Internet Versus Virtual Reality Settings for Genomics Information Provision

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Abstract

Current models of genomic information provision will be unable to handle large-scale clinical integration of genomic information, as may occur in primary care settings. Therefore, adoption of digital tools for genetic and genomic information provision is anticipated, primarily using Internet-based, distributed approaches. The emerging consumer communication platform of virtual reality (VR) is another potential intermediate approach between face-to-face and distributed Internet platforms to engage in genomics education and information provision. This exploratory study assessed whether provision of genomics information about body weight in a simulated, VR-based consultation (relative to a distributed, Internet platform) would be associated with differences in health behavior-related attitudes and beliefs, and interpersonal reactions to the avatar-physician. We also assessed whether outcomes differed depending upon whether genomic versus lifestyle-oriented information was conveyed. There were significant differences between communication platforms for all health behavior-oriented outcomes. Following communication in the VR setting, participants reported greater self-efficacy, dietary behavioral intentions, and exercise behavioral intentions than in the Internet-based setting. There were no differences in trust of the physician by setting, and no interaction between setting effects and the content of the information. This study was a first attempt to examine the potential capabilities of a VR-based communication setting for conveying genomic content in the context of weight management. There may be benefits to use of VR settings for communication about genomics, as well as more traditional health information, when it comes to influencing the attitudes and beliefs that underlie healthy lifestyle behaviors.

Keywords: virtual reality, e-health, health communication, genomics, genetics

Introduction

INTEGRATION OF GENOMICS into medical care has been on the horizon for some time, and progress has been made in translating genomic content to medical encounters. For example, in line with the Precision Medicine Initiative/All of Us Research Program,¹ it is envisioned that primary care providers may use patients' genetic information to predict their risk for common diseases like diabetes, and recommend approaches toward disease management once diagnosed.^{2,3} Moreover, as genomic concepts enter medical settings, general conversations linking genetics to common health conditions, even in the absence of individualized test results, are likely to occur more regularly. For example, with the increased advertisement of consumer-facing genetic testing services, patients have begun to discuss the relevance and role of genetic information with their providers.⁴ In this study, we compare two methods for communicating genomic concepts to the public: Internet-based and virtual reality (VR)-based platforms.

As we continue to approach this future, it becomes clear that current models of genomic information provision will be unable to handle large-scale clinical integration of this information, as may occur in primary care settings.⁵⁻⁷ As such, many researchers and clinicians have been seeking alternative information provision models, including distributed platforms that capitalize on existing and emerging technologies for information provision to explain concepts around genetic contributions to health conditions, provide genetic feedback, and explain the implications of results.⁸⁻¹⁰

For these reasons, adoption of Internet-based tools for genetic and genomic information provision to increase patient and public understanding of complex genomic factors in health and disease is anticipated.⁸ Such tools will be especially necessary as the scope of genetic and genomic information and feedback available expands to cover common health conditions, which apply widely to the public.² Several studies have explored the ramifications of a move toward Internet-based genetic information provision, including

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studies exploring the use of Web-based tools for genetic education and risk evaluation.^{9,11–15} Other research has explored the provision of genetic test results in Web-based settings.^{16,17} In general, research suggests that these tools can support informed medical decisions for many members of the public,¹⁷ and findings include high levels of satisfaction, coupled with low levels of psychological distress following online tool use.^{12,16} In all, the use of Internet-based communication modalities seems to be a central element of plans for future provision of genomic information in many domains.¹⁸

Use of an Internet-based genetic communication and result disclosure delivery mode would essentially leapfrog from interpersonal communication in the clinical setting to distributed, text and image-oriented information provision, bypassing several possible intermediate platforms through which genomic information could be transmitted. It stands to reason that certain intermediate delivery platforms could improve upon Internet-based models, while still addressing some of the resource problems inherent in face-to-face models. Telemedicine and telephone counseling are examples of intermediate steps, which allow provision of services in locations that are underserved or unserved by genetics professionals. However, this approach does little to reduce the demands on genetic professionals' time. Another such intermediate step would be implementation of a computer-based solution within the medical setting, which, because it relies on automated, digital communication, would address workforce shortages. In addition, such clinically based digital testing-oriented decision aids have shown promise in past research.^{19,20}

