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SYMPOSIUM

# The Potential of Virtual Reality Technologies to Improve Adherence to Weight Loss Behaviors

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## Abstract

A significant proportion of the global population is obese, foreshadowing an epidemic of chronic disease. Self-monitoring (of diet, exercise, and body weight), decreasing energy intake, and increasing energy expenditure are robust predictors of successful weight loss. However, few individuals consistently practice these behaviors, making long-term weight loss and maintenance unlikely. Technologies afford unique opportunities to overcome barriers and increase the reach of traditional obesity interventions. In this article, we introduce ENGAGED, a technology-enhanced modification of the Diabetes Prevention Program designed to improve adherence to weight loss behaviors. Using a treatment implementation framework, we suggest how virtual reality technologies might further improve the delivery, receipt, and enactment of ENGAGED to maximize patient impact.

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## Addressing Adherence to Weight Loss Behaviors

More than 400 million adults have a body mass index greater than 30 kg/m$^2$, and the global obesity epidemic shows little sign of abating. In the United States, 32% of men and 26% of women satisfy that criterion, placing them at risk for developing significant morbidity and premature mortality.[1–4]

The behaviors required to achieve and maintain weight loss are well established. They include (1) self-monitoring of diet, physical activity, and body weight; (2) reducing energy intake (by eating fewer calories); and (3) increasing energy expenditure (by increasing physical activity).[5–8] However, few obese individuals practice these behaviors with consistency, making successful weight loss and maintenance unlikely.[9,10]

Several barriers impede adherence to weight loss behaviors. First, achieving a negative energy balance requires people to make a series of complex decisions about dietary choices and physical activity multiple times throughout a day. Second, whereas desired weight loss is a distant future outcome, weight loss behaviors are associated with many immediate costs (e.g., higher financial cost and lower palatability of less calorie-dense healthy foods, hunger associated with decreased calorie intake, and increased time, inconvenience, and discomfort associated

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**Abbreviations:** (DPP) Diabetes Prevention Program, (ENGAGED) E-Networks Guiding Adherence to Goals in Exercise and Diet (VR) virtual reality

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with physical activity).[11,12] Consequently, higher order cognitive abilities are needed to self-regulate diet and activity behaviors if they are to be practiced consistently. Lastly, self-monitoring of intake by maintaining a food diary is a robust predictor of weight loss and maintenance.[13–15] However, the completion of food logs is burdensome and prone to inaccuracies, which makes their benefit difficult to realize.[16,17]

Unequivocally, intensive behavioral weight loss programs produce superior weight loss outcomes.[7,18,19] However, intensive treatments require professional expertise that is limited in supply, rendering these treatments largely inaccessible and too costly for much of the population. Therefore, novel intervention approaches are needed that preserve the efficacy of intensive treatments while helping more of the population to succeed in adhering to weight loss behaviors. Technology-supported approaches to weight loss hold that potential.

## Technology to Improve Adherence to Weight Loss Behaviors

To conceptualize adherence to behavioral weight loss interventions, Lichstein and colleagues[20] provide a useful framework. Their treatment implementation model portrays three phases of treatment penetration: (1) fidelity, i.e., ensuring that treatment reflects its underlying theoretical model and is delivered to recipients as intended; (2) receipt, i.e., the extent to which intended recipients of an intervention are exposed to and comprehend treatment materials and learn how to perform targeted behaviors; and (3) enactment, i.e., the extent to which participants perform and practice behaviors targeted by the intervention. Emerging technologies have the potential to improve each level of treatment implementation to promote weight loss and maintenance. The built-in features of technology solutions can preserve fidelity to key components of intensive behavioral treatments while increasing their scalability and cost-effectiveness.

