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Health Literacy Changes in a Technology-Enhanced Diabetes Prevention Program

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HEALTH LITERACY CHANGES IN A TECHNOLOGY-ENHANCED DIABETES PREVENTION PROGRAM

By

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Background: In 2001, the Diabetes Prevention Program was published evaluating the efficacy of a pharmaceutical intervention, Metformin, and a behavioral lifestyle intervention (LI) to reduce incidence of Type 2 diabetes mellitus. The LI was observed to reduce the incidence of the disease by 58% relative to 31% in the medication treatment. Amongst technology based LIs, little has been done to address different health literacy populations.

Objectives: This dissertation evaluated how teach-back and teach-to-goal can influence the uptake of information obtained in each health education lesson, behaviors and its influence on engagement and weight loss.

Methods: Four hundred forty-two participants were analyzed in study #1, and only 425 were maintained for study #2 and #3. General regression modeling with White's Standard Error heteroskedacity adjustments was performed assessing the differences in engagement and comprehension performance by health literacy level and modality.

Results: In a teach-back/teach-to-goal call, differences in reverse score performance (DVD-15.4±2.5; Class-14.8±2.6; $F(3, 425)= 13.72$, $p<0.001$), number of teach-back rounds (DVD-1.9±0.7; Class-2.1±0.7; $F(3, 425)=5.98$, $p<0.001$) and number of round 1 questions

(DVD-4.2±1.6; Class-3.4±1.8; $F(3,425)=20.95$, $p<0.001$) was observed. While not significant, 38.7% of LHL participant completed all 22 lessons vs. 28.7% of HHL. Mean overall comprehension average scores improved 0.8±1.1 to 1.2±0.3 and 0.7±1.0 to 1.5±1.1 for those LHL and HHL participants completing only 1 call versus all 22 calls, respectively, as did physical activity and muscle strengthening minutes per week. Models evaluating IVR-reported weight change against engagement and overall comprehension average revealed engagement had an indirect relationship ($\beta= -0.59$, $p<0.01$) with magnitude of weight change ($R^2=0.13$, $F(3, 420)=20.8$, $p<0.001$), and a direct relationship with aerobic physical activity, muscle strengthening and fruit and vegetable intake.

Conclusions: Amongst high and low health literacy groups, both groups benefitted from teach-back and teach-to-goal health literacy techniques to improve patient comprehension, which in turn, improved engagement rates, especially in the low health literacy population. Reinforcement strategies to promote information uptake is necessary to allow for behavior uptake lending to greater weight loss.

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List of Abbreviations

LHL	Low health literacy
HHL	High health literacy
DVD	Digital video disk
IVR	Interactive voice response
LI	Lifestyle intervention
DPP	Diabetes Prevention Program
CLT	Cognitive Load Theory
MLT	Mastery Learning Theory
T2DM	Type 2 diabetes mellitus
SPSS	Statistical Package for the Social Sciences
SD	Standard deviation
BMI	Body mass index
NVS	Newest Vital Sign health literacy assessment
PI	Pharmaceutical intervention
LOC	Low overall comprehension
HOC	High overall comprehension
CL	Comprehension level

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Chapter 1: Introduction

Background

Health literacy is the ability to obtain, gather and process health information to make informed health decisions influential to achieving a desired health outcome (Berkman, Davis, & McCormack, 2010; National Academies of Sciences, Engineering, and Medicine, 2015; Nutbeam, 2000). This topic has received increased attention over the years as models of clinical care have adapted to meet patient needs while looking to provide effective care. The concept was first introduced in the 1970's, and only recently in the last 15 years has it gained traction and importance with regards to the functional health status of an individual (Kickbusch, 2001; Nutbeam, 2000). Various reviews and publications have suggested the need and possible methods to enhance health literacy levels of people at various levels—clinical and community(Cornett, 2009; Sheridan et al., 2011). At the same time, care has looked to include the patient in a more prominent role (Baker et al., 2011; Davis, K., Schoenbaum, & Audet, 2005; Sherson, Yakes Jimenez, & Katalanos, 2014).

As a result, calls for various strategies to enhance health literacy in an effort to enhance patient understanding and comprehension of their care have been made (Cornett, 2009; DeWalt et al., 2011; Schwartzberg, Cowett, VanGeest, & Wolf, 2007; Taggart et al., 2012). Those in this field have gone further by suggesting common terminology and methods applicable to various patient and provider populations(Berkman et al., 2011; National Academies of Sciences, Engineering, and Medicine, 2015; Nielsen-Bohlman, Panzer, & Kindig, 2004; Nutbeam, 2000). As a result,

health literacy will evolve with methods and techniques that are easily understandable to all people in the wide spectrum of clinical and community health care.

Impact of health literacy on health education and lifestyle interventions

One of the major goals of any health education initiative is improving health literacy. By being able to acquire and synthesize information and apply it in a meaningful way will provide a patient the opportunity to act towards their health with the goal of improved health outcomes. A review conducted in 2004 found that low health literacy was associated with several adverse outcomes as it pertained to health and health services (DeWalt, Berkman, Sheridan, Lohr, & Pignone, 2004). More specific to lifestyle interventions, two reviews have suggested improved health literacy can improve health outcomes (Clement, Ibrahim, Crichton, Wolf, & Rowlands, 2009; Pignone, DeWalt, Sheridan, Berkman, & Lohr, 2005). Outcomes reported to be influenced have included knowledge enhancement, health behaviors, use of preventive health services, reduced disease prevalence and self-efficacy (Clement et al., 2009; Pignone et al., 2005).

However, gaps have been identified in these interventions tailored towards low literacy populations. The gaps include lack of attention toward health numeracy skills, methods towards enhancing health literacy, long term outcomes, cost-effectiveness, comparative effectiveness, and the degree to which various mechanisms of complex interventions provide the most benefit (Clement et al., 2009). Many of these gaps are further compounded by patient-provider rapport, minimal understanding and

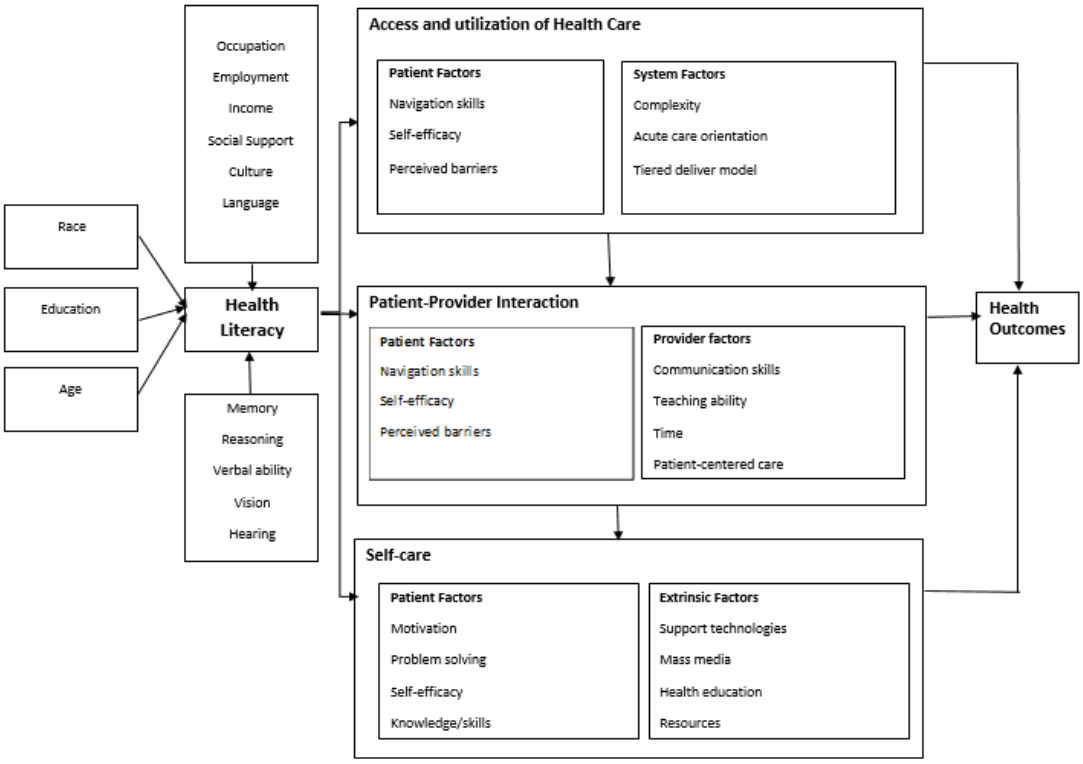
familiarity with how medical care and patient involvement may enhance health outcomes (Coulter & Ellins, 2007; Ford, Schofield, & Hope, 2002).

Specific to diabetes prevention, in one weight loss intervention, low literacy levels were reported as a barrier to success, and in another a barrier to effective functioning in the healthcare environment (Kirsch, 1993; Laatikainen et al., 2007). In a review of 73 studies on the relationship between literacy and health outcomes, DeWalt and colleagues found that those who read and comprehend on lower levels are 1.5 to 3 times more likely to have adverse health outcomes than those who read at higher levels (DeWalt et al., 2004).

In 2007, health literacy researchers, Drs. Paasche-Orlow and Wolf, proposed a conceptual model for the complex causal pathways between limited health literacy and health outcomes and suggested that health literacy may influence health outcomes at the point of access and utilization of healthcare, through patient-provider relationships and patient self-care (Paasche-Orlow & Wolf, 2007). While health literacy levels haven't been objectively evaluated, many of the afore mentioned trials have tried to close the gap suggested by Paasche-Orlow and Wolf. Emphasis has been placed on patient assessment, measurement and enhancement of health literacy levels through various methods—adapted printed educational materials, clearer communication, small group classes, telephone counseling calls and exercise logs (Coulter & Ellins, 2007; Taggart et al., 2012). Another cost-effective and feasible avenue to deliver interventions reinforcing educational and lifestyle change objectives of diabetes prevention programs is the

automated interactive voice response system (IVR) (Biem, Turnell, & D'Arcy, 2003; Piette 1999; Piette, McPhee, Weinberger, Mah, & Kraemer, 1999; Steinberg et al., 2014). To our knowledge, very little is known about how these different educational modalities may influence the three critical types of health literacy—functional, critical and interactive (Nutbeam, 2000).

Figure 1 Health literacy to health outcomes model



Note: Adapted from "The causal pathways linking health literacy to health outcomes" by Paasche-Orlow and Wolf, 2007.

Methods to assess health literacy levels

Three different health literacy assessment tools are widely recognized—the Test of Functional Health Literacy Assessment, Rapid Estimate of Adult Literacy in Medicine and the Newest Vital Sign (Weiss et al., 2005).The Newest Vital Sign is a very brief 6-item instrument that makes strong use of functional health literacy components where

the individual is at task evaluating and applying the health information and assesses comprehension that could inform the patient's decision making. Its brief questions to assess one's health numeracy skills asking individuals to do simple mental math (i.e. subtraction and multiplication) make it a very useful tool for both providers and patients, as well (Weiss et al., 2005). The Test of Functional Health Literacy Assessment (TOFHLA) or the Rapid Estimate of Adult Literacy in Medicine (REALM) evaluate levels of health literacy in written and word-recognition formats more (Weiss et al., 2005).

Critical and interactive health literacy test higher levels of communication that can include one or many people, and both test the dynamic natures of those interactions to ultimately look at control over all life events to live a healthy life and make appropriate health decisions, in a collective sense (Nutbeam, 2000). Researchers have struggled with a way to evaluate these components of health literacy due to their collective and grander elements of communication and interaction (Guzys, Kenny, Dickson-Swift, & Threlkeld, 2015; Sykes, Wills, Rowlands, & Popple, 2013).

Effectiveness of different methods to improve health literacy

Various methods to improve health literacy among low literacy groups have been employed throughout the years such as adapted printed health information brochures, easy-to-use computer/website health information, multilevel approaches for disadvantaged groups, or targeted mass media campaigns (Coulter & Ellins, 2007). Examples of effective interventions have included faith- and culture-based tailored programs over 2 years, chronic disease self-management program that was 15 hours

over 6 months, small group classes and follow-up phone calls over 1 year, mailings of self-help manuals and motivational messages, lifestyle counseling by a doctor with video and written materials and 6 months of telephone counseling and exercise logs (Taggart et al., 2012).

Successful attributes of these interventions have included multi-component behavior change (i.e. diet and physical activity). Many of the interventions reviewed failed to evaluate functional, interactive and critical health literacy (Taggart et al., 2012). Calls have also suggested development and validation of better instruments to assess health literacy while also considering health literacy as an outcome (Taggart et al., 2012). Health literacy interventions for diabetes prevention may be better suited for community applications suggesting a need to improve methods at the clinical level (Taggart et al., 2012).

In this same review, the intensity of the health literacy techniques was found negligible to behavior change; however, this article evaluated mostly smoking and nutrition change interventions where smoking interventions were most effective in low dosages. This may be due to the simple fact that behavior changes for smoking require less cognition and skills than nutrition interventions (Taggart et al., 2012). As a result, there is a need, especially among diabetes prevention programs, to evaluate the frequency, dosage and time-intensity needed to change health literacy levels through the appropriate health education channels for any given population.

If considering health education related to diabetes prevention, one study found that teaching providers techniques to enhance patient's health literacy levels pre-intervention may improve counseling rates; however, the use of these techniques, has been limited in these types of interventions, especially teach-back/teach-to-goal educational methods, where participants receive reinforcement of the correct answer by the assessor, regardless if correct or incorrect, after each attempt until a successful response is given, (Davis et al., 2008; Sudore, Williams, Barnes, Lindquist, & Schillinger, 2006; Sudore & Schillinger, 2009). Only Paasche-Orlow et al. and Goessl et al. have ever reported to have successful health literacy outcomes through teach-to-goal techniques; however, both studies were cross-sectional designs (Goessl et al., 2019; Paasche-Orlow et al., 2005).

With health counseling and health literacy strongly intertwined, the use of cost-efficient automated support telephone calls has been a popular option towards tracking health behaviors. While a review published in 2007 didn't evaluate health literacy changes, it did suggest designs comparing different intervention types while evaluating frequency, dosage, intensity and brevity of all calls, recruitment with less stringent inclusion criteria, representativeness of study participants and how reach and delivery of these interventions could influence behavior change (Eakin, Lawler, Vandelanotte, & Owen, 2007). To our knowledge, no automated support calls in a diabetes prevention intervention have evaluated these measures stated.

These ideas suggest the need to research the reach and effectiveness of different modes of educational media and how they may enhance health literacy while influencing behavior change. Furthermore, if behavior change is enacted, does it impact weight loss in a diabetes prevention program?

Do different health literacy methods lead to better comprehension?

A 2012 review and meta-analysis found, regardless of the setting in which a diabetes prevention program is offered, weight loss was nearly equal. Of the 28 studies analyzed, 14% (n=4) utilized electronic media which reported low drop-out rates (Ali, Echouffo-Tcheugui, & Williamson, 2012). Two of the studies included telephone call support, and only one employed interactive voice response behavior monitoring. The latter observed a small sample size (n=39), a moderate completion rate of 71.19%, and a higher percentage of weight loss relative to a control group (Estabrooks & Smith-Ray, 2008). None of the studies analyzed monitored health literacy changes throughout their interventions (Estabrooks & Smith-Ray, 2008; Kramer et al., 2010; McTigue et al., 2009; Tate, Jackvony, & Wing, 2003).