VR is another potential intermediate communication approach that could address resource issues in genomic communication. VR encounters related to genomics could retain some of the immediacy of traditional, face-to-face clinical interactions. The computerized nature of VR could address the issue of provider burden by automating communication activities. In addition, the digital nature of VR would allow for use of dynamic communication aids and unlimited repetition of information to enhance learning of complex concepts like genetic contribution to common disease.^{21,22}

Users of electronic communication tools have been noted to prefer psychological and emotional support characteristic of in-person communication modes.⁸ This is unsurprising given the sensitive and potentially emotional content inherent in genetic conversations.^{23,24} As such, patients may benefit from an interaction with a provider stand-in (i.e., virtual human) that could introduce some elements of a supportive, interpersonal clinical interaction into the digital encounter. Although a simulated provider can be presented in distributed Internet-based platforms, a VR interaction might make a simulated provider feel more immediate and more present within the interpersonal interaction.^{25,26} This could increase patient receptivity to genomic information provided in this manner (as opposed to Internet presentation modalities), which could, in turn, provide support for the beliefs and intentions that underlie healthy behaviors.

For the time being, a VR approach would most likely be implemented within the clinical setting rather than distributed as the technology is not yet widely available. Al-

though this would not address patient accessibility issues, it would allow providers to address misunderstandings before patients depart from a clinical setting. However, VR has recently moved into the realm of mainstream consumer electronics, greatly bringing down the cost and reducing barriers to implementation, thereby making it a feasible communication medium for future genomic communication activities using VR in a distributed way (e.g., in one's home).

Although VR's move into the mainstream is recent, it has long been used in clinical research and practice areas with promising results. For example, VR approaches have been successfully applied to clinician training.^{27–29} It has also been employed as a treatment modality in clinical settings for patients with psychological disorders, including posttraumatic stress disorder and specific phobias,³⁰ and researchers have posited that it may become useful for addressing obesity and eating disorders in the near term.³¹ The use of VR in educational environments has furthermore underscored its ability to convey technical and scientific concepts like genomics to learners at a variety of ages and education levels.²² Users of VR simulations in these and other areas have found them to be a well-accepted way to access clinically relevant simulations and information.³²

This study represents a preliminary look at whether in-clinic, VR-based modes of genomic information provision might be able to provide benefits over distributed, Internet-based modes. Specifically, we examined reactions of otherwise healthy overweight women to receiving generalized genomic information with respect to body weight through a clinician-avatar, in an encounter that was nearly identical except for the communication setting (distributed Internet vs. in-clinic VR).

Our primary aim was to determine whether patient reactions to genomics-oriented information differ between a distributed, Internet-based information provision model, and an in-clinic, VR-based model. It is important to note that VR and Internet-based approaches, in this study, are not simply presentation modalities, rather they are larger information provision scenarios that also encompass the context that comes with execution of these methods (e.g., clinic vs. home-based location).

We examined the influence of these approaches in two areas: (1) health behavior-related outcomes regarding the motivation to take action to reduce health threats represented by the genetic risk information provided, and (2) interpersonal reactions in interaction with the avatar-clinician who provided genetic information. We hypothesized that the in-person VR approach would heighten both health behavior-related and interpersonal outcomes.

An important subtext around this issue is that as genomic information becomes more prevalent in medical and community settings, there are unsettled issues as to whether genetic and genomic information are "exceptional," and therefore requires specialized communication approaches.³³ Therefore, a secondary aim of this analysis was to assess whether the communication approach outcomes seen in this study would differ between communication content that focuses on genomics versus more standard behavioral factors in body weight. We did not make a specific hypothesis in this regard.