Research in our laboratory is examining how handheld technologies can improve adherence to intensive diet and physical activity interventions. Whereas traditional paper-and-pencil diet and activity diaries are burdensome and fail to provide immediate feedback, handheld devices offer a powerful and portable platform to support self-regulation. By automating the self-monitoring process and providing real-time feedback on goal attainment, a customized smartphone application can provide just-in-time decision support to ensure healthy diet and activity choices. The devices used in our laboratory also afford real-time personalized virtual support from coaches and peers to improve behavioral adherence.

ENGAGED (E-Networks Guiding Adherence to Goals in Exercise and Diet) is an integrated smartphone weight loss system that incorporates persuasive design elements. This system was developed in our laboratory and is currently being tested in a randomized controlled trial supported by NIH National Institutes of Diabetes and Digestive and Kidney Diseases.[21,22] ENGAGED's diet and activity decisional support tools were designed based on the control systems theory of self-regulation.[23] These tools express discrepancies between current behavioral status and goals in an intuitive, color-coded format that motivates adherence. Findings on social network influences[24] were the basis for ENGAGED's connective technology. That component of the system links the client to a coach and a weight loss support group that receive updates about the client's self-monitoring behaviors.

A randomized controlled trial now ongoing in our laboratory implements the ENGAGED system as a technology-enhanced abbreviated version of the Diabetes Prevention Program (DPP) designed to improve adherence to weight loss behaviors. Participants in the ENGAGED intervention self-monitor their diet and activity on a customized smartphone application, as compared to controls who receive the same modified DPP, which is a gold standard behavioral weight loss intervention that relies on paper and pencil diary recording.[25] We hypothesize that the technology-enhanced system will enhance behavioral adherence to self-monitoring and, thereby, improve weight loss outcome. Our modified version of the DPP involves 8 rather than the original 16 treatment sessions, because we anticipate that the use of technology will allow the intervention to be as effective but twice as efficient.

The ENGAGED technology persuasively reinforces goal achievement in two ways. First, it affords real-time, objective feedback on diet and physical activity via color-coded visualizations that display discrepancies between current behaviors and goals. As individuals use the provided feedback to adjust their diet and activity behaviors and approach their goals, they produce reinforcing changes in the smartphone's visual display. For example, goal concordant behaviors raise the fill level in a goal thermometer or change an icon's color from red to yellow and then to green. Second, the ENGAGED mobile application is customized to facilitate accountability and social support from coaches and peers for diet and physical activity self-monitoring. An

interactive, virtual weight loss social network fosters frequent communication and social support for behavioral adherence among teammates and behavioral coaches. The trial tests the hypothesis that use of the ENGAGED technology improves adherence to diet and physical activity self-monitoring and goal attainment, resulting in greater weight loss, as compared to self-monitoring with traditional paper–pencil diaries.

## Could Virtual Reality Enhance the Implementation of Behavioral Weight Loss Treatment and Improve Adherence?

Virtual reality (VR) represents an advanced form of human–computer interface that allows the user to interact naturalistically with, and become immersed in, a computer-generated environment.[26] In several related lines of research, VR has been applied successfully to augment the impact of various psychological interventions. These include using VR to facilitate fear reduction among patients with anxiety disorders,[27,28] to promote stress reduction and relaxation, and to assist a subset of individuals with obesity to improve their body satisfaction and self-efficacy.[29–32]

Adding VR to the ENGAGED system could enhance the implementation of weight loss treatment in three ways. First, VR holds great potential to enhance treatment fidelity. Even when using a manualized treatment protocol and being monitored for fidelity, humans exhibit considerable variability in their delivery of behavioral interventions. In contrast, having coaching delivered by a programmed avatar rather than a live person ensures reliable treatment delivery.

Second, the immersive experience might engage participants more fully in the treatment process, thereby enhancing treatment receipt. Virtual reality users have been found to increase their physical activity after their avatar has done so.[33] This finding suggests the operation of vicarious identification processes that can mediate the generalization of healthy behaviors from the virtual world to the real world.