Specific to T2DM, one intervention found improvements in health literacy levels when a multimedia program was used to facilitate diabetes education and learning; however, disparities between high and low literacy still existed post-intervention (Kandula et al., 2009). Another technology-enhanced T2DM intervention observed no significant differences between high and low health literacy groups regarding knowledge and self-efficacy of disease self-management behaviors and skills (Gerber et al., 2005). These studies, however, failed to employ any health literacy enhancement

methods (Kandula et al., 2009). To our knowledge, no diabetes prevention programs utilizing multimedia education ***and*** methods to improve health literacy have evaluated literacy changes among high and low health literacy groups.

Among the health literacy techniques, a 2007 review reported evaluating was the follow-up telephone call evaluating patient comprehension. It was the second least common method providers reported using; however, it was deemed the 5th most effective method (Schwartzberg et al., 2007). Studies have indicated the utility of a follow-up phone call in providing a form of extended care (i.e.. decreased utilization, medication usage and cost savings) (Wasson et al., 1992). Furthermore, telephone-based interventions have been demonstrated as effective for enhancing patient understanding of care and treatment (Aaronson et al., 1996; Giorgino et al., 2005; Rodrigues et al., 2015). Together, the use of the teach-back/teach-to-goal and automated support telephone calls may provide a promising avenue for health education.

Does reinforcement of health education material through teach-back lead to behavior change?

In recent years, calls have been made to address multiple behavior change and possible mediators influencing the dynamic, inter-related processes, especially in the primary care setting where value-based, patient-involved care has been emphasized (Orleans, 2004). As is the case in diabetes prevention follow-up, long term behavior tracking of influential behaviors such as aerobic physical activity, muscle strengthening and a healthy diet has been limited and can be difficult (Whitlock, Orleans, Pender, & Allan, 2002). Going further, most diabetes prevention patients have little knowledge of

the proper amounts of those behaviors, and providers often have difficulty providing effective education and counseling, as well (Kristeller & Hoerr, 1997; Wylie, Hungin, & Neely, 2002). To date, we are unaware of any health education intervention that has been delivered through technology-based channels reinforcing proper lifestyle behavior education through teach-back and teach-to-goal methods.

Does behavior change through teach-back lead to increased weight loss to reduce diabetes risk?

To our knowledge, limited literature has evaluated the connections between health literacy, knowledge reinforcement through teach-back/teach-to-goal, behavior modification and outcomes as it translates to diabetes risk. More work has evaluated health literacy as it relates to diabetes self-management. Schillinger and colleagues discovered independent associations between inadequate health literacy and health outcomes associated with diabetes such as glycemic control and rate of retinopathy (Schillinger et al., 2002). However, little work has been done within the diabetes prevention field evaluating health literacy and it associated components against secondary health outcomes. Figure 1 (below) identifies some these factors that should be addressed in interventions that can influence both health literacy and their relationships to health outcomes (Paasche-Orlow & Wolf, 2007).

Learning Mastery and Cognitive Load Theory

Cognitive Load Theory was first published in 1988 by John Sweller, and suggests that an individual has a certain level of mental load to handle, process, and make connections between large loads of information, which can largely be influenced

individualistic factors like stress, fatigue, timing, life demands, etc. (Sweller, 1994). When a person is given a task, long-term memory can largely dictate how a person processes information; however, we can reconstruct that information, or schema, into a single unit that allows for operable solutions. The best example of this is a chess player and his next possible move to better his/her odds of winning. Again, this process can translate from information acquisition to restructuring of the information, and over time, is a cyclical, adaptive process where long-term memory is constantly reevaluated (Plass, Moreno, & Brünken, 2010).

Levels of intrinsic cognitive load, known as the executive processing, influenced directly by information acquisition and restructuring, and extrinsic cognitive load, known as factors external to learning, can be influential against processing and can be additive throughout a day or lifetime. Germanic cognitive load is a byproduct of intrinsic cognitive load where devotion of excessive cognitive resources to tasks influence the person's ability to dedicate working memory to the schema acquisition and processing. To better influence the potential of information uptake, or in parallel to CLT, teach-back and teach-to-goal provides reinforcement that may reduce psychological factors that influence germanic and intrinsic cognitive load, which in turn, increases working memory capacity. Over time, this effect enhances long-term memory of needed information, or in the case of this dissertation, informs proper lifestyle habits for diabetes prevention (Plass et al., 2010).

DiaBEAT-it!—A technology-enhanced diabetes prevention program

This dissertation is based off of a National Institute of Digestive, Diabetes and Kidney Disorders R021 grant called, "The Reach and Effectiveness of a Technology-Enhanced Diabetes Prevention Program." Coined formally as, "DiaBEAT-it!" the parent study, a hybrid preferential randomized control trial (RCT), was delivered through 4 primary care clinics located in the greater Roanoke, Virginia with IRB approval through Carilion Clinic, Virginia Tech and the University of Nebraska Medical Center.

Patients with a body mass index (BMI) greater than 25.0 and considered at risk for diabetes were invited to participate in the study after receiving their primary care provider's approval to participate. Telephone recruitment was completed, and participants completed two baseline assessments. The first assessment was intended to complete all anthropometric measures while the second assessment, eight to ten days later, was intended to finish all surveys, provide a report on their physical activity levels from a tri-axial accelerometer, and to be assigned to one of three possible treatments—class only, class+IVR, DVD+IVR. In-person assessments were repeated at 6, 12 and 18 months. In all three treatments, participants either attended a one-time, two-hour in-person class covering the initial objectives of the diabetes prevention program or watched a 90-minute DVD covering much of the same material. After completing a teach-back/teach-to-goal telephone call with a research assistant, participants were enrolled to receive a possible 22 interactive voice response telephone calls that contained a DPP lesson and subsequent questions, opportunities to report on aerobic physical

activity, muscle strengthening and fruit and vegetable daily consumption goals, and review questions, if lesson questions were answered incorrectly in the previous call.

All IVR calls, DVD and the workbook connected with the study was formulated with clear communication strategies, which, included simple, short wording, no jargon, the most important health education lesson message stated implicitly and first, and reading levels around a 6th grade level.

Specific aims and hypotheses

Our intervention proposes to improve factors associated with health literacy, including motivation, problem-solving, self-efficacy, knowledge and skills within the patient self-care realm of the Paasche-Orlow model with the goal of improving cardiovascular and diabetes risk, as well as health outcomes. To accomplish these goals, we use a variety of modalities, including DVDs, written materials, in-person classes, and IVR, to provide health information in different formats to patients at risk for developing diabetes. Furthermore, teach-back and teach-to-goal, commonly utilized in improving knowledge and comprehension in low literacy patients supplement each session (Baker et al., 2011; Kripalani, Bengtzen, Henderson, & Jacobson, 2008). To our knowledge, no diabetes prevention trial has compared the effectiveness of these various health communication approaches in providing health information to participants. Thus, we propose to evaluate the effectiveness of different health communication modalities and strategies in improving participant health information comprehension, behavior engagement and health outcomes in a diabetes prevention program.

With that said, the specific aims and hypotheses of this study include:

1. The degree to which different health education modalities influence comprehension of intervention information based on participant's health literacy status. We hypothesize that

Hypothesis 1.1: Individuals with higher health literacy will present better comprehension independent of modality used.

2. If participants with high versus low health literacy levels differ on the number of rounds of teach-back and teach-to-goal necessary to achieve comprehension. We hypothesize that participants with higher health literacy will need less rounds of teach-back and teach-to-goal questions.

Hypothesis 2.1: Teach-back and teach-to-goal strategies will improve overall comprehension rates over the course of the intervention, regardless of health literacy levels or modality.

Hypothesis 2.2: Those participants with higher comprehension rates are more likely to be engaged over the course of the 12 months.

3. If the relationship between dose of intervention (i.e. number of IVR calls completed) received and the changes in behavior and weight are influenced by participant health literacy status.

Hypothesis 3.1: Those participants with higher health literacy will need a smaller dose of intervention to achieve the same behavior and weight outcomes.

Chapter 2: Effectiveness of DVD vs. group-initiated diabetes prevention on information uptake for high and low health literacy participants

Introduction

Currently in the United States, approximately 35% of the population have prediabetes, 38% are obese and approximately 40% have either impaired glucose tolerance or fasting glucose levels (Centers for Disease Control and Prevention, 2014; Centers for Disease Control and Prevention (CDC), 2003; McQueen et al., 2016). Additionally, most Americans have at least one other risk factor that has been observed to contribute to diabetes and/or cardiometabolic risk such as physical inactivity, family history of type 2 diabetes, hypertension, or high body mass index (Gress, Nieto, Shahar, Wofford, & Brancati, 2000; Mokdad et al., 2003; Pradhan, Manson, Rifai, Buring, & Ridker, 2001). Annual medical costs incurred for an individual patient have been observed to range from $417 to $4117 for one to four risk factors, respectively, as well as experiencing diminished quality of life (Boyle, Thompson, Gregg, Barker, & Williamson, 2010; McQueen et al., 2016; Meigs et al., 2006).

To address the growing number of adults with pre-diabetes, the Diabetes Prevention Program (DPP), a large multi-center trial, tested the ability of lifestyle intervention and modest weight loss to delay the onset of diabetes (Diabetes Prevention Program Research Group, 2002). In short, the study found that lifestyle intervention resulted in better outcomes when compared to medication such as reduced incidence of T2DM (58% lower than placebo), improved uptake of physical activity (74% at 24 weeks)

and weight reduction (50% achieved 7% or greater weight loss) (Diabetes Prevention Program Research Group, 2002).

Since then, researchers at several institutions have adapted the lifestyle intervention using technology-enhanced mediums, thus eliminating intensive direct provider-to-patient contact while allowing patient to receive intervention materials asynchronously while also automating goal-setting and feedback loops (Almeida et al., 2014; Ma et al., 2013). A meta-analysis published in March 2017 evaluated the use of different content delivery channels among diabetes prevention programs to address what methods may be most effective in-patient engagement lending to better weight loss (Bian et al., 2017). Those programs that used the original DPP lifestyle intervention or adapted from that content, when combined with multiple modalities, displayed greater average weight loss (~2.4 kg) than those that didn't follow the evidence-based curriculum (Bian et al., 2017).

While these results are very promising, there is a gap in the literature related to the effectiveness of these interventions for participants with varying degrees of health literacy—defined as the ability to acquire, synthesize, and understand health information and services required to make decisions regarding an individuals or community's health (Aguiar et al., 2016; Betzlbacher et al., 2013; Kickbusch, 2001; Kramer et al., 2010; Ma et al., 2013; Nicklas et al., 2014; Piatt, Seidel, Powell, & Zgibor, 2013; Ramachandran et al., 2013; Sakane et al., 2015; Sepah, S. Cameron, Jiang, Ellis, McDermott, & Peters, 2017; Tate et al., 2003; Vadheim et al., 2010; Zarcadoolas, Pleasant, & Greer, 2003).

While one could hypothesize that the ability to clarify educational content or the ability to do teach-back or teach-to-goal—mechanisms to ensure comprehension of the content—could lead to reduced effectiveness of interactive technology interventions, there are also some reasons to hypothesize the opposite (Baker et al., 2011; Bavelier, Green, & Dye, 2010; Kripalani et al., 2008). Technological approaches may have several advantages for patient with lower health literacy such as repeatability. Most interactive technology-based interventions allow participants to review, play back or redo intervention activities. Similarly, most use auditory rather than text-based information delivery with images that reduce the need to read content. Finally, when comparing these approaches to in-person, group settings, many interactive educational components of a video or telephone call, may require more active participation of patients (Bavelier et al., 2010).

With regards to information uptake relative to a specific modality, when patients receive information through an educational DVD, regardless of health condition, several studies have observed positive outcomes (Eckman et al., 2012; McAuley et al., 2013; Xiao, Yank, Wilson, Lavori, & Ma, 2013). For example, in a group of sedentary older adults, a DVD-based intervention observed improvements in overall physical function (McAuley et al., 2013). Another program adapted their in-person weight loss intervention to be delivered via DVD and recorded an 83% completion rate of lessons and 6% average weight change at 12 months (Katula, J. A. et al., 2011). Furthermore, a DVD-mediated intervention was observed to have clinically-significant weight loss maintained 24 months after baseline, suggesting the potential of a DVD to initiate

sustainable weight loss and behavior change (Xiao et al., 2013). When considering the use of a DVD delivery format compared to text-based information for patients with lower health literacy, coronary artery disease patients did not have significantly worse clinical outcomes or health behaviors than their counterparts, suggesting that a DVD can enhance knowledge retention, understanding of their condition, and how to best manage their health (Eckman et al., 2012).

In contrast to technology-facilitated interventions, traditional patient education is primarily delivered through in-person and small group mechanisms. Participants or patients attending a small-group class have been observed to have positive results , as well. Researchers from Wake Forest University observed improved blood glucose, decreased insulin resistance, weight and waist circumference in participants that had attended small-group class versus a standard care treatment group (Katula et al., 2011). Those results parallel much of Seidel and colleagues achieved in their adapted group-based lifestyle diabetes prevention intervention in an urban, medically underserved neighborhood suggesting participants can engage in the core curriculum at a different pace and setting while being able to engage in behavior change lending to favorable outcomes (Seidel, Powell, Zgibor, Siminerio, & Piatt, 2008). These advantages could enhance the ability of low health literacy participants to receive the information in more conducive manners due to the ability to interact with a trained medical professional, registered dietician or other class participants; however, largely uncertain is the degree to which participants can interact with the educational content to enhance their comprehension levels.

As we have documented, alternative hypotheses could be posed related to the benefits of DVD versus in-person, class-initiated diabetes prevention interventions for patients of varying health literacy levels. However, no research to date has compared the information uptake of key learning objectives when a diabetes prevention program is initiated with either a technology or in-person facilitated approach. The purpose of this study is to fill the gap by comparing the effectiveness of a DVD versus an in-person group-initiated diabetes prevention class to enhance patient comprehension of diabetes prevention program learning objectives based on health literacy status (i.e., high (HHL) and low health literacy (LHL)).

Methods

Research design

DiaBEAT-it! is an 18-month pragmatic hybrid-preference randomized control trial with primary aims to determine the reach, effectiveness, and cost of a technology-initiated diabetes prevention program when compared to an in-person initiated program and standard care diabetes prevention class (Almeida et al., 2014). The design allowed for participants to be initially assigned into one of two groups—choice of intervention or randomization into one of three conditions(Almeida et al., 2014). Participants in the randomized control trial (RCT; n=334) were randomly assigned into one of three treatments—standard care (Class; n=117), small group in-person class-initiated intervention with interactive voice response follow-up (Class/IVR; n=110) or DVD initiated intervention with interactive voice response follow-up (DVD/IVR; n=107). Those assigned to choice group (n=264) could choose between the class/IVR (n=114) or

the DVD/IVR conditions (n=150) (Almeida et al., 2014). For the purposes of this study, participant were grouped according to the intervention received (Class/IVR=224 or DVD/IVR=257) independent of original group assignment (Choice vs. RCT) and were categorized as having adequate or high health literacy (HHL ≥4/6) versus possible inadequate or low health literacy (LHL≤3/6) based on the validated Newest Vital Sign (NVS) health literacy assessment (Weiss et al., 2005). Compared to other health literacy instruments, the NVS is a brief, objective, one-on-one in-person assessment that mimics patient-provider communication, especially as it relates to nutrition and health behaviors, and is not as cumbersome upon the patient to complete (Weiss et al., 2005).