Methods

The data analyzed in this report come from a pair of studies that were designed to assess the same outcomes through different presentation modes. These studies were designed in tandem with the aim of implementing overlapping methods and content for the purposes of this comparison. Full details of each study are reported elsewhere.^{34,35} The human subjects protocol containing both of these studies was approved by the IRB of the National Human Genome Research Institute.

Internet-based, distributed study

Participants in the Internet arm were 882 women who were part of a probability-based online research panel through the market research firm GfK. The study was conducted by the Time-Sharing Experiments in the Social Sciences program, a National Science Foundation-funded initiative in which studies are peer-reviewed in a competitive framework before data collection. Eligibility criteria included a self-reported body mass index of 25 or greater at most recent assessment (typically less than 1 year). Eligibility criteria for this analysis also include meeting criteria for inclusion in the primary outcome article (e.g., correctly completing study activities).³⁵ The study employed a 3×2 design, in which participants were randomized to six conditions wherein they received a standard autobiographical emotion induction (fear, anger, or neutral), and received information about genomic (including genetic, gene-environment, and gene-behavior interactions) versus behavioral causal factors in body weight.

A probability-stratified sample of panelists was invited to participate in the experiment through e-mail and the entire study was conducted online. Those who chose to participate then consented to the study. Some data previously collected by the survey company were provided (e.g., participant body mass index [BMI]); there was no pretest questionnaire specific to this study. Participants were given a writing prompt that served as the emotion elicitation.³⁶ Emotion elicitation was part of the self-contained study, but is not of interest to this comparison and thus is used as a control variable and not analyzed in this study.

Immediately following the writing task, participants were asked to watch a series of videos depicting a virtual physician delivering information about clinical weight management. The virtual physician videos were a direct recording of the virtual physician used in the laboratory-based VR study described below. Participants were asked to answer the questions that the virtual doctor posed either mentally or aloud. Upon completing answers to the virtual physician's questions, participants clicked a button to continue with the interaction.

The virtual doctor presented information related to the importance of weight management, the link between overweight and increased breast cancer risk, and that one's lifestyle behaviors are important for health. The virtual doctor also presented information about either the genomic or behavioral underpinnings of weight, depending upon condition. In the genomic condition, information included topics such as high heritability of weight, that those with a genomic predisposition for overweight may need to work harder to manage weight, and the notion that genes interact with the environment and one's behavior to influence weight. In the

behavior condition, material focused on the importance of both diet and exercise, the difficulty that overweight individuals may have in managing weight, and the role that environmental influences have on weight. Following the encounter with the virtual physician, participants completed a short questionnaire online. The entire study lasted for 20–30 minutes.

Laboratory-based VR study

Participants in the laboratory arm were 190 women who were recruited from the Washington, DC, metropolitan area through flyers, Internet postings, and word of mouth. Eligibility criteria again included a self-reported body mass index of 25 or greater, as well as being between the age of 18 and 50. Eligibility criteria for this analysis also include meeting criteria for inclusion in the primary outcome article (e.g., completing all study activities).³⁴

The study employed a 2×2 design, in which participants were randomized to four conditions, wherein they received a standard video emotion induction (fear or anger), and received information about genomic versus behavioral causal factors in body weight. Meta-analyses suggest that the video induction produces emotional reactions similar to the autobiographical induction used in the Internet study, both in laboratory and Internet studies.³⁷ Thus, although emotion elicitation is not of interest for this analysis, its influence was expected to be comparable in the two studies.

Participants completed online consent and filled out an online questionnaire at baseline, and then received an appointment to come into the laboratory at the National Institutes of Health Clinical Research Center. Participants arrived at the laboratory and completed the consent process. At that point, emotions were induced with a short film clip that had previously been validated to reliably elicit fear or anger.³⁸ Participants then completed a short questionnaire containing items related to the film clip. They were then seated and interacted with the VR-based physician in a virtual clinic room. The virtual encounter was created and administered using the Vizard software package (WorldViz, Santa Barbara, CA), using an nVis SX60 head mounted display and a WorldViz Position Point Tracker tracking system.

