0.37$, SE = 0.24, 95% CI: (0.04, 1.05). The model also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.05$. However, the direct effect c was not significant $\beta = 1.12$, SE = 0.77, 95% CI: (-0.39, 2.63), indicating full mediation. BAS reward responsiveness significantly affected VAD (virtual alcohol decision) as indicated by the significant "a" path ($\beta = 0.33$, SE = 0.16, 95 % CI = 0.01, 0.65), and the significant 'b' path from VAD to change in alcohol intake ($\beta = 0.85$, SE = 0.32, 95 % CI = 0.22, 1.48). The overall indirect effect c' (the multiplicative of a and b) was significant: $\beta = 0.28$, SE = 0.20, 95% CI: (0.01, 0.80). However, the direct effect c was not significant $\beta = 1.12$, SE = 0.77, 95% CI: (-0.39, 2.63), indicating full mediation. The model also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.05$.

(Q_{1c}) BAS fun-seeking significantly affected VAND (virtual non-alcohol decision) as indicated by the significant "a" path ($\beta = -0.35$, SE = 0.16, 95 % CI = -0.67, -0.02), and the significant 'b' path from VAND to change in alcohol intake ($\beta = -0.80$, SE = 0.32, 95 % CI = -1.42, -0.17). However, the overall indirect effect c' (the multiplicative of a and b) was not significant: $\beta = 0.27$, SE = 0.22, 95% CI: (-0.01, 0.83). But the overall direct effect c was significant $\beta = 2.01$, SE = 0.76, 95 % CI = (0.51, 3.51). The model also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.08$. Similarly, BAS fun-seeking also significantly affect VAD (virtual alcohol decision) as indicated by the significant "a" path ($\beta = 0.35$, SE = 0.16, 95 % CI = 0.02, 0.67), and the significant 'b' path from VAD to change in alcohol intake ($\beta = 0.80$, SE = 0.76, 95 % CI = 0.51, 3.51). However, the overall indirect effect c' (the multiplicative of a and b) was not significant: $\beta = 0.27$, SE = 0.21, 95% CI: (-0.01, 0.85). But the overall direct effect c was significant $\beta = 2.01$, SE = 0.76, 95 % CI = (0.51, 3.51), The model also explained a small, but significant proportion of variance in alcohol changes $R^2 = 0.08$.

5. Discussion

In this study, we evaluated the extent to which interactions with a digital agent, especially the virtual choices made in such interactions, were prognostic of behavior changes due to a video game intervention. Indeed, results of this study showed that the virtual choice of water can be an excellent predictor of reductions in alcohol consumptions for YMSM. Equally important, we found that virtual choice of beer could be a predictor of lack of changes in alcohol consumption, in a way, we could interpret the results as those who consistently chose to take beer offered by their virtual partners were less likely to be compliant to the drinking messages embedded in the game. As such, by using virtual choices, we can

immediately pinpoint those who are less likely to be responsive towards the messages while those people are still participating. Therefore, in subsequent studies, we can perhaps provide alternative messages in a timely manner before by targeting those participants who are more likely not to be responsive to and drop out of the intervention.

We also found that personality factors could also be important factors that can affect virtual choices. Consistent with previous findings on BAS, we found that all dimensions of BAS could affect virtual choices to a certain extent, which can subsequently predict the efficacy of the intervention. Specifically, sensitive BAS drive and reward responsive individuals showed negative correlation in making virtual water choices and virtual beer choices. As indicated by our results, an increase in the choice of virtual water fully mediated the relationship between individual BAS scores (i.e. drive and reward responsiveness) and their reduction in post-intervention alcohol intake. That is, sensitive BAS individuals are those individuals who chose more virtual water during the intervention, and they are more likely to reduce their risky behaviors. Likewise, our results also showed that choice of virtual beer fully mediates individual's BAS scores (i.e. drive and reward responsiveness) and their increase in post-intervention alcohol intake. Thus, we can also conclude that if those YMSM who are high BAS drive and reward responsiveness chose more virtual beers during the intervention, they are less likely to reduce their alcohol intake. That is, results of this study indicate the necessity of creating more choice points that can enhance the choice of virtual water for sensitive BAS drive and reward responsiveness YMSM.

We also see an interesting pattern for BAS fun-seeking YMSM. Our results have shown that while virtual choices were significant in predicting the link between BAS fun-seeking and alcohol intake, virtual choices were not significant mediators that can reduce post intervention alcohol intakes. That is, using virtual choice, we found a specific population (i.e. sensitive BAS fun-seeking) who might need an enhanced version of the game. Perhaps interacting with virtual agents within only two-levels (a bar and a house-party) of the video game would not be sufficient for decisions to reduce alcohol intake among BAS fun-seeking YMSM. And also, perhaps, those individuals might need some alternative interactive narratives to change their alcohol intake decisions. Regardless, using virtual choices, we can pinpoint and create more effective interventions for those individuals who are not compliant to the existing one, thus increasing the reach of the intervention.