All participants were asked to complete an informed consent to participate at the baseline assessment. The study procedures were approved by the Carilion Clinic, Virginia Tech, and University of Nebraska Medical Center Institutional Review Boards and the protocol was registered at clinicaltrials.gov (NCT01262901).

Participant eligibility and recruitment

Participants were recruited through the Carilion Clinic Department of Family and Community Medicine in southwest Virginia. Patients over the age of 18 with a body mass index (BMI) greater than 25 were eligible to participate (Almeida et al., 2014). Patients with diabetes, that were pregnant or planning a pregnancy, those unable to read or communicate in English, or medically incapable were ineligible(Almeida et al., 2014).

Initial baseline assessments (i.e. height, weight, blood pressure, dual X-Ray absorptiometry, health literacy) were completed on the first study visit(Almeida et al., 2014). Health literacy levels were assessed via the validated Newest Vital Sign(Almeida

et al., 2014). On the second study visit, the participants were assigned to or chose a program, and given educational materials to follow the design and objectives of the study (Almeida et al., 2014).

Interventions

Small group diabetes prevention class (Class/IVR)

The in-person small group diabetes prevention class was offered twice a month lasting two hours and was led by a Carilion Clinic registered dietician (Almeida et al., 2014). As part of the curriculum, diabetes prevention objectives (i.e. appropriate physical activity, ideal food choices and portion sizes) were reviewed in addition to participants creating a personalized action plan to reduce weight by 10% over the course of twelve months (Almeida et al., 2014). The class was formulated to encourage discussion among participants on how to live a healthy lifestyle (Almeida et al., 2014), and was followed by a teach-back/teach-to-goal (referred to as teach-back in the remainder of the article) call that was intended to provide reinforcement for intervention learning objectives, review the personalized action plan, and prepare participants to receive follow-up IVR intervention calls (Almeida et al., 2014).

DVD diabetes prevention intervention

A 60-minute DVD was designed to cover the same content and process of the in-person class session (Almeida et al., 2014). The DVD was a convenient form of media that can be reproduced at low cost while affording the participant the opportunity to watch the DVD multiple times, if necessary. Participants used the DVD to work through the development of an action plan to set their health behavior goals (i.e. physical activity, weight loss, fruits and vegetable consumption) and identify strategies and

barriers to behavior change. About 4 to 5 days after watching the DVD, participants completed a teach-back call with a research assistant to review the action plan and reinforce the material presented in the DVD (Almeida et al., 2014).

Teach back/teach-to-goal call

After attending the class or viewing the DVD, participants were asked to complete a teach-back call that included teach-to-goal opportunities and lasted 20 to 30 minutes. The call was designed to reinforce key learning objectives from the small group class or viewing of the DVD. A series of six questions were assessed using teach-back for each question to initiate the process of teach-to-goal to ensure information uptake. Question one asked participants to provide a description of factors that could help to prevent diabetes. Correct responses included reducing body weight, blood pressure, levels of LDL and triglycerides as well as increasing physical activity and healthful eating patterns. Each question had detailed responses that were used to determine if a participant answered correctly or not. Questions 2 through 6 focused on identifying the amount of weight loss necessary to reduce the risk of progressing into diabetes, the recommended amount and intensity of physical activity, appropriate resistance training activities, and the components of a MyPlate eating plan. Any question answered incorrectly was repeated for up to 3 rounds of assessment. After each round, participants reviewed components of their action plan.

Following previous studies in the literature, we selected three measures for assessing comprehension: teach back rounds completed, number of round one questions correct, and reverse score averages (Kripalani et al., 2008; Porter et al., 2016). First, we

calculated the number of teach-back rounds completed with fewer reflecting high comprehension as a result of the DVD or Class. Second, we calculated the number of times each participant answered the questions correctly during the first round without need for further clarification. Scores ranged from zero to six with higher scores indicating better overall comprehension. Third, reverse scoring methods were applied by assigning a higher value for providing the correct answer in earlier rounds (i.e. Round 1 correct=3, Round 2 correct=2, Round 3 correct=1, Incorrect in all 3 rounds=0) and calculating a sum to gauge overall performance in the teach-back call (Tables 3-5). Scores ranged from zero to eighteen with higher scores indicating better comprehension and less overall rounds needed to complete all six questions. For instance, a score of 18 indicated a participant needed 6 overall rounds (responded every question correctly in the first round) to answer all six questions, a score of 17 indicated a participant needed 7 overall rounds, a score of 16 indicated a participant needed 8 overall rounds and so forth.

Data analysis

All participants that completed a teach back call were analyzed according to the intervention they selected or were randomized to, as well as their performance on NVS health literacy assessment (i.e. HHL or LHL). Descriptive statistics were computed for age, height, weight, BMI, income, sex and insurance status. Comparisons using multiple linear regression techniques controlling for age, initial randomization for choice or RCT, days between viewing DVD or attending class and completing the teach-back call were conducted to determine the relationships between intervention condition, health literacy

status, and comprehension. To control for heteroskedasticity, White's Robust Standard Errors adjustment procedures were calculated for number of round one questions correct, teach back round completed, and reverse score averages as a measure of overall performance to evaluate models by modality, health literacy level, as well as modality + health literacy level. The general regression model $y= \beta_0 + \beta_1 \chi_i + \beta_2 \chi_i^2 + \beta_3 \chi_i^3 + \beta_4 \chi_i^4 + \varepsilon_i$ where i=1,...n and class were coded as 1, DVD=0, HHL=1 and LHL=0. The round to which all questions were completed answered correctly were analyzed by treatment groups using chi-square procedures (Table 6). All calculations were performed using IBM SPSS Statistics Version 23.0 (IBM Corp., 2015).

Results

Of 481 eligible participants, 442 (92%) completed a teach-back call with 225 (47%) and 217 (45%) receiving the DVD and class session, respectively. The average age of the entire sample was 52.3 year (±12.1) and 68% were female. DVD (50.8±12.2 years) and class (53.9±11.9 years) samples differed significantly on age. Over three quarters of the sample were Caucasian and 17% were African-American. Eighteen percent (n=81) of the participants had low health literacy, conversely, 82% of the participants (n=361) had adequate or high health literacy based on the Newest Vital Sign scores. Overall, 20% of those who chose or were assigned the DVD (n=40) had LHL, comparable to the other LHL participants in the class treatment at 17% (n=41). Participants with lower health literacy were significantly older (57.1±11.9) than those with higher health literacy (51.2±11.9) and significantly more likely to be African-American (30% when compared to other racial categories (14%). Finally, the duration between watching the DVD (4.3±7.0

days) or attending the class (5.0±6.0 days) and completing the teach-back call was not significantly different between groups. Table 1 contains descriptive information by health literacy level, modality and modality/health literacy level.

When considering participants who completed the intervention via the DVD versus class we found that there were significant differences in the reverse score performance (DVD-15.4±2.5; Class-14.8±2.6; $F(3, 425)= 13.72$, $p<0.001$), number of teach-back rounds (DVD-1.9±0.7; Class-2.1±0.7; $F(3, 425)=5.98$, $p<0.001$) and number of round 1 questions correct (DVD-4.2±1.6; Class-3.4±1.8; $F(3,425)=20.95$, $p<0.001$) (See Table 2). Based on health literacy level we found consistently that participants with HHL performed better across the outcomes (See Table 6). Finally, when considering intervention modality by health literacy status, we found that the DVD delivery resulted in superior comprehension for HHL participants across all outcomes. However, DVD versus class differences for participants with LHL were not significant and approximately, 18% and 16% of DVD and class LHL participants did not achieve the teach-to-goal purpose after the final round of teach-back was completed (Table 6). In the analysis of teach-back rounds, number of round 1 questions and reverse score performance, every predictor variable mentioned above was significant except for class/LHL vs. DVD/LHL (Tables 3-5).

Discussion

The need for interventions that include strategies to address participants with varied levels of health literacy is well documented (Nutbeam, 2000; Paasche-Orlow & Wolf, 2007). Consistent with other research, our study found that even when

information is presented using clear communication strategies during an initial intervention session, it may not be enough to ensure information uptake, in our case, related to diabetes prevention objectives. In fact, less than 21% of all participants were able to demonstrate complete comprehension of the materials during the first round of questioning indicating the importance of additional rounds of material reinforcement even for individuals with higher health literacy (Paasche-Orlow et al., 2005; Schillinger et al., 2003; Sudore et al., 2006). Also, like previous research, outside of the context of a diabetes prevention intervention, when information uptake is evaluated, researchers have observed improved comprehension over multiple rounds of teach-to-goal educational assessment (Paasche-Orlow et al., 2005; Schillinger et al., 2003; Sudore et al., 2006).

In the review by Bian et al. (2017), the use of multiple health education modalities relative to single health education modality interventions to deliver diabetes prevention lessons was observed to lead to greater participant weight loss (Bian et al., 2017). However, none of the multiple modality interventions reviewed measured information uptake through teach-back or teach-to-goal or used an initial teach-back call to evaluate uptake of key learning objectives (Block et al., 2015; Cha et al., 2014; Ma et al., 2013; Piatt et al., 2013; Tate et al., 2003). The lack of strategies focusing on enhanced information uptake may help explain the levels of attrition (38% to 57%) and variability in weight outcomes across studies (Bian et al., 2017; Piatt et al., 2013; Weinstock, Trief, Cibula, Morin, & Delahanty, 2013).

When teach-back and teach-to-goal methods are utilized, positive outcomes have been observed (DeWalt et al., 2009; Schillinger et al., 2003; Sudore et al., 2006). For example, in executing an informed consent procedure with teach-to-goal strategies, proportions of marginal and inadequate health literacy participants were nearly equivalent after two rounds of assessment (Sudore et al., 2006). In an asthma administration education program by providers tailored towards low health literacy patients, 59, 21 and 10 percent of patients needed one, two, or three additional rounds of teach-to-goal education, respectively (Sudore et al., 2006). The latter study has suggested that through increasing information uptake, patient engagement may be more likely through enhanced self-efficacy of the behavior lending to a greater likelihood of behavioral uptake and health outcome achievement (Paasche-Orlow et al., 2005; Paasche-Orlow & Wolf, 2007). While reporting on the relationship between teach-back strategies and health outcomes is beyond the scope of this paper, our results support the importance of multiple opportunities for presenting health information to individuals, regardless of health literacy levels. Indeed, the initial 21 percent of participants that had achieved the learning objectives as demonstrated by the first teach back opportunity, grew to over 90 percent demonstrating this achievement by the completion of the third round of teach back.

Perhaps our most interesting and actionable finding was that the DVD initiated diabetes prevention intervention was superior to supporting patient uptake of information when compared to the in-person initiated version. It is not clear why this might be, but as we proposed earlier, it is possible that the DVD gave participants

multiple opportunities to review the material over time. Similar to Paasche-Orlow et al. and Sudore et. al. studies (2011), the difference between modalities was reduced over time as a result of teach-to-goal strategies used. A fruitful area for additional research would be to determine the potential mechanism that underlies the superiority of the DVD or other interactive technology-based interventions when compared to in-person sessions.

The primary limitations of our study include the short duration and the lack of health or behavioral outcomes associated with learning objective comprehension. It is unlikely that simply providing a DVD or in-person session would lead to sustained changes in behavior, weight and diabetes risk. However, as part of a larger trial and intervention, our finding may be generalizable to other contexts and health promotion outcomes—we demonstrated that the DVD approach could improve initial information uptake and that the use of a teach-back and teach-to-goal strategy can be used to reinforce key learning objectives. An additional possible explanation for our findings could be that in-person class sessions had variable implementation fidelity which could influence the results.

Conclusion

The use of a DVD may produce superior uptake of learning objectives when compared to an in-person class and participants with LHL typically perform worse on assessment of information uptake regardless of implementation modality. Nevertheless, we identified that a teach-back call may enhance information uptake of diabetes prevention learning objectives in diabetes prevention programs, especially among

participants with lower health literacy. Finally, many of the participants with higher health literacy were able to improve comprehension through the reinforcing structure of the teach-back and teach-to-goal call. Teach-back strategies may be important components to be considered for future diabetes prevention programs, independent of delivery method, to ensure participants, independent of health literacy level, fully comprehend the materials and learning objectives being covered.

Practice implications

A teach-back call has many practical implications—easy-to-complete, pragmatic, efficient and it may enhance a provider's ability to help a patient comprehend important information related to health behaviors needed to prevent the onset of T2DM. Furthermore, a teach-back call may enhance engagement of participants in diabetes prevention interventions, especially LHL members, due to greater information understanding, thus improving the likelihood of health behavior uptake. As such, clinical interventions may observe a greater proportion of the patient population achieving the primary or secondary outcomes of weight loss or improvements in preventive behaviors such as better nutrition or more physical activity.

Table 1 Participant characteristics of teach-back/teach-to-goal call

	RCT n= 198						Choice n= 244						Overall n= 442					
	Class/IVR			DVD/IVR			Class/IVR			DVD/IVR			LHL	HHL	Class/ IVR	DVD/ IVR	Choice	RCT
	Overall	LHL	HHL	Overall	LHL	HHL	Overall	LHL	HHL	Overall	LHL	HHL						
	n= 104	n= 21	n= 83	n= 94	n= 15	n= 79	n= 113	n= 22	n= 91	n= 131	n= 23	n= 108	n= 81	n= 361	n= 217	n= 225	n= 244	n= 198
	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)
Age[a, b, g, j, q]	52.3 (12.2)	58.5 (10.4)	50.7 (11.9)	51.7 (12.2)	51.3 (15.7)	52.1 (11.7)	55.8 (11.6)	60.7 (9.3)	54.1 (11.7)	49.9 (11.9)	56.0 (11.8)	48.6 (11.7)	57.1 (11.9)	51.2 (11.9)	50.8 (12.2)	53.9 (11.9)	52.5 (12.1)	52.1 (12.1)
Weight[c, d, r]	231.3 (45.5)	218.5 (35.1)	234.7 (49.8)	239.8 (56.5)	243.2 (54.1)	239.5 (55.8)	220.3 (41.1)	212.2 (50.4)	222.4 (38.6)	226.3 (37.5)	220.5 (36.1)	227.7 (37.6)	221.9 (44.3)	230.6 (45.5)	232.2 (46.0)	225.7 (44.5)	223.7 (39.2)	235.5 (51.4)
BMI[e, s]	37.8 (7.9)	35.6 (4.7)	38.2 (8.4)	38.4 (7.7)	37.4 (7.6)	38.7 (7.7)	35.8 (6.1)	34.7 (5.9)	36.1 (6.1)	36.4 (5.0)	36.6 (5.0)	36.4 (5.0)	36.0 (5.7)	37.2 (6.9)	37.3 (6.3)	36.7 (7.0)	36.1 (5.5)	38.1 (7.8)
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
% Female	67 (67.7)	12 (12.1)	57 (57.6)	65 (65.7)	9 (9.1)	54 (54.5)	74 (69.2)	16 (15)	62 (57.9)	94 (68.6)	17 (12.4)	73 (53.2)	54 (66.7)	246 (68.1)	153.0 (68.0)	147.0 (67.7)	168 (68.9)	132 (66.7)
% Minori-ies[h, k, n]	21 (21.2)	4 (4.0)	17 (17.2)	20 (20.2)	7 (7.1)	13 (13.1)	17 (15.9)	7 (6.5)	12 (11.2)	24 (17.5)	7 (5.1)	15 (10.9)	25 (30.8)	57 (15.8)	42 (18.7)	40 (18.5)	41 (16.8)	41 (20.7)
% Uninsu-red[f, l, o,]	1 (1.0)	1 (1.0)	0 (0)	2 (2.0)	1 (1.0)	1 (1.0)	3 (2.8)	2 (1.9)	2 (1.9)	7 (5.1)	3 (2.2)	3 (2.2)	7 (8.6)	6 (1.7)	8 (3.6)	5 (2.3)	10 (4.1)	3 (1.5)
% low-income[i, m, p]	19 (19.2)	4 (4.0)	16 (16.2)	22 (23.2)	7 (7.1)	15 (15.2)	26 (24.2)	10 (9.3)	17 (15.9)	31 (22.6)	10 (7.3)	20 (14.6)	31 (38.3)	68 (18.8)	52 (23.1)	47 (21.7)	57 (23.4)	42 (21.3)

[a] Choice only, p<0.001

[b-f] All 4 treatment arms, (b) p<0.01; (c and d) p<0.05; (e) p<0.001; (f) p<0.001

[g, h] LHL v. HHL within Choice, (g) p<0.05; (h) p<0.05

[i-l] LHL v. HHL within RCT, (i) p<0.001; (j) p<0.01; (k) p<0.05; (l) p<0.001

[m-p] LHL v. HHL all treatments, (m) p<0.001; (n) p<0.001; (o) p<0.01; (p) p<0.001

[q] Class v. DVD, p<0.01; [r, s] Choice v. RCT, (r) p<0.01; (s) p<0.05.