The content of the encounter with the virtual physician was identical to that in the Internet-based study, except that participants spoke their response to the physician's question aloud, and once finished, a research assistant would trigger the virtual physician to continue the interaction. Because the virtual encounters were identical, the amount of time participants spent in the interaction with the virtual physician was approximately the same as in the Internet study. Following the encounter, participants completed a set of self-report measures on a computer in the laboratory space. The entire laboratory portion of study took approximately an hour.

Measures

Measures analyzed in this report were identical between the two studies. All items were measured on 1–7 scales. Participants' beliefs related to the causes of overweight and obesity were assessed with three items from a larger published instrument that measured beliefs about genetics, physical activity, and diet (e.g., "To what extent do you agree or disagree that each of the following factors cause or

TABLE 1. DEMOGRAPHICS

	Internet setting study	VR setting study	Difference between studies
			χ^2 or t-test
Race, %			$p < 0.0001$
White	66	45	—
Black	12	49	—
Other	22	4	—
Education—college degree, %	35	64	$p < 0.0001$
Perceived weight—not overweight, %	15	12	NS
Perceived health status—very good+, %	33	59	$p < 0.0001$
Body mass index	M = 32.45 (6.20)	M = 32.66 (6.50)	NS
Age	M = 36.45 (8.27)	M = 35.91 (9.24)	$p = 0.072$

VR, virtual reality.

contribute to your body weight?”—“Not doing enough exercise”; 1 = strongly disagree, 7 = strongly agree).³⁹

Participants' exercise behavioral intentions were measured using an average of two items (“I intend to make changes to get more exercise in the next 6 months”; “How likely is it you will try to get more exercise in the next 6 months?” 1 = not at all likely, 7 = extremely likely).⁴⁰ Items for dietary behavioral change intentions were identical, except that they referred to diet. A single item assessed participants' self-efficacy for weight management (“I feel as if I could take the right actions to achieve a healthy weight,” 1 = strongly disagree; 7 = strongly agree). This item was created for this study based on self-efficacy theory.⁴¹

Interpersonal items consisted, first, of two items assessing participants' perceived level of social presence in the interaction with the virtual doctor [adapted from Bailenson et al.⁴²: “Even when the doctor was present, I still felt alone” (reversed); “I felt like the doctor and I were in the clinic room together,” 1 = strongly disagree, 7 = strongly agree]; the items were averaged. In addition, a single item assessed trust in the virtual doctor (“If this were your doctor, how much would you trust him?” 1 = not at all; 7 = extremely). The latter item was created *de novo* as suitable items did not exist.

Data analysis

To make participants in the two samples more equivalent, we retained in the Internet-based sample only those participants who met age criteria for the laboratory-based study (ages 18–50). In addition, we omitted all participants in the control emotion condition of the Internet study as there was no equivalent in the laboratory study, and it was thus confounded with the distributed Internet setting. This reduced differences between the 2 samples that could be potential confounds, and resulted in a sample size of 315 for the distributed, Internet-based sample. The emotion induction factor in the two studies was not a primary focus of this analysis. We therefore tested in preliminary analyses whether emotion condition interacted with study platform. We found no significant interactions and thus included emotion induction condition as a covariate in all analyses. Other covariates in analyses included participant age, BMI, education, race (white/nonwhite), and perceived health status. ANCOVAs were therefore conducted for each outcome variable with two independent variables: study setting (Internet vs. VR) and

information type (genetic vs. behavioral). Although study setting is the focus of this analysis, we also report main effects of information type in data tables.

Results

Demographics

Participants between the Internet and VR platforms differed significantly in terms of their racial composition,* education level, and perceived health status. They did not differ on self-reported BMI, their perceived weight, or their age (Table 1). All differing characteristics as well as age and BMI were entered as control variables in subsequent analyses so as to see effects above and beyond any demographic influences.