Implications, Limitations, and Future Directions

The current work examined the prognostic potential of interacting with a virtual agent, during an interactive VE intervention, in predicting subsequent real-life behavior changes. In addition to previous studies that found significant correlations between virtual game behaviors and prior real-life ones (Godoy et al., 2013), the current work demonstrates that this relationship is in fact predictive of behavior change. That is, by using the interactive patterns between the participants and their virtual agents, researchers could make immediate predictions about who was and was not likely to be affected by the intervention.

This study is also examined whether personality affects virtual interactions. Consistent with prior work that found high associations found between drinking behaviors in real-life and Behavioral Activation System (BAS) scores (Bruce et al., 2013; Hundt et al., 2008; Pardo,

Aguilar, Molinuevo, & Torrubia, 2007; Voigt et al., 2009), we found similar correlation patterns when our participants were interacting with a virtual agent under the same social drinking scenario. That is, we not only found that individuals higher on BAS are more likely to choose the virtual choice of beer over water, we also found that those virtual choices mediated the relationship between BAS and subsequent drinking behavior changes. That is, researchers should consider how to design more tailored interventions through virtual agents may significantly reduce drinking behaviors on those who are high on BAS.

While demonstrating the potential diagnostic nature of virtual choices, this study was limited in the following ways. First, we had to rely on participants' self-reports of subsequent behaviors as there was a lack of biobehavioral measures (e.g. biometrical measures to test alcohol intake) in the SOLVE intervention. Therefore, we may face the challenges of participants misreporting their alcohol intake. Future work may implement more rigorous measurements of subsequent risky behaviors so as to provide more accurate assessment of virtual choices. Second, unlike other studies that focuses on psychological mechanisms that can explain the efficacy of a VE-based intervention, this study has a limited focus. It only looked at virtual social interaction as a means to indicate real-time acceptance of the intervention. That is, if the participants made a desirable virtual choice/decision (accepting water rather than beer), this virtual choice is only suggestive of compliance towards the suggestions given by the virtual character. Therefore, this study does not have a causal claim regarding virtual choices being responsible for subsequent behavior changes. Indeed, other psychological mechanisms may be responsible for the reduction of drinking behaviors. For example, perhaps the VFS avatar changed participants' perspectives regarding their future self. And perhaps the VFS avatar created high levels of involvement and realism such that participants were more likely to follow their suggestions. Regardless of what psychological mechanisms, the focus is only on a simple virtual choice of water may be enough to indicate that participants were responsive to change their drinking behaviors.

The implications of the present study could potentially open a new perspective to understand communications between humans and virtual characters. Even the result only explained very small variance of behavioral changes, it still provides evidence that virtual interactions have the potential to predict the efficacy of the intervention. Using virtual environment for diagnostic assessment purposes has already been proposed in a range of fields including in education, training, and clinical settings (Rizzo et al., 2011). Here we went one-step further and delineated specific means, virtual choices, as indicators to assess the efficacy of health interventions.

As hypothesized by studies using adaptive means to assess human behaviors through video games and virtual technology, virtual interactions could be the assessment that researchers need to address problematic behaviors to provide in the moment feedback and support: while observing difficult sex talk is hard in real-life, eliciting similar behaviors using a virtual dating partner can do the trick. Therefore, virtual social interactions may be the key for understanding and addressing social problems that are otherwise hard to target in real life (as in our case) to remind those young MSMs that they may need to drink less. From a clinical perspective, the capacity to observe participants' on-line choices in a virtual game and to diagnostically assess and predict what those in-context in-the-moment choices mean

for subsequent behavior is a game-changer. If we “up our game,” it means we might no longer need to wait 6-months to see the results of the meaning of virtual intervention. Rather, we could interactively respond to participants’ game decision-making in interventions on-line “just-in-time” to optimize individual game, and thereby real-life risk-reduction.

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Highlights

- Virtual social agents can predict outcomes of VE-based health interventions.
- Virtual choices of water were associated with the reduction of alcohol intake.
- Individual personality factors were associated with virtual choices in a VE game.

Figure 1.
Statistical model for analysis

Figure 2.
results for H₁

$*p < .05$

$**p < .01$

Figure 3:

Results for Q1: How does (a) BAS drive affect the outcome of the intervention?

Figure 4:

Result for Q1: How does (b) BAS reward responsiveness affect the outcome intervention?

Figure 5:
Results for Q1: How does (c) BAS fun-seeking affect the outcome of the intervention?