Table 2 Mean comprehension outcome scores

	Overall	DVD	Class	DVD		Class	
				High health literacy	Low health literacy	High health literacy	Low health literacy
Reverse score average	15.4 (2.5)	15.9 (2.3)	14.8 (2.6)	16.3 (1.7)	13.5 (3.3)	15.2 (2.5)	13.3 (2.6)
Number of round 1 questions correct	3.8 (1.7)	4.2 (1.6)	3.4 (1.8)	4.5 (1.4)	2.8 (1.9)	3.7 (1.7)	2.4 (1.4)
Number of teach-back rounds	2.0 (0.7)	1.9 (0.7)	2.1 (0.7)	1.8 (0.6)	2.3 (0.8)	2.0 (0.7)	2.4 (0.6)

*Note: Significance between modalities or health literacy level addressed by Table 3-6.
**p<0.001, ^p<0.05

Table 3 Live call reverse score

	Coefficient	SE	t
Constant**	18.2734	0.5806	31.4758
Choice vs. RCT	0.692	0.2266	0.3055
Modality and health literacy status	-0.1292	0.1255	-1.0297
Age	-0.0440	0.0095	-4.6259
Days between viewing or attending class	-0.0847	0.0302	-2.8047
R^2=0.0948, F (4, 424) = 7.0218			
Constant**	18.2383	0.5232	34.8591
Choice vs. RCT	0.1011	0.2231	0.4534
Class vs. DVD	-0.8402	0.2259	-3.7186
Age	-0.0405	0.0093	-4.3413
Days between viewing or attending class	-0.0807	0.0292	-2.7619
R^2=0.1204, F (4, 424) = 10.4998			
Constant**	15.6880	0.6654	23.5765
Choice vs. RCT	0.0160	0.2171	0.0738
Health literacy levels	1.9647	0.3520	5.5813
Age	-0.0314	0.0092	-3.4027
Days between viewing or attending class	-0.0631	0.0310	-2.0351
R^2=0.1790, F (4, 424) = 15.0776			
Constant**	14.1757	1.6777	8.4829
Choice vs. RCT	-0.01216	0.3315	-0.3666
Class/LHL vs. Class/HHL	1.2151	0.4167	2.9156
Age	-0.0442	0.0156	-2.8378
Days between viewing or attending class	-0.0572	0.0463	-1.2343
R^2=0.1263, F (4, 208) = 6.2971			
Constant**	14.6050	0.8257	17.6884
Choice vs. RCT	0.1399	0.2591	0.5398
DVD/LHL vs. DVD/HHL	2.6952	0.5872	4.5900
Age	-0.0152	0.0103	-1.4738
Days between viewing or attending class	-0.0632	0.0509	-1.2429
R^2=0.2649, F (4, 211) = 7.0037			
Constant	15.0278	1.8814	7.9876
Choice vs. RCT	-0.03483	0.6665	-0.5226
Class/LHL vs. DVD/LHL	0.1028	0.3296	0.3119
Age	-0.0289	0.0286	-1.0107
Days between viewing or attending class	0.0155	0.0492	0.3151
R^2=0.0205, F (4, 72) = .8386			
Constant**	18.7002	0.5076	36.8381
Choice vs. RCT	0.0632	0.2143	0.2949
Class/HHL vs. DVD/HHL	-0.5225	0.1099	-4.7526
Age	-0.0280	0.0091	-3.0801
Days between viewing or attending class	-0.1142	0.0409	-2.7952
R^2=0.1681, F (4, 347) = 10.7243			
Constant**	18.0633	.5236	34.4964
Choice vs. RCT	.0517	.2286	.2261
Age	-0.0443	.0095	-4.6599
Days between viewing or attending class	-0.0844	.0306	-2.7578
R^2=0.0918, F (3, 425) = 8.9730			

**p<0.001

Table 4 Teach-back rounds

	Coefficient	SE	t
Constant^	1.5278	0.1477	10.3442
Choice vs. RCT	0.0253	0.0650	0.3890
Modality and health literacy status	0.0267	0.0325	0.8234
Age	0.0071	0.0025	2.8767
Days between viewing or attending class	0.0090	0.0060	1.4843
R^2=0.0245, F (4, 424) = 2.8009			
Constant^	1.5352	0.1370	11.2064
Choice vs. RCT	0.0187	0.0645	0.2905
Class vs. DVD	0.1731	0.0652	2.6542
Age	0.0063	0.0025	2.5812
Days between viewing or attending class	0.0081	0.0058	1.3995
R^2=0.0390, F (4, 424) = 4.5016			
Constant**	2.0595	0.1699	12.1187
Choice vs. RCT	0.0363	0.0633	0.5731
Health literacy levels	-0.4038	0.0875	-4.6140
Age	0.0045	0.0024	1.8550
Days between viewing or attending class	0.0045	0.0063	0.7206
R^2=0.0720, F (4, 424) = 8.0491			
Constant^	2.7948	0.4456	6.2719
Choice vs. RCT	0.0154	0.0937	0.1641
Class/LHL vs. Class/HHL	-0.3445	0.1175	-2.9326
Age	0.0045	0.0035	1.2805
Days between viewing or attending class	0.0040	0.0082	0.4845
R^2=0.0587, F (4, 208) = 3.9194			
Constant^	2.1042	0.2310	9.1076
Choice vs. RCT	0.0435	0.0873	0.4991
DVD/LHL vs. DVD/HHL	-0.4635	0.1377	-3.3671
Age	0.0029	0.0035	0.8450
Days between viewing or attending class	0.0040	0.0101	0.3934
R^2=0.0809, F (4, 211) = 3.3813			
Constant	2.1138	0.3585	5.8955
Choice vs. RCT	0.1109	0.1611	0.6884
Class/LHL vs. DVD/LHL	0.0463	0.0830	0.5577
Age	0.0042	0.0059	0.7094
Days between viewing or attending class	-0.0119	0.0086	-1.3826
R^2=0.0490, F (4, 72) = .5885			
Constant^	1.4807	0.1558	9.5009
Choice vs. RCT	0.0253	0.0687	0.3691
Class/HHL vs. DVD/HHL	0.0931	0.0348	2.6789
Age	0.0035	0.0026	1.3388
Days between viewing or attending class	0.0151	0.0087	1.7323
R^2=0.0430, F (4, 347) = 3.3393			
Constant^	1.5713	.1369	11.4745
Choice vs. RCT	.0289	.0649	.4462
Age	.0071	.0024	2.9198
Days between viewing or attending class	.0089	.0061	1.4534
R^2=0.0227, F (3, 425) = 3.4785			

**p<0.001, ^p<0.05

Table 5 Number of round 1 questions correct

	Coefficient	SE	t
Constant**	5.6543	0.3961	14.2768
Choice vs. RCT	0.0279	0.1621	0.1722
Modality and health literacy status	-0.1256	0.0844	-1.4875
Age	-0.0255	0.0065	-3.9153
Days between viewing or attending class	-0.0613	0.0204	-3.0111
R^2=0.0864, F (4, 424) = 6.4029			
Constant**	5.5872	0.3624	15.4170
Choice vs. RCT	0.0496	0.1594	0.3112
Class vs. DVD	-0.6581	0.1615	-4.0741
Age	-0.0228	0.0064	-3.5702
Days between viewing or attending class	-0.0581	0.0200	-2.9082
R^2=.1160, F (4, 424) = 10.5822			
Constant**	3.8304	0.4463	8.5819
Choice vs. RCT	-0.0135	0.1555	-0.0866
Health literacy levels	1.3397	0.2160	6.2015
Age	-0.0170	0.0064	-2.6476
Days between viewing or attending class	-0.0465	0.0218	-2.1310
R=0.1624, F (4, 424) = 15.7430			
Constant**	2.0387	1.1501	1.7726
Choice vs. RCT	0.0157	0.2323	0.0675
Class/LHL vs. Class/HHL	1.0052	0.2756	3.6468
Age	-0.0234	0.0104	-2.2357
Days between viewing or attending class	-0.0349	0.0296	-1.1822
R=0.1163, F (4, 208) = 7.1254			
Constant**	3.3070	0.5418	6.1043
Choice vs. RCT	-0.0438	0.1942	-0.2257
DVD/LHL vs. DVD/HHL	1.6782	0.3493	4.8049
Age	-0.0054	0.0076	-0.7115
Days between viewing or attending class	-0.0514	0.0377	-1.3620
R=0.2275, F (4, 211) = 6.7917			
Constant	2.8861	0.9948	2.9011
Choice vs. RCT	-0.1131	0.4146	-0.2727
Class/LHL vs. DVD/LHL	-0.1291	0.2113	-0.6111
Age	-0.0048	0.0155	-0.3094
Days between viewing or attending class	0.0133	0.0348	0.3817
R=0.0157, F (4, 72) = .1843			
Constant**	5.9893	0.3697	16.2022
Choice vs. RCT	-0.0043	0.1618	-0.0267
Class/HHL vs. DVD/HHL	-0.3699	0.0819	-4.5138
Age	-0.0157	0.0066	-2.3790
Days between viewing or attending class	-0.0844	0.0214	-3.9494
R=0.1501, F (4, 347) = 11.4096			
Constant**	5.4502	.3669	14.8528
Choice vs. RCT	.0109	.1625	.0668
Age	-.0258	.0065	-3.9550
Days between viewing or attending class	-.610	.0208	-2.9296
R=0.0805, F (3, 425) = 7.4941			

**p<0.001, ^p<0.05

Table 6 Round all questions answered correctly by treatment and health literacy group

	Round 1		Round 2		Round 3		Didn't get in any of the 3 rounds	
	N	% Correct	N	% Correct	N	% Correct	N	% who missed
LHL[1]	5	6.2	37	45.7	25	30.9	14	17.3
HHL[1]	84	23.3	212	58.7	42	11.6	23	6.4
DVD[2]	54	22.9	141	59.7	27	11.4	14	5.9
Class[2]	35	17.0	108	52.4	40	19.4	23	11.2
DVD+LHL[3],[4]	4	10.5	16	42.1	11	28.9	7	18.4
DVD+HHL[3],[4],[6]	47	25.1	120	64.2	14	7.5	6	3.2
Class+LHL[3], [5],	1	2.3	21	48.8	14	32.6	7	16.3
Class+HHL[3], [5],[6]	37	21.3	92	52.9	28	16.1	17	9.8

[1, 3, 4]$p<0.001$, [2, 5, 6]$p<0.05$

Chapter 3: Understanding the role of teach-back and teach-to-goal educational strategies in improving comprehension and engagement in a technology-enhanced diabetes prevention intervention

Literature review

The original Diabetes Prevention Program was first published in 2002 and included 22 in-person lessons for patients at-risk for Type II diabetes mellitus. Since then, health care systems, providers and researchers have tried to adapt the program with technology-based mediums that provide health education lessons and asynchronous behavior tracking, in order, to provide extended forms of patient care that relieve the burden upon providers and their system. However, adaptations have failed to implement techniques of health information reinforcement to the patient to assure patient comprehension of proper health behaviors to prevent diabetes. This quasi-experimental study looks to evaluate the effect of teach-back and teach-to-goal health literacy techniques upon patient comprehension of lesson and review questions given at 22 possible interactive voice response telephone lessons, according to health literacy levels and modality, and to observe how comprehension rates may predict engagement in the intervention. Results suggest overall comprehension rates predicted the number of lessons completed, regardless of modality or health literacy levels, and both high and low health literacy groups benefited from the additional reinforcement over the length of the intervention; thus, closing a prominent disparity gap among those groups in diabetes prevention knowledge.

Technology-based translation of the Diabetes Prevention Program Lifestyle Intervention

In America, approximately 84 million people have prediabetes while 93.3 million are considered obese (Centers for Disease Control and Prevention (CDC), 2003; Centers for Disease Control and Prevention (CDC), 2017; McQueen et al., 2016)]. These levels have put many people at risk for other co-morbidity related conditions such as cardiovascular disease, cancer and diabetes (Bianchini, Kaaks, & Vainio, 2002; Meigs et al., 2006; Mokdad et al., 2003). As a result, calls and significant research were made and published, respectively, in the last 20 years to combat obesity and the conditions associated with it (Benjamin, 2010; Hedley et al., 2004; Manson, Skerrett, Greenland, & VanItallie, 2004).

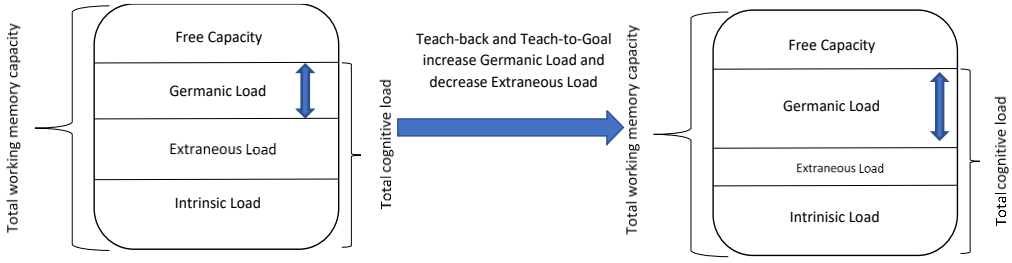
In 2002, a large multi-center trial known as the Diabetes Prevention Program observed that modest weight loss (i.e. ~5%) through a lifestyle intervention (LI) focused on increasing physical activity (PA) and fruit and vegetable intake reduced the incidence of type 2 diabetes at a greater rate than a pharmaceutical treatment (i.e. 58% vs. 31%) (Diabetes Prevention Program Research Group, 2002). Since then, efforts to translate and disseminate the LI into practice utilizing technology-based mediums such as websites, interactive voice response, DVD, telephone, text message and e-counselling have been well known (Almeida et al., 2014; Bian et al., 2017; Castro Sweet et al., 2018; McCoy, Couch, Duncan, & Lynch, 2005; Sepah, Jiang, & Peters, 2014; Tate et al., 2003). Most, if not all, diabetes prevention programs, published have stated positive effects after the intervention has been completed.