Causal belief outcomes

The interaction with the virtual doctor did not differentially influence causal beliefs related to genetics and exercise between the Internet and VR settings. There were also no significant interactions; setting did not differentially influence the effect of the doctor's message on these causal beliefs. There was a significant main effect of participants' postinteraction beliefs about dietary causes of overweight such that these endorsements were higher among those in the VR setting (Table 2).

Health behavior-oriented outcomes

Controlling for the sociodemographic factors mentioned above, there were significant differences between settings for all health behavior-oriented outcomes such that participants reported greater self-efficacy, dietary behavioral intentions, and exercise behavioral intentions in the VR setting than the Internet-based setting. Again, there was no interaction between setting effects and the content of the information (behavioral vs. genetic) (Table 2).

* Because racial composition differences between settings were large, we assessed the influence of race on study effects. While there were main effects of race, there were no setting-by-race interactions and no three-way interactions.

TABLE 2. GENERAL, HEALTH BEHAVIOR-ORIENTED, AND INTERPERSONAL STUDY OUTCOMES BY CONDITION: COVARIATE-ADJUSTED MEANS AND 95% CI

	Approach			Information type		
	Internet	VR	Difference ^a	Genetic	Behavior	Difference ^a
Causal beliefs						
Genetic causal beliefs	4.84 (4.67–5.01)	5.10 (4.88–5.32)	NS	5.20 (5.01–5.38)	4.74 (4.56–4.93)	$F = 11.25$ $p = 0.001$ $\eta_p^2 = .022$
Dietary causal beliefs	5.89 (5.75–6.03)	6.25 (6.06–6.43)	$F = 7.91$ $p = 0.005$ $\eta_p^2 = .016$	5.95 (5.79–6.10)	6.19 (6.04–6.35)	$F = 4.92$ $p = 0.027$ $\eta_p^2 = .010$
Exercise causal beliefs	5.90 (5.75–6.05)	6.14 (5.94–6.33)	NS	5.82 (5.66–5.99)	6.21 (6.05–6.37)	$F = 11.24$ $p = 0.001$ $\eta_p^2 = 0.022$
Health behavior-oriented outcomes						
Self-efficacy for weight management	5.20 (5.05–5.36)	5.97 (5.76–6.17)	$F = 30.96$ $p < 0.0001$ $\eta_p^2 = 0.058$	5.63 (5.46–5.80)	5.54 (5.37–5.71)	NS
Dietary intentions	5.47 (5.31–5.63)	6.09 (5.88–6.29)	$F = 12.04$ $p < 0.0001$ $\eta_p^2 = 0.038$	5.76 (5.59–5.94)	5.79 (5.62–5.96)	NS
Exercise intentions	5.62 (5.47–5.77)	6.17 (5.97–6.36)	$F = 12.66$ $p < 0.0001$ $\eta_p^2 = 0.033$	5.88 (5.72–6.05)	5.90 (5.74–6.06)	NS
Interpersonal outcomes						
Perceived social presence with doctor	4.01 (3.94–4.27)	4.89 (4.67–5.10)	$F = 27.76$ $p < 0.0001$ $\eta_p^2 = 0.053$	4.53 (4.34–4.71)	4.46 (4.28–4.65)	NS
Trust	4.67 (4.49–4.84)	4.77 (4.55–5.00)	NS	4.74 (4.55–4.93)	4.70 (4.52–4.89)	NS

^aThere were no significant interactions between setting and information type for any outcome variable.
NS, not significant.

Interpersonal outcomes

Participants in the in-clinic VR setting perceived the virtual doctor to be more socially present in the interaction than participants in the distributed Internet setting. There were no setting-oriented differences for participants' self-reported trust in the doctor (Table 2).