Third, the VR environment offers unparalleled opportunity to enhance treatment enactment. New behaviors such as portion-size estimation and balanced meal selection that are learned during treatment and are essential for weight regulation can be rehearsed in the virtual environment until they become habitual. As proficiency develops, new self-regulatory challenges (e.g., palatable treats, negative interpersonal events, positive social cues) can gradually be introduced until exposure to these provocative cues can be tolerated without temptation to overeat. With repeated practice and skill at making healthy decisions in the virtual environment, the patient's growing sense of self-efficacy should support generalization of new healthy behaviors to real-world settings. In turn, having access to the VR environment gives patients a safe zone in which they can practice overcoming eating challenges that they find insurmountable in the real world.

Virtual reality represents a powerful emerging clinical tool with broad applicability to behavioral treatment in general and obesity treatment in particular. It bears noting, though, that VR is a delivery channel or modality rather than a stand-alone treatment. Thus its potential is most likely to be realized when used to implement interventions that are theoretically guided and evidence based (e.g., cognitive behavior therapy for anxiety or eating disorders).

## How to Induce and Assess Adherence to Virtual Reality Technology

Increased adherence to diet and activity self-monitoring is presently the best-established pathway to improved weight loss outcome. Our working hypothesis is that technology will enhance effective weight loss behaviors by providing engaging decisional tools to main energy balance and connectivity to social support. We believe that augmenting a technology-supported intervention with VR could improve weight loss by further enhancing treatment fidelity, receipt, and enactment of new skills. For such potential to be realized, the next challenge is how to maximize utilization, time spent, and engagement with a VR technology. Fortunately, features of the technology may, in and of themselves, help to overcome the challenge of "receipt" by making the VR experience persuasive, or inherently engaging and reinforcing to use.[34] Personalizing the treatment content in ways that promote an enjoyable experience should further augment clients' engagement with the intervention.[35,36]

Metrics to assess adherence to VR obesity interventions are, we suggest, analogous to those used to quantify adherence to traditional weight loss programs. Ordinarily, treatment fidelity is assessed by monitoring sessions to determine whether interventionists followed protocol. In VR, the protocol is implemented by programmed algorithms with far greater precision than a therapist using a treatment manual could achieve. Establishing treatment fidelity is, therefore, a matter of assessing whether equipment or the system functioned properly. For treatment receipt, time spent using a device, or

levels achieved when rehearsing skill modules, are the VR equivalent to attendance, homework completion, and role plays in face-to-face interventions. An advantage of VR for measuring treatment receipt is that exposure or usage can be quantified automatically and objectively through sensors built in to the device. Because the target adherence behaviors occur in the real world, enactment (i.e., change in diet, activity, and self-monitoring) would be measured identically in the VR and non-VR context. Degree of immersion is the process or mechanism by which VR is assumed to facilitate change in behaviors—a hypothesis that remains critical to examine.

## Implications and Conclusions

Poor treatment adherence continues to impede successful weight loss and weight maintenance. In this article, we highlighted the potential of technology-enhanced interventions to improve fidelity and adherence to weight loss intervention in a manner that increases population reach. Unlike a human coach or support group that can be accessed only infrequently, virtual ones on a smart phone can provide near continual support and guidance. As such, VR-enhanced devices afford a platform to engage more of the population in mastering new diet, activity, and self-regulatory strategies that are the gateway to healthy weight regulation.

The frontier of VR-mediated intervention is being pressed forward by an emerging interdiscipline that integrates behavioral science, neuroscience, computer science, engineering, and graphic design.[37,38] The great scientific potential inherent in working across disciplines is matched only by the inherent challenges of achieving shared language, understanding, and collaboration. A body of science to support the conduct of team science has begun to emerge,[39,40] as have online learning tools (*www.teamscience.net*). The transdisciplinary science that emerges can be expected to shed new light on how diet and activity habits are learned and how unhealthy habits can be unlearned to improve public health.

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