While a variety of strategies have been used for achieving modest weight loss, little is known about engagement, especially amongst different health literacy

groups (Sepah et al., 2017). In two different reviews published in March and April 2017 evaluating technology-mediated diabetes prevention programs, 36 different studies were evaluated. Of those interventions, only 2 assessed health literacy levels (Bian et al., 2017; Cha et al., 2014; Estabrooks & Smith-Ray, 2008; Joiner, Nam, & Whittemore, 2017). This lack of health literacy assessment has prevented researchers from understanding of how the uptake of information provided by these interventions, as well as comprehension rates may impact overall engagement, in order, to improve health communication and program materials.

Several different strategies have been proposed to improve comprehension rates. One strategy that has been suggested is teach-back and teach-to-goal (Schwartzberg et al., 2007). Teach-back and teach-to-goal reinforce educational information by providing the correct material after initial assessment, regardless if the participant was right or wrong, and the provider may assess the question until the participant correctly identifies the appropriate answer, respectively (DeWalt et al., 2009; Kripalani et al., 2008; Porter et al., 2016; Sudore, R. L. & Schillinger, 2009; White, Garbez, Carroll, Brinker, & Howie-Esquivel, 2013). These methods guarantee comprehension, which according to Cognitive Load Theory, may help participants cope with large amount of information and help reduce extrinsic load, one of two components influencing total cognitive load (see Figure 2) (Plass et al., 2010). Previous research employing multiple rounds of teach-back led to higher overall comprehension, and as a result, may be more likely to remain engaged in the intervention due to understanding the strategies necessary to reduce their likelihood of acquiring type 2 diabetes (Goessl et al., 2019).

Figure 2 The proposed effect of teach-back and teach-to-goal upon domains of Cognitive Load Theory



Thus, our hypothesis:

H1: Teach-back and teach-to-goal strategies will improve overall comprehension rates over the course of the intervention, regardless of health literacy levels or modality.

which we predict:

H2: Those participants with higher comprehension rates are more likely to be engaged over the course of the 12 months.

To our knowledge, no diabetes prevention program adaptations have reported on the use of these strategies to improve comprehension (Bian et al., 2017; Joiner et al., 2017; Tronieri, Wadden, Chao, & Tsai, 2019). The purpose of this manuscript is to determine the potential influence of teach-back and teach-to-goal strategies on comprehension and engagement in a technology-enhanced DPP. Further, we will determine whether these strategies have a differential impact among participants of varying health literacy levels.

As a result, the chief research questions are:

RQ1: Will teach-back and teach-to-goal improve overall comprehension rates over the course of the intervention?

RQ2: Will overall comprehension rates influence the degree of engagement among participants?

Methods

This quasi-experimental study is based off its parent study, DiaBEAT-it!, that employed a hybrid preferential randomized control trial design initially randomizing patients prior to recruitment into choice or RCT groups. At baseline assessment, participants were either randomized into three possible treatments—class only, class/IVR or DVD/IVR or if in the choice group were given the option of either class/IVR or DVD/IVR. Our evaluation is looking at differences throughout the IVR intervention between low (LHL) and high health literacy (HHL) participants after being assessed through the validated six question Newest Vital Sign health literacy measure at baseline (HHL=4-6 correct answers out of 6 questions) (Weiss et al., 2005). We also evaluated by modality and overall comprehension level, which the metric is defined below.

Participants

DiaBEAT-it! was a technology-based diabetes prevention program delivered to patients from four primary care clinics within Carilion Clinic of Roanoke, VA. After assessing patients through electronic medical records for type 2 diabetes risk factors (i.e.. body mass index over 25 and high likelihood of diabetes risk according to the American Diabetes Association Risk Test), a list of patients were provided to

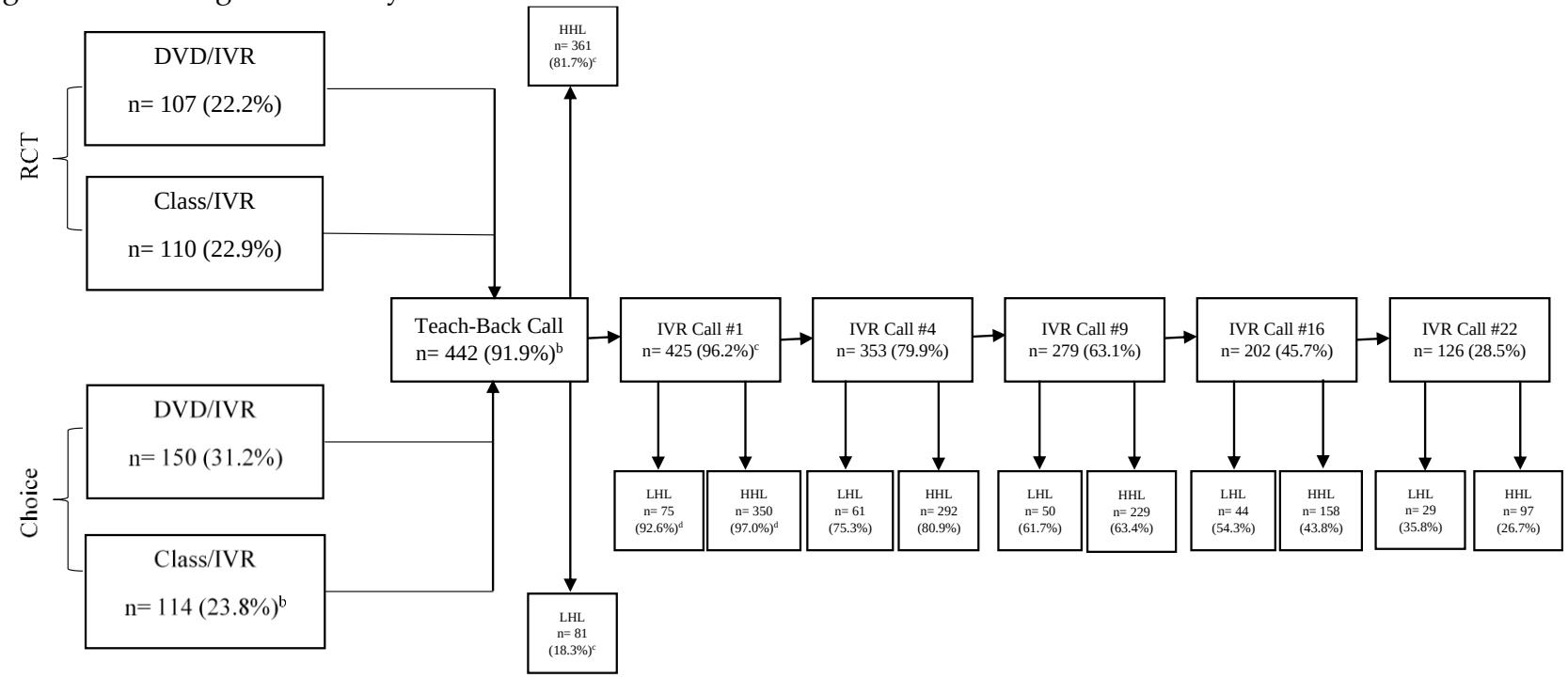
the primary care physicians for approval to potential participate in the trial (Almeida et al., 2014; Bang et al., 2009). Upon approval, participants were recruited via telephone or could opt-in by calling our study center phone number (Almeida et al., 2014).

Upon agreeing to participate, participants were scheduled for two in-person assessments, roughly 8-10 days apart. At Day 1, anthropometric measurements such as height, weight, and DXA body composition scan, as well as blood pressure, Godin Physical Activity Questionnaire, Newest Vital Sign (NVS) health literacy assessments and various lifestyle surveys were completed. At day 2, treatment assignments were completed. This series of assessments were repeated at 6, 12 and 18 months.

Post-baseline, participants watched the DVD or attended a one-time, two-hour in-person class taught by a registered dietician and were later able to choose 9 convenient times throughout the week to receive their calls. Phone calls occurred weekly in months 1 and 2 (Calls 1-8), bi-weekly in months 3-6 (Calls 9-16) and monthly thereafter (Calls 17-22). Each phone call provided one lesson coordinated with a workbook adapted from the original DPP lifestyle intervention with questions assessing the participant's ability to retain information provided in each lesson, and review questions in each subsequent lesson if answered incorrectly the first time (Almeida et al., 2014). Participants electing not to complete the calls could notify DiaBEAT-it! staff of their desire to end calls. Those choosing not to answer calls were forwarded to a project associate that solicited the participant for their desire to continue receiving the phone calls.

Descriptive, analysis of variance and chi-square calculations were conducted by health literacy level, modality, and modality with health literacy level. Four hundred and forty-two participants were eligible to complete IVR call #1, of which 425 participants or 95.9% chose to. Of the 425 participants, 51.1% (n=217; LHL-n=37; HHL-n=180) and 48.9% (n=208; LHL-n=38; HHL-n=170) were in the class and DVD groups, respectively. In the entire sample, 76.5% (n=325) were Caucasian and 16.5% (n=70) were African-Americans with an average age of 52.5 ± 12.1 with significant differences observed amongst HHL and LHL for age, NVS score, average number of review assessments completed, overall comprehension average, proportions of minorities, college education and low income status (see Table 7).

Figure 3 Flow Diagram of study



Note:
[a]Proportion based off final sample size of DiaBEAT-it! of n= 598.
[b]Proportions based off number of total IVR-eligible participants.
[c]Proportions based off number who completed teach-back call.
[d]Proportions based off number of participants completing teach-back call according to health literacy status.

Table 7 Characteristics of IVR participants by modality and health literacy level

	Overall	Small Group Class			DVD			LHL	HHL
		Overall	LHL	HHL	Overall	LHL	HHL		
	N=425	n=208	n=38	n=170	n= 217	n=37	n=180	n=75	n= 350
	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)
Age	52.5 (12.1)	53.2 (12.4)[a]	59.4 (9.8)	52.8 (1 1.9)	50.2 (12.0)[a]	54.2 (13.6)[j]	50.4 (11.8)[j]	56.0 (12.8)[b]	50.6 (11.9)[b]
Weight (lbs.)	227.4 (44.3)	226.2 (43.6)	208.9 (33.8)[e]	226.8 (44.3)	231.8 (47.4)	229.3 (45.4)[e, k]	231.5 (45.3)[k]	220.3 (43.8)[c]	231.1 (45.9)[c]
BMI	36.8 (6.4)	36.8 (6.8)	34.4 (4.5)	36.8 (6.9)	37.3 (6.7)	36.9 (6.2)[k]	37.2 (6.3)[k]	35.9 (5.6)	37.3 (6.9)
NVS Score	4.8 (1.4)	4.7 (1.5)	2.3 (0.9)[g]	5.3 (0.8)[g]	4.9 (1.4)	2.4 (0.8)[i]	5.4 (0.7)[i]	2.2 (.90)[b]	5.4 (.76)[b]
Average number of lessons completed	13.3 (7.9)	13.4 (7.8)	15.9 (7.8)	12.9 (7.7)	13.2 (8.0)	13.0 (8.8)[k]	13.3 (7.8)[k]	14.5 (8.4)	13.1 (7.8)
Average number of review assessments completed	4.9 (2.6)	5.2 (2.5)	6.0 (3.0)[h]	5.0 (2.3)[h]	4.7 (2.6)	5.6 (3.2)	4.5 (2.4)	5.8 (3.1)[b]	4.7 (2.4)[b]
Average % of review assessments needed over lessons completed	38.0 (15.0)	39.0 (14.9)	40.2 (15.9)	38.7 (14.6)	37.1 (15.1)	41.2 (12.2)	36.3 (15.5)	40.7 (14.2)	37.4 (15.1)
Overall comprehension average	1.0 (0.5)	1.0 (0.5)	1.0 (0.6)[h]	1.1 (0.5)[h]	1.1 (0.5)	0.9 (0.6)	1.1 (0.5)	0.9 (0.6)[d]	1.1 (0.5)[d]
Overall comprehension score	16.9 (13.1)	16.8 (12.7)	19.3 (13.4)	16.2 (12.6)	17.0 (13.4)	14.2 (12.8)	17.5 (13.5)	16.8 (13.3)	16.9 (13.1)
	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)	n(%)
% Female	286 (67.3)	140 (67.3)	25 (65.8)	115 (67.6)	146 (67.3)	25 (67.6)	121 (67.2)	50 (66.7)	236 (67.4)
% Minorities	78 (18.4)	37 (17.8)	8 (21.1)[g]	29 (17.1)[g]	41 (18.9)	14 (37.8)	27 (15.0)	22 (29.3)[c]	56 (16.0)[c]
% with 1+ years of college education	317 (74.6)	153 (73.6)	21 (55.3)[g]	132 (77.6)[g]	164 (75.6)	19 (15.4)[i]	145 (80.6)[i]	40 (53.3)[b]	277 (79.1)[b]
% Uninsured	10 (2.4)	4 (1.9)[a]	2 (5.3)[g]	2 (1.2)[f, g]	6 (2.8)[a]	3 (8.1)	3 (1.7)[f]	5 (6.6)	5 (1.4)
% Low income	62 (14.6)	24 (11.6)	6 (15.8)[g]	18 (10.6)[g]	38 (17.5)	15 (40.5)	23 (12.8)	21 (28.0)[b]	41 (11.7)[b]

[a]Class vs. DVD, p<0.05
[b]LHL vs. HHL, p<0.001
[c]LHL vs. HHL, p<0.01
[d]LHL vs. HHL, p<0.05
[e]Class/LHL vs. DVD/LHL, p<0.05
[f]Class/HHL vs.DVD/HHL, p<0.01
[g]Class/LHL vs. Class/HHL, p<0.001
[h]Class/LHL vs. Class/HHL, p<0.05
[i]DVD/LHL vs. DVD/HHL, p<0.001
[j]DVD/LHL vs. DVD/HHL, p<0.01
[k]DVD/LHL vs. DVD/HHL, p<0.05

Results

To evaluate longitudinal differences in health literacy and engagement changes, general regression modelling was conducted at three different levels below with all models employing White's Standard Error procedures to reduce heteroskedacity. The general regression equation was $y= \beta_0 + \beta_1 \chi_i + \beta_2 \chi_i^2 + \beta_3 \chi_i^3 + \beta_4 \chi_i^4 + \varepsilon_i$ where i=1,...n and HOC was coded as 1, LOC=0, HHL=1 and LHL=0. In all three models, health literacy levels, age and initial randomization into choice or RCT groups were controlled for (See Table 10). All calculations were performed using IBM SPSS Statistics Version 25.0 (IBM Corp., 2017).