Discussion

The coming "precision medicine era"¹ represents exciting potential for primary care medicine. However, these medical technologies are likely to strain a system in which medical visits are already too brief for all desired content, and in which primary care providers do not have the requisite understanding to address genetic and genomic concepts.⁷ In addition, specialty genetics providers are, and will continue to be, in short supply.^{5,6} Certainly, technologically based communication solutions will not be appropriate for all patients, or in all clinical scenarios; however, they may be a boon for healthcare communication in many cases. As such, a variety of future, mainly distributed, Internet-based delivery methods for patient education, information, and care provision related to genetics and genomics are envisioned. Due to the potential shortcomings of such platforms, this study was a first attempt to examine the potential capabilities of a VR-based communication setting for conveying genomic content in the context of weight management, a common primary care issue.

Findings of this preliminary study suggest that there may be benefit to integrating VR-based platforms within the healthcare setting for communicating weight-related genomic content. In this study, such platforms were more likely than an Internet platform to prompt attitudes and beliefs consistent with healthy lifestyle behaviors. Information communicated to participants through VR was associated with higher levels of self-efficacy and intention to perform dietary and physical activity health behaviors, holding sociodemographic factors constant. However, VR platforms may not provide as many benefits related to interpersonal, satisfaction-oriented aspects of the communication. Although participants receiving information through VR did report more social presence with respect to the virtual doctor, they did not differ in how much they trusted him.

Beyond this, these findings suggest that the influence of the information communication setting (clinic-based VR vs. distributed Internet) may not be particular to the communication of genomic information. Indeed, setting outcome patterns were identical regardless of whether the virtual doctor communicated about genomics or standard behavioral information. At least in this context, genetic information may not be special or "exceptional"⁴³ in its communication needs. This suggests that the findings reported in this study may be relevant beyond the specific domain of genomic information provision. As such, future research should assess the potential gains of including VR-based information provision approaches for other health communication topics where in-person clinical communication may need augmentation for practical or logistical reasons. Indeed, now that VR hardware has decreased substantially in price, and become accessible to medical systems and the public, alike, it is a crucial time to assess and employ its capabilities as a health communication tool more broadly.

This study demonstrated that a VR approach did not influence participants' level of trust in the virtual provider even though they did feel he was more present within the interaction. This is counterintuitive, as one of the posited benefits of VR is increased fidelity of social and interpersonal interactions.^{44,45} In the end, however, in these clearly digital interactions with a computerized physician, the interpersonal aspects of the interaction may not be the most important outcomes on which to judge the merits of applying this platform. Particularly, if employed as a clinic-based interaction, participants will likely also see real clinicians with whom they can have meaningful interpersonal interactions.

This work is only a first step toward assessing the potential of VR to serve as a genomic communication tool (and general health communication tool) vis-a-vis distributed Internet platforms. As such, there are several limitations to this study. First, the two samples consisted of only women and are different on certain characteristics, such as educational attainment, which has known links to technology acceptance and health behavior. In addition, there are differences in the design of the two studies, and participants were not randomized to study. We controlled for as many differences as possible, and some of these differences (e.g., amount of control over participant behavior) are inherent in the characteristics of a given communication platform. Nevertheless, there is the possibility of an unknown confounding variable in this study.

The virtual physician and clinical interaction tested in this study was a simple one, reflective of the current state of technology; the capabilities of virtual clinical tools will grow as technology advances. We also did not assess participants' previous knowledge and comfort with VR and other technologies, and did not assess participants' experiences with the communication approaches, including ease of use. Finally, there were only a limited number of outcomes assessed, in this study, relevant to health behavior and interpersonal communication, and simple items were used; this should be expanded upon in future research. These weaknesses are offset by the fact that the message and message source were identical between the two communication modes, thereby providing one of the first direct comparisons of VR and Internet-based health communication. Future research should conduct additional comparisons—in particular to in-person interactions—to assess how use of VR approaches compares to face-to-face approaches, and what would be lost in the translation.

In all, it is well worth exploring communication modalities for genomic and other health information that fall between the extremes of face-to-face care and distributed Internet-based settings. VR is certainly not a panacea for such conversations and may have yet unidentified drawbacks. However, we may also find that such tools fill the gaps in current models of care, while also providing a better experience for patients, and helping them to optimize their care and decision-making.

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