Table 8 Performance on lesson and review questions by call—LHL vs. HHL

	Overall		LHL				HHL				
	Number of Participants completing call	% Attrition	Number of Participants completing call	% Attrition	Lesson questions correct	Review questions correct	Needed review questions	Number of Participants completing call	% Attrition	Lesson questions correct	Review questions correct	Needed Review Questions
	n=442*				n=75					n=350		
Call			f (%)		μ (SD)	μ (SD)	f(%)	f (%)		μ (SD)	μ (SD)	f(%)
1	425	3.9*	75 (100.0)	7.7*	1.5 (1.2)[a]	N/A	N/A	350 (100.0)	3.1*	2.1 (1.1)[a]	N/A	N/A
2	399	6.3	69 (92.0)	8.3	1.5 (1.2)	1.9 (.73)	43 (49.4)	330 (94.3)	5.9	2.1 (1.1)	2.1 (.76)	143 (36.3)
3	374	6.5	63 (84.0)	9.1	.81 (.93)[c]	2.7 (.54)	29 (33.3)	311 (88.9)	5.9	1.0 (.98)[c]	2.8 (.48)	105 (26.6)
4	353	5.8	61 (81.3)	3.2	1.1 (1.3)	2.6 (.87)	55 (63.2)	292 (83.4)	6.3	1.4 (1.5)	2.8 (.80)	253 (64.2)
5	335	5.2	57 (76.0)	6.8	.51 (.50)	1.4 (.51)	15 (17.2)	278 (79.4)	4.9	.59 (.49)	1.6 (.48)	55 (14.0)
6	321	4.3	55 (73.3)	3.6	1.1 (.95)	2.1 (.63)	43 (49.4)	266 (76.0)	4.4	1.3 (.91)	2.3 (.55)	203 (51.5)
7	308	4.1	54 (72.0)	1.8	1.1 (.94)	1.8 (.42)[c]	49 (56.3)	254 (72.6)	4.6	1.3 (.94)	1.9 (.31)[c]	252 (64.0)
8	295	4.3	53 (70.7)	1.9	1.2 (1.1)	2.1 (.68)	42 (48.3)	242 (69.1)	4.8	1.4 (1.1)	2.1 (.60)	183 (46.4)
9	279	5.6	50 (66.7)	5.8	1.1 (1.0)	2.0 (0.0)	2 (2.3)	229 (65.4)	5.5	1.2 (.98)	2.0 (0.0)	7 (1.8)
10	258	7.8	50 (66.7)	0.0	1.4 (1.4)	2.0 (.87)[b]	17 (19.5)	208 (59.4)	9.6	1.6 (1.4)	2.7 (.54)[b]	31 (7.9)
11	244	5.6	48 (64.0)	4.1	1.0 (.99)	2.1 (.75)[b]	31 (35.6)	196 (56.0)	5.9	1.2 (1.3)	2.5 (.71)[b]	111 (28.2)
12	236	3.3	46 (61.3)	4.3	1.4 (1.4)	2.3 (.67)	18 (20.7)	180 (51.4)	8.5	1.4 (1.5)	2.3 (.65)	22 (5.6)
13	222	6.1	46 (61.3)	0.0	1.0 (.99)	0	0 (0)	176 (50.3)	2.2	.90 (.99)	0	0 (0.0)
14	216	2.7	46 (61.3)	0.0	.75 (.81)	1.0 (0.0)	3 (3.4)	170 (48.6)	3.5	.70 (.85)	1.0	1 (0.3)
15	213	1.4	45 (60.0)	2.2	1.3 (1.3)	2.7 (.46)	15 (17.2)	168 (48.0)	1.2	1.2 (1.3)	2.8 (.40)	53 (13.5)
16	202	5.3	44 (58.7)	2.2	1.4 (1.4)	2.1 (.93)[a]	9 (10.3)	158 (45.1)	6.1	1.1 (1.4)	2.8 (.36)[a]	33 (8.4)
17	194	4.0	42 (56.0)	4.7	1.2 (1.4)	2.1 (.86)	14 (16.1)	152 (43.4)	3.9	.38 (.50)	2.6 (.58)	24 (6.1)
18	181	6.9	41 (54.7)	2.4	.45 (.50)	1.0 (0.0)	2 (2.3)	140 (40.0)	8.2	.34 (.33)	1.0 (0.0)	2 (0.5)
19	169	6.9	39 (52.0)	5.0	.41 (.50)	1.0 (0.0)	4 (4.6)	130 (37.1)	7.4	.33 (.47)	1.0 (0.0)	5 (1.3)
20	163	3.6	38 (50.7)	2.6	.41 (.49)	1.0 (0.0)	3 (3.4)	125 (35.7)	3.9	.30 (.46)	1.0	1 (0.3)
21	146	11.0	34 (45.3)	11.1	.21 (.41)	1.0 (0.0)	2 (2.3)	112 (32.0)	11.0	.21 (.40)	1.0 (0.0)	7 (1.8)
22	126	14.7	29 (38.7)	15.8	.31 (.47)	1.0 (0.0)	7 (8.0)	97 (27.7)	14.4	.24 (.43)	1.0 (0.0)	17 (4.3)

*Note: Reflects number eligible to complete IVR Call #1 or those that didn't continue with IVR intervention after completing teach-back/teach-to-goal call.

[a]$p<0.001$, [b]$p<0.01$, [c]$p<0.05$

Table 9 Proportion of participants getting everything correct and when--Lesson subjects, topics and number of questions per lesson

Call	Lesson Subject	Lesson Topic	Lesson Questions	Lesson Performance		Review Performance*		Overall Performance*	
				LHL %	HHL %	LHL %	HHL %	LHL %	HHL %
1	PA	PA plan[a, d, g]	3	59.6	79	19.1	10.7	78.7	89.7
2	PA	PA strategies[c, i]	3	74.3	82.3	14.8	12.3	89	94.6
3	Diet	MyPlate	4	55.5	59.5	13.7	14.9	69.1	74.4
4	Diet	Fat consumption	2	84.4	89.2	8.2	6.3	92.6	95.6
5	Diet	Sugar consumption[b]	3	63.7	71	13.5	9.8	77.1	80.8
6	Diet	Calorie tracking[a, g]	2	83.6	94.1	5.5	4.3	89	98.5
7	Lifestyle	Unhealthy cues[b]	3	64.2	71.5	11.8	7.7	75.9	79.2
8	Lifestyle	PA and diet problem solving	2	94.3	97.1	3.8	2.3	98.1	99.4
9	Diet	Healthy eating out[b, g]	3	84	92.9	6.7	4.3	90.7	97.3
10	Lifestyle	Avoid negative thoughts[c, g]	3	66.7	76.3	14.7	15.2	81.3	91.5
11	Lifestyle	Avoiding relapses[a, f, h]	3	81.9	93.9	6.9	2.4	88.9	96.3
12	PA	Maintain PA motivation	2	94.6	98.3	4.3	1.4	98.9	99.7
13	Lifestyle	Social cues	2	71.7	78.7	13	11.8	84.8	90.4
14	Diet	Reducing sodium intake	3	81.2	84.4	12.3	12.3	93.5	96.7
15	Lifestyle	Stress management	3	91.9	91.9	5.2	6.3	97	98.2
16	Lifestyle	Staying motivated[a, f, h]	3	79.5	92.9	10.6	4.4	90.2	97.3
17	Diet	Mindful eating[c]	1	92.9	98.7	4.8	1.3	97.6	100
18	Lifestyle	Stress and time management[c]	1	87.8	96.5	9.8	2.8	97.6	99.3
19	PA	Reducing sedentary behaviors[c, f]	1	92.3	99.2	7.7	0.75	100	100
20	Diet	Calorie reduction	1	92.1	93.7	5.3	5.5	97.4	99.2
21	PA	Muscle strengthening review	1	52.9	68.3	20.6	14.2	73.5	82.5
22	Lifestyle	Behavior change maintenance	1	90	87.3	N/A	N/A	90	89

*Note: Review performance reflects additional proportion that got 100% in subsequent call after failing to get 100% in lesson performance. Overall performance is the sum of the lesson and review performance proportions.

[a]$p<0.001$, Lesson performance [d]$p<0.001$, Review performance [g]$p<0.001$, Overall performance

[b]$p<0.01$, Lesson performance [e]$p<0.01$, Review performance [h]$p<0.01$, Overall performance

[c]$p<0.05$, Lesson performance [f]$p<0.05$, Review performance [i]$p<0.05$, Overall performance

Table 10 Regression analyses evaluating effects of health literacy, overall comprehension and engagement

	Coefficient	**SE**	**t**
Regression Model #1-- Health literacy level and overall comprehension**			
Constant	0.18	0.13	1.41
Choice vs. RCT	-0.009	0.05	-0.18
Health literacy level	0.12	0.06	1.86
Age	0.006	0.002	2.92
$R^2 = 0.024$, $F(3, 422) = 3.65$			
Regression Model #2--Health literacy level and number of IVR calls completed***			
Constant	5.91	2.08	2.84
Choice vs. RCT	0.22	0.76	0.29
Health literacy level	-0.57	1.08	-0.53
Age	0.15	0.03	4.92
$R^2 = 0.06$, $F(3, 422) = 9.16$			
Regression Model #3—Overall comprehension, health literacy levels and number of IVR calls completed***			
Constant	0.35	0.12	2.94
Choice vs. RCT	0.01	0.04	0.40
Health literacy level	0.21	0.06	3.70
Age	-0.02	0.00	-1.30
Total number of IVR calls completed	0.05	0.00	15.9
$R^2 = 0.52$, $F(4, 421) = 65.5$			

**p<0.01, ***p<0.001

Figure 4 Overall comprehension average according to engagement by health literacy levels

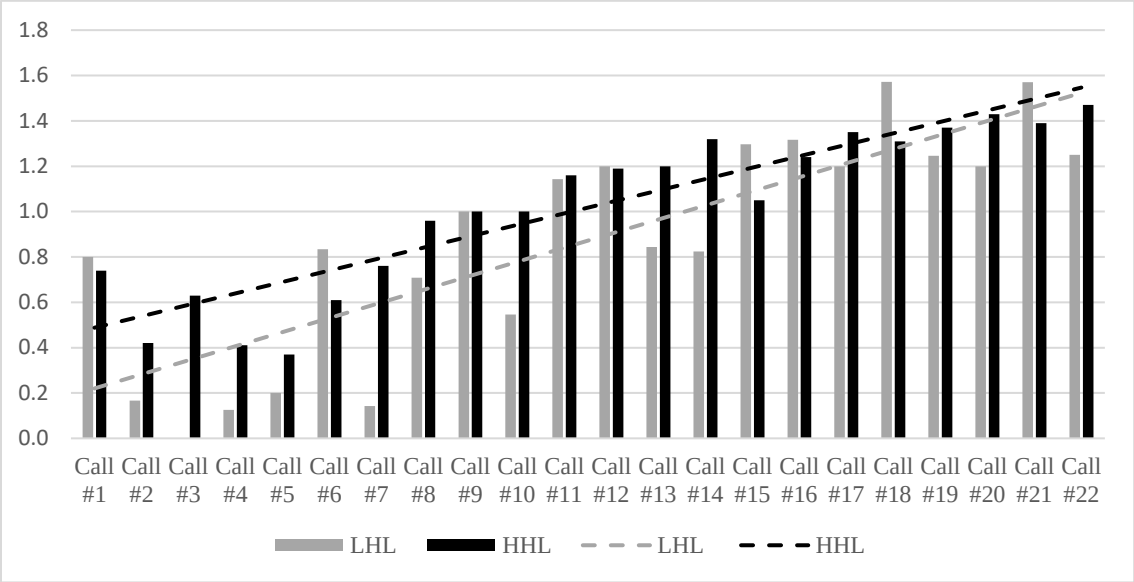


Figure 5 Overall comprehension average according to engagement by modality

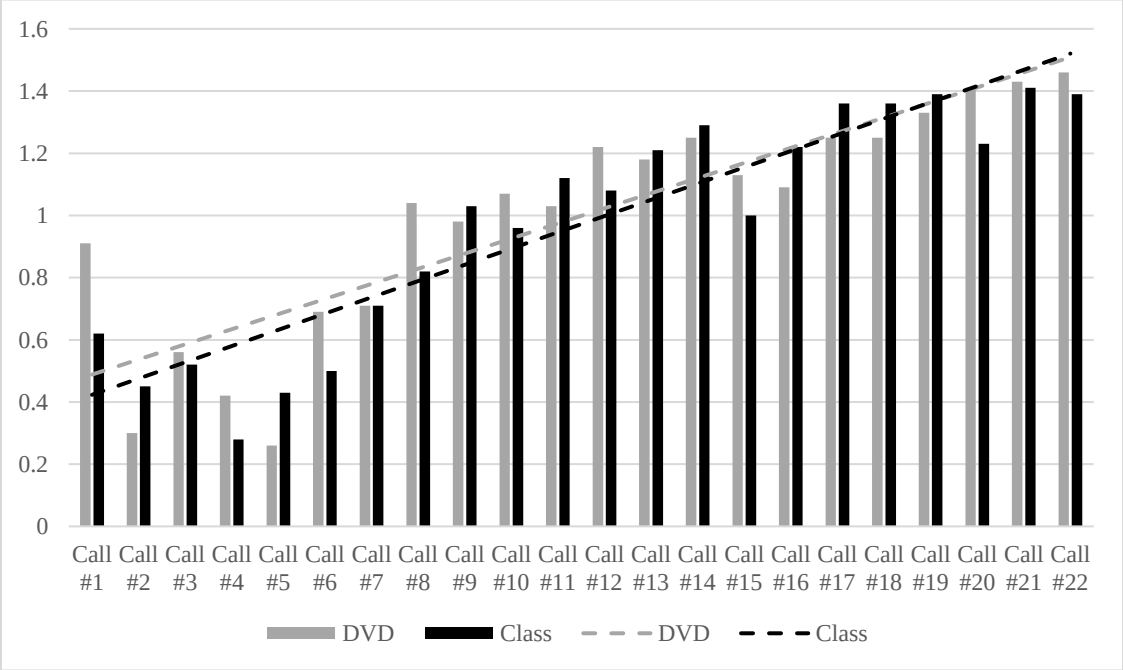
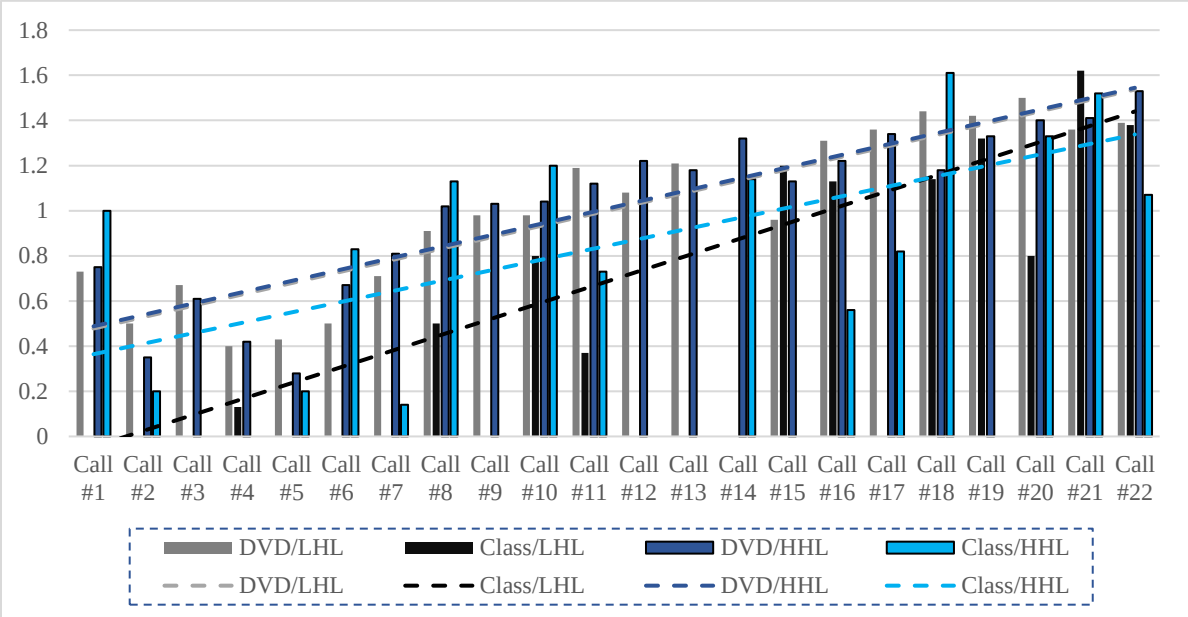


Figure 6 Overall comprehension average according to engagement by modality and health literacy levels



The first model evaluated overall comprehension average in the intervention by health literacy levels (0-39 points score; 2 points=100% correct on lesson performance, 1 point=100% on review performance and 0 points= Less than 100% on both lesson and review performance; Sum divided by number of calls completed). A second model compared health literacy levels against the number of calls completed. The final model evaluated overall comprehension average, health literacy levels and engagement. In all models, the general regression models were $y= \beta_0 + \beta_1 \chi_i + \beta_2 \chi_i^2 + \beta_3 \chi_i^3 + \beta_4 \chi_i^4 + \varepsilon_i$ where i=1,...n and HHL and HOC was coded as 1 and LOC and LHL=0 where i=1, ….n in all models.

Test of hypotheses

H1 predicted overall comprehension rates would improve over the course of the intervention, regardless of modality or health literacy level. H2 predicted those with

higher overall comprehension score average would be more engaged. Figures 2, 3 and 4 show overall comprehension averages according to the call at which the participant quit the intervention by health literacy level, modality, and modality and health literacy levels combined. Table 3 identified three statistically significant models ($p<0.01$) where overall comprehension average was predicted from health literacy levels and engagement to confirm H1, Models #1 and #3, while the latter hypothesis was validated by model #2. All variables added except for age and initial randomization to choice or RCT groups were statistically significant to the model, $p<0.05$.

Discussion

Summary of findings

The primary goal of this article was to evaluate how teach-back and teach-to-goal could influence comprehension rates and engagement among two different health literacy levels in a technology-enhanced diabetes prevention program. After data analysis, several observations struck note.

As thought in the first model of health literacy and overall intervention comprehension, high health literacy participants achieved a better score (LHL-16.8±13.1; HHL-16.9±13.3). A previous study conducted by our research team confirmed that high health literacy folks initially score better comprehension scores (Goessl et al., 2019); however, when looking at overall comprehension rates, being of HHL was irrelevant as the trendlines in Figures 2, 3 and 4 suggest the gap between the health literacy groups disappears, scores improve and the proportion needing review questions with further intervention participation goes down drastically (see Table 9).

Our second analysis looked at health literacy and engagement. In this model, LHL completed a significantly different percentage of calls with 38.7% (n=29) completing all 22 calls vs. HHL at 28.9% ($p<0.001$). For those that disengaged in the post-core intervention (calls #17-21), still, a greater proportion of LHL completed those calls relative to the HHL folks (17.3% vs. 14.6%). These observations could suggest reinforcement of educational material over time may enhance LHL participants willingness to remain an active participant in the intervention. Looking at the changes over the intervention, while LHL did worse early on in the first few lessons lending to this group's early disengagement, we observed that around call #8 the proportions completing this call and after was consistently greater on the LHL side suggesting LHL participants could have felt less overwhelmed with the intervention and more receptive to the lifestyle changes suggested in the health education.

Implications

This study is an extension of our research team's previous work recently that cross-sectionally evaluated information uptake of diabetes prevention program objectives if delivered via viewing a DVD or attending a one-time, two-hour class taught by a registered dietician (Goessl et al., 2019). Assessment was conducted through a one-time, teach-back/teach-to-goal telephone call administered by a trained research assistant and lasted 26.5 ± 9.8 minutes consisting of a minimum of one round of six questions up to a maximum of three rounds. That study found significant differences for overall performance, number of teach-back rounds needed, and number of round 1 questions correct—all in favor of the DVD. The primary conclusion was by having

multiple opportunities to review information through a DVD or receive assessment and reinforcement during the teach-back call can enhance information uptake, regardless of health literacy levels (Goessl et al., 2019).

This study is more so concerned with evaluating how comprehension levels can change longitudinally over the 12-month program. Weight loss programs can be overwhelming and nerve-racking, initially, for any participant emotionally and cognitively due to the amount of information provided. More research is identifying that early success in any weight loss trial may predict future engagement (Brownell, Heckerman, & Westlake, 1979; Fabricatore et al., 2009; Greenberg, Stampfer, Schwarzfuchs, Shai, & DIRECT Group, 2009; Mitchell & Stuart, 1984; Packianathan, Sheikh, Boniface, & Finer, 2005). Providing repetition and reinforcement strategies throughout the intervention may help information overload, and in time, quell the participant's anxiety leading to better overall comprehension performance, especially amongst LHL participants where their confidence levels grasping any amount of information may be lower than someone of HHL (Chew, Bradley, & Boyko, 2004; Wallace, Rogers, Roskos, Holiday, & Weiss, 2006).

Limitations and suggestions for future research

While this was the first longitudinal diabetes prevention study measuring comprehension, it does come with limitations. Due to the design of the parent study, we couldn't evaluate how much individuals would engage and retain within the intervention had the participant received an IVR treatment that didn't include teach-back and teach-to-goal strategies. Furthermore, the effect of teach-back and teach-to-goal

only applied to those that completed the calls, and not those that disengaged from the calls. Regardless of these methods, our results suggested both HHL and LHL benefited from the extra educational reinforcement.

Our comprehension average metric and analysis of high and low overall comprehension had significant outcomes. However, future research should include an analysis of those two groups call-by-call, as well as accounting for the differences due to attrition in the level of intervention received. More specifically, such a metric would be the quotient of total comprehension score and number of calls completed all over the level of engagement (i.e. 22 calls – number of IVR lessons completed).

Health literacy contains many sensory and cognitive elements (i.e.. audio and visual). Lesson messages were only delivered in audio; hence, the breadth and balance of cognitive processes couldn't be ascertained at any point in the intervention. Fulfilling only learning preferences, a dynamic personal trait, could influence a participant's comprehension levels, but other factors such as overall memory function, motivation, anxiety and complexity of the information need to be addressed in other ways like our study employed with teach-back and teach-to-goal (Truluck, Bradley, Janet, 1999; Fleming & Mills, 1992; Kessels, 2003; Kolb, Boyatzis, & Mainemelis, 2002).

As indicated by many health literacy experts, it is possible that health literacy outcomes can be influenced by state-like conditions, instead of trait-like circumstances (Baker, David W., 2006; DeWalt et al., 2011; Karl & McDaniel, 2018; National Academies of Sciences, Engineering, and Medicine, 2015). Therefore, due to the variability in IVR

call times, it is possible participants completed the lesson in an altered state of consciousness, defined as any mental state induced by any number of possible agents that create differences in psychological functioning (Ludwig, 1966). These influences, whether psychological, physiological or pharmacological, could have impacted their lesson or review question performance due to insufficient cognitive processing (Ludwig, 1966). Again, teach-back and teach-to-goal strategies may have helped to reduce the effect of these agents.

Chapter 4: Effects of dose of a technology-enhanced diabetes prevention program on behavior and weight according to health literacy and overall comprehension levels

Background

According to a 2015-2016 evaluation of National Health and Nutrition Examination Survey data, obesity and overweight rates were around 71.6% in the United States making it one of the most prevalent chronic diseases nationwide (Fryar, Carroll, & Ogden, 2012). This condition has been known to contribute to cancer, heart disease, diabetes and many other chronic diseases (Rothman et al., 2005). Beyond obesity being a risk factor for type 2 diabetes, hypertension, genetics, sedentary activity and poor diet have contributed to the poor health status of some individuals in this country (Hu et al., 2001; Hu, Li, Colditz, Willett, & Manson, 2003; Lyssenko et al., 2008; Manson et al., 2004; Mokdad et al., 2003). With prevalence rates of diagnosed and undiagnosed diabetes as high as 30.2% and prediabetes as high as 33.9%, as reported in the 2017 National Diabetes Statistics Report by the Center for Disease Control and Prevention, calls have been made to curb these outstanding numbers (Eckel, Kahn, Robertson, & Rizza, 2006).

In 1999, the University of Pittsburgh created a trial to help reduce the type 2 diabetes risk among many patients throughout America. Published in 2001 as the Diabetes Prevention Program, the trial observed results suggesting that a lifestyle intervention (LI) could have more impactful results relative to a pharmaceutical intervention (PI) (i.e. metformin) (Diabetes Prevention Program Research Group, 2002).

Type 2 diabetes incidence was reduced by 58% for the LI while the PI observed a 31% rate (Diabetes Prevention Program Research Group, 2002). The results led to the dissemination and adaption of this LI program amongst various settings, locations and educational formats (Balagopal, Kamalamma, Patel, & Misra, 2008; Bian et al., 2017; Joiner et al., 2017; Katula et al., 2010).

Around 2003, clinical researchers started asking if the DPP LI could be delivered in alternative educational channels (Tate et al., 2003). This first technology-enhanced DPP trial observed their e-behavioral LI reduced body weight by 4.8% compared to 2.2% in a basic internet delivered format (Tate et al., 2003). Within the next eight years, an average of 4.3% weight loss was report amongst technology-based studies(Ali et al., 2012). DPP LI's since then have made adaptations such as frequency, dosage, education channels, agents and health literacy technique implementation, in an effort to improve weight loss figures (Ackermann, Finch, Brizendine, Zhou, & Marrero, 2008; Almeida et al., 2014; Bian et al., 2017; Goessl et al., 2019; Sepah, Jiang, & Peters, 2014; Sepah et al., 2017).

While much focus has been on dose, frequency and duration of these LI lessons, less has been given to health literacy assessment and modulation. Health literacy is defined as the ability to take basic health information, cognitively process the information and apply it in ways to make appropriate health decisions (Nutbeam, 2000). Health literacy impacts the way patients interact with their health and health care systems (Paasche-Orlow & Wolf, 2007).

Health literacy has been also identified as a possible mediator in any intervention seeking to improve the care status of any patient (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011). As Baron and Kenny (1986) define it, a mediator is on the causal pathway and helps explain the relationship between independent variable on the dependent variable (Baron & Kenny, 1986). Amongst diabetes prevention trials, where the outcome is either Hemoglobin A1c levels or weight loss, generally, health literacy levels may impact the rate of information uptake (Goessl et al., 2019). Regardless of these levels, educational reinforcement is necessary to improve understanding of needed lifestyle behaviors to reduce their risk for type 2 diabetes (Goessl et al., 2019).

Cognitive Load Theory suggests that factors beyond mental load facilitate understanding of educational material such as demand expectations, actual effort expended during performance and perceived adequacy of performance (Plass et al., 2010). Mastery learning theory suggests that individuals need different time schedules to suggest comprehension of information (Block & Airasian, 1971). Any weight loss or diabetes prevention program can be overwhelming to any patient or participant initially, which may limit their potential to increase their germanic load capacity, defined as the working ability to permanently store data and make relationships upon information given (Plass et al., 2010) (see Figure 2). Therefore, intervention adjustments must be appropriated to account for these participant issues.

Through teach-back methods, educational reinforcement is made by repeating the correct answer within a statement, regardless of outcome. Teach-to-goal provides that schedule by ensuring individuals achieve full comprehension of questions before

moving onto the next question (Baker et al., 2011). Both health literacy techniques ensure initial reception through conception. After it is understood, an active decision making process, consciously and unconsciously, takes place leading to implementation, then monitoring with adjustments made as needed (Schoenfeld, 2010). Teach-back and teach-to-goal facilitates and aligns with MLT and CLT, to ensure that patients have the resources to enhance working memory, in order to promote greater germanic load capacity, defined as the space dedicated to schema acquisition and automation, to ensure their total cognitive load is capable of comprehension (Block & Airasian, 1971; Plass et al., 2010).

Within DPP LI's, much of the education centers around physical activity, diet, lifestyle modification and stress reduction. Each lesson provides different content that influences type 2 diabetes risk. To our knowledge in any technology-mediated DPP LI trials, lessons have not been reinforced with comprehension questions or utilized teach-back and teach-to-goal techniques (Ali et al., 2012; Bian et al., 2017; Joiner et al., 2017). While health literacy involves many components, addressing it through the techniques mentioned may improve working memory and germanic cognitive load through reinforcement.

Within the many dynamic elements of health literacy (i.e. functional, critical and interactive) exists a varying degree of control to make personal health care decisions (van der Heide, Uiters, Boshuizen, & Rademakers, 2015). This degree of control, consistent with Social Cognitive Theory, can build stronger efficacy beliefs, which in turn, can lead to greater willingness to undertake the activity(Bandura, 1997). To build

strength in efficacy beliefs, routinization is necessary for behaviors to become second nature and can lend to mastery motivation, a product of attentiveness and the willingness to strive for goal-directed behaviors (Bandura, 1997).

According to reviews of diabetes prevention programs, there lacks a consistent effort to reinforce educational information to build mastery motivation (Ali et al., 2012; Bian et al., 2017; Joiner et al., 2017). In turn, efforts to encourage patient engagement may be enhanced leading stronger behavioral uptake and outcomes (i.e. increased aerobic physical activity, muscle strengthening, fruit and vegetable consumption and weight loss) (Baker, Simpson, Lloyd, Bauman, & Singh, 2011). As a result, the overall aim of this study is to evaluate the dose of intervention (i.e. number of IVR calls completed) received and the degree of changes in behavior and weight as influenced by participant health literacy status, overall comprehension levels and modality. Our team hypothesizes that through teach-back and teach-to-goal strategies, participants will engage in more of the diabetes prevention intervention, which in turn, will improve overall comprehension, physical activity levels and diet, and see a greater degree of weight loss (see Figure 7).

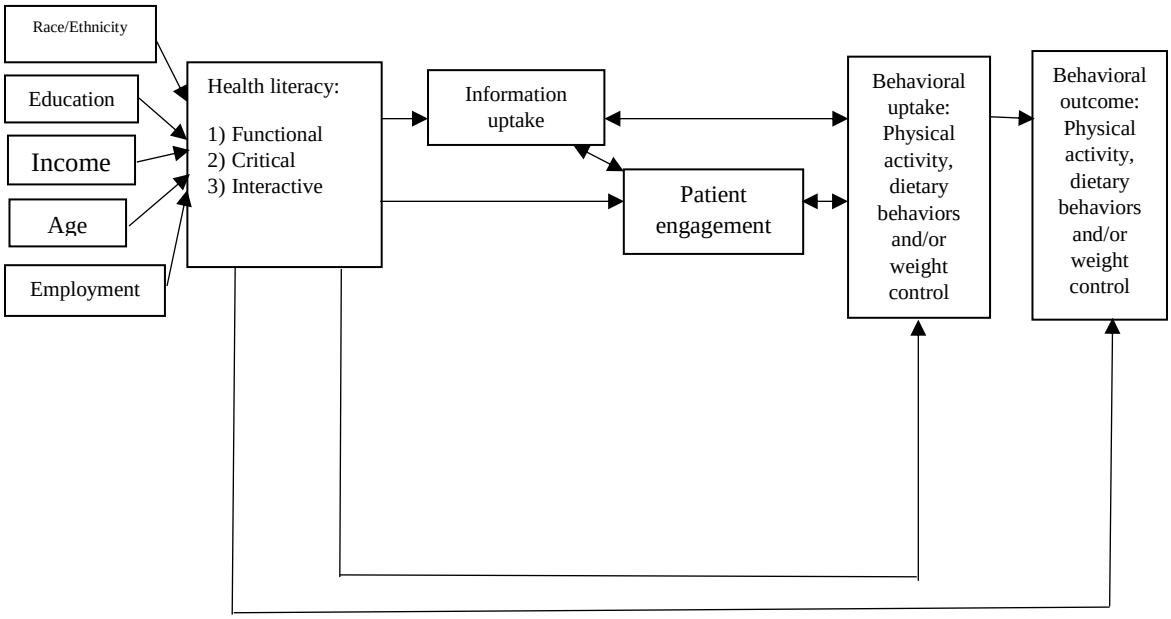


Figure 7 Proposed health literacy to health outcomes model with regards to diabetes prevention

Methods

Participants

DiaBEAT-it! was a hybrid-preferential randomized control technology-enhanced diabetes prevention trial conducted through twelve primary care clinics affiliated with Carilion Clinic located in the greater Roanoke, Virginia region. Patients with a body mass index score of 25 or greater, at risk for type 2 diabetes according to ADA standards and approved for this study by their primary care physicians were referred for recruitment(Almeida et al., 2014). During telephone screening by a research assistant, patients were assessed using the Physical Activity Readiness Questionnaire (PAR-Q) (Thomas, Reading, & Shephard, 1992). Those agreeing to participate were scheduled for two baseline appointments—one to conduct anthropometric measures, complete a dual X-ray absorptiometry (DXA) scan, complete a battery of survey instruments and to

assign or choose their treatment group (i.e. standard care (RCT group only), class+IVR or DVD+IVR) (Almeida et al., 2014).

Once a participant was assigned or chose one of the IVR treatments, a teach-back/teach-to-goal call was scheduled after watching the 60-minute DVD or attending the one-time, two-hour diabetes prevention class taught by a registered dietician. This call was conducted by a trained research assistant that assessed the patient's understanding of the core objectives the DPP delivered through those two modalities in a series of 6 questions. After each question, regardless of right or wrong, the correct answer was reinforced through teach-back methods. Any correct question was not further assessed; however, any incorrect question was repeated in the next round of questions, up to a total of 3 rounds. In between rounds, participants reviewed their personalized action plan that included weekly behavioral and weight loss goals. At the end of the call, participants picked the nine best times during the week to receive their possible 22 IVR calls (Almeida et al., 2014; Goessl et al., 2019).

The 22 IVR calls, contracted through Intervision Media, Inc. of Eugene, OR, consisted of each original DPP lesson, evaluation of their personalized action plan goals regarding quantity of aerobic physical activity, muscle strengthening, and daily intake of fruits and vegetables, reporting of the participant's current body weight, identification of any barriers limiting their plan and strategies to overcome, and assessment of comprehension of each lesson. To apply teach-to-goal techniques, any incorrect questions in any IVR call were reviewed in the subsequent call with the exception of the final call, Call #22. Participants could engage in all 22 calls or choose to

disengage. In the case of the latter, a research assistant followed up with the participant to confirm their desire to resume calls or quit the calls all together. At months 6, 12 and 18, participants were asked to return for follow-up assessments visits following the same procedures as previously mentioned (Almeida et al., 2014; Goessl et al., 2019).

Engagement and comprehension metrics

Since this study is one of the first of its kind to evaluate the effects of teach-back and teach-to-goal upon health literacy levels in a diabetes prevention trial, our research team took a multi-faceted approach. The CDC DPP dosage classifications were updated as recently as March of 2018, and identified groups of engagement as 1-3, 4-16, 17-21 and all 22 lessons completed (Centers for Disease Control and Prevention, 2018). Our analyses operationalized health literacy in several ways, as outlined in Table 11. Participants scoring 4 or more right out of six questions on the validated Newest Vital Sign were termed “high health literacy,” while those scoring less were “low health literacy” participants (Weiss et al., 2005).

Table 11 Engagement, comprehension evaluation methods and rationale

Number	Method	Rationale
1	According to CDC DPP dosage classifications	To evaluate dose-response outcomes according to CDC DPP recognition guidelines
2	By LHL and HHL across the intervention	To evaluate differences across health literacy groups to understand information uptake
3	Level of engagement according to modality and health literacy level	To evaluate differences between the modalities and their effect on the uptake of the program's objectives and how that impacted intervention performance
4	Proportions of immediate comprehension, review comprehension and no comprehension	To evaluate the differences amongst groups and the point where material was reinforced
5	Overall Comprehension	To evaluate longitudinal changes of both immediate and review comprehension

Table 12 Participant engagement and performance assessment tables

	Frequency of Call Completion		Lesson Performance (Average % Correct)		Review Performance (**)		Total Proportion getting question correct on lesson or review assessment	
	LHL	HHL	LHL	HHL	LHL	HHL	LHL	HHL
	f (%)	f (%)	%	%	%	%	%	%
Call #1	75 (98.7)	325 (99.7)	59.6	79	19.1	10.7	78.7	89.7
Call #2	69 (92.0)	330 (94.3)	74.3	82.3	14.8	12.3	89	94.6
Call #3	63 (84.0)	311 (88.9)	55.5	59.5	13.7	14.9	69.1	74.4
Call #4	61 (81.3)	292 (83.4)	84.4	89.2	8.2	6.3	92.6	95.6
Call #5	57 (76.0)	278 (79.4)	63.7	71	13.5	9.8	77.1	80.8
Call #6	55 (73.3)	266 (76.0)	83.6	94.1	5.5	4.3	89	98.5
Call #7	54 (72.0)	254 (72.6)	64.2	71.5	11.8	7.7	75.9	79.2
Call #8	53 (70.7)	242 (69.1)	94.3	97.1	3.8	2.3	98.1	99.4
Call #9	50 (66.7)	229 (65.4)	84	92.9	6.7	4.3	90.7	97.3
Call #10	50 (66.7)	208 (59.4)	66.7	76.3	14.7	15.2	81.3	91.5
Call #11	48 (64.0)	196 (56.0)	81.9	93.9	6.9	2.4	88.9	96.3
Call #12	46 (61.3)	180 (51.4)	94.6	98.3	4.3	1.4	98.9	99.7
Call #13	46 (61.3)	176 (50.3)	71.7	78.7	13	11.8	84.8	90.4
Call #14	46 (61.3)	170 (48.6)	81.2	84.4	12.3	12.3	93.5	96.7
Call #15	45 (60.0)	168 (48.0)	91.9	91.9	5.2	6.3	97	98.2
Call #16	44 (58.7)	158 (45.1)	79.5	92.9	10.6	4.4	90.2	97.3
Call #17	42 (56.0)	152 (43.4)	92.9	98.7	4.8	1.3	97.6	100
Call #18	41 (54.7)	140 (40.0)	87.8	96.5	9.8	2.8	97.6	99.3
Call #19	39 (52.0)	130 (37.1)	92.3	99.2	7.7	0.75	100	100
Call #20	38 (50.7)	125 (35.7)	92.1	93.7	5.3	5.5	97.4	99.2
Call #21	34 (45.3)	112 (32.0)	52.9	68.3	20.6	14.2	73.5	82.5
Call #22	29 (38.7)	97 (27.7)	90	87.3	N/A	N/A	90	89

To deem participants of high or low overall comprehension levels, two and one point(s) were awarded for each correct IVR lesson and review answer, respectively. If incorrect in all cases, no points were awarded. The sum of both the lesson and review answer points was calculated and divided by the number of IVR calls completed to derivate an average. Those around 1.01-2.0 were identified as "high overall comprehension" and anything less was "low overall comprehension." By dichotomizing this metric, it identifies participants that benefitted from either the lesson or the teach-back methods to reinforce material.

Statistical analyses

Descriptive and ANOVA calculations were calculated by modality, health literacy level, high and low overall comprehension for those completing baseline assessments. To evaluate the effects that the dose of intervention had upon changes in behavior and weight, multiple regression modeling procedures along with White's Standard Error adjustment procedures to eliminate heteroskedascity was employed. Age, health literacy level and initial randomization to either choice or RCT groups was controlled for in all analyses. All calculations were performed using IBM SPSS Statistics Version 25.0 (IBM Corp., 2017).

The following models were assessed: 1-3) number of IVR calls vs. overall comprehension level and each behavior (i.e. aerobic PA, MS, FV servings); 4) number of IVR calls vs. overall comprehension level vs. IVR-reported weight loss. Building upon our previous research suggesting overall comprehension predicted the degree of

engagement, our final models evaluated engagement, early and overall comprehension, all the 3 behaviors and weight loss reported through the IVR mechanisms. The general format of the multivariate regression equations was $y= \beta_0 + \beta_1 \chi_i + \beta_2 \chi_i^2 + \beta_3 \chi_i^3 + \varepsilon_i$ where i=1,...n and HOC was coded as 1 and LOC=0.

Results

Four hundred forty two out of 481 participants completed the teach-back/teach-to-goal call with a trained research assistant making them eligible to complete IVR call #1. Of the 425 participants that finished that call, only 88.2% (n=374; LHL-63, 14.8%; HHL-311, 73.1%) completed IVR Call #3 that could be deemed as having completed the initial intervention as defined by CDC DPP Recognition Guidelines. Looking at overall comprehension, 91.5% (n=389) were at a high level with an average score of 16.9±13.1, age of 52.5 ±12.1 (LHL- 56.8±12.0: HHL-51.6±11.9), 16.5% (n=70) were African-American, 1.4% Hispanic, 82.4% (n=350) considered high health literacy, 30.6% (n=130) completed all 22 IVR calls. Of the 39 participants that didn't complete the teach-back call and IVR call #1, the average age was 43.3±10.8, 30.8% (n=12) were African-American and 15.4% (n=6) were low health literacy. The average number of IVR calls completed was 13.3±7.9 with significant differences at the $p<0.001$ level only seen amongst the LOC and HOC groups (LHL-14.5±8.4; HHL-13.1±7.8; DVD-13.2±8.0; Class-13.4±7.8; LOC-6.8±5.6; HOC-18.0±5.6).

Looking at behaviors, the average reported amount of aerobic physical activity in the IVR calls was 17.9±29.9 (LOC-25.8±34.3; HOC-12.0±24.7), muscle strengthening was 6.3± 15.5 (LOC-9.7±16.7; HOC-3.9±14.3) while fruit and vegetable intake was 3.3±1.5

(LOC-2.8±1.5; HOC-3.5±1.4). No statistical differences were observed for all 3 behaviors when comparing the DVD versus Class treatments; however, significant differences were observed between LHL versus HHL for physical activity and muscle strengthening ($p<0.01$; PA: LHL-26.9±54.3 vs. HHL-15.9±21.0; MS: LHL-9.6±25.3 vs. HHL-5.6±12.4) and for all three behaviors when looking HOC versus LOC levels, $p<0.001$.

Considering weight loss from the reported weight at IVR Call #1, the average weight loss was 9.4± 12.9 lbs. (LOC-5.5±9.1; HOC-12.2±14.5; DVD-9.6±12.5; Class-9.2±13.4; LHL-9.2±15.5 ; HHL-9.4±12.3) reflecting an average of 4.0±5.3% weight loss (LOC-2.4±3.8%; HOC-5.2±5.9% ;DVD-4.0±5.2%; Class-4.0±5.5%; LHL-4.0±6.4%; HHL-4.0±5.1%). Differences, at the $p<0.001$ level, were only observed in those metrics among high and low overall comprehension groups. Of the total sample, 42.8% (n=182) achieved any weight loss, 13.2% (n=56) between 0.01-2.99%, 7.8% (n=33) 3-4.99%, 6.4% (n=27) 5-6.99% and 15.5% (n=66) 7 % or greater. Those that had completed 0, 1-3, 4-16, 17-22 calls lost on average 1.2± 19.3 lbs. or 0.5 ± 8.3%, 0.8 ± 9.2 lbs. or 0.3 ± 4.3%, 4.4 ± 14.7 lbs. or 1.9 ± 6.8%, 6.3 ± 13.2 lbs. or 2.6 ± 5.7%, 10.9 ± 18.0 lbs. or 4.7 ± 7.4%, respectively. When engagement versus overall comprehension levels are evaluated, a similar trend is observed of progressive, improved weight loss with high overall comprehension participants showing greater percentages with the exception of those completing all 22 calls (1-3 Lessons: LOC-0.2±4.4%, HOC-1.0±4.3%; 4-16 Lessons: LOC-1.6±7.2%, HOC-2.3±6.4%; 17-21 Lessons: LOC-1.8±3.2%, HOC-2.7±5.9%; All 22 Lessons: LOC-7.2±7.1%, HOC-4.5±7.4%).

When evaluating engagement categories by comprehension levels, differences were observed for the magnitude of IVR-reported weight loss (in lbs.) and the percent of weight loss achieved during the IVR calls, $p<0.001$; $F(7, 423)=9.65$ and $p<0.001$; $F(7,423)=9.65$. These differences were also noted for aerobic physical activity [$F(7, 417)=16.7$, $p=0.000$], muscle strengthening [$F(7, 417)=10.3$, $p=0.000$] and diet [$F(7, 417)=16.7$, $p=0.000$].

Our first regression model evaluated how overall comprehension and engagement levels predicted each of the three behavioral outcomes, as well as magnitude of weight change and percentage of weight change. Statistical significance was observed in all 5 models (Table 13) where engagement had a significant impact, $p<0.001$, on every behavioral and primary outcome.

No differences were observed between the DVD and Class across all calls for aerobic physical activity, muscle strengthening, fruit and vegetable intake and weight loss. When both modalities were analyzed by overall comprehension levels, significance was seen for all behaviors, magnitude and percent weight loss, as well as, the number of IVR calls completed (See Tables 15-18).

Table 13 Engagement vs. primary and secondary outcomes against comprehension levels

	Coefficient	SE	t
Regression Model #1--Engagement vs. Mean IVR-reported aerobic physical activity and Overall comprehension levels***			
Constant	57.3	15.4	3.7
Choice vs. RCT	4.8	2.8	1.7
Age	-0.2	0.1	-1.0
Comprehension level	9.4	7.2	1.3
Health literacy level	-15.3	7.3	-2.1
Engagement	-1.9	0.48	-4.0
$R^2 = 0.22$, $F(5, 419) = 12.3$			
Regression Model #2-- Engagement vs. Mean IVR-reported muscle strengthening and Overall comprehension levels***			
Constant	25.5	8.3	3.1
Choice vs. RCT	1.7	1.5	1.1
Age	-0.1	0.1	-1.6
Comprehension level	3.4	4.4	0.8
Health literacy level	-6.0	3.8	-1.6
Engagement	-0.8	0.3	-2.7
$R^2 = 0.14$, $F(5, 419) = 7.91$			
Regression Model #3-- Engagement vs. Mean IVR-reported daily fruit and vegetable consumption and Overall comprehension levels***			
Constant	0.3	0.4	0.8
Choice vs. RCT	0.1	0.1	0.7
Age	0.03	0.01	4.7
Comprehension level	-0.1	0.2	-0.4
Health literacy level	0.6	0.2	3.6
Engagement	0.1	0.01	5.5
$R^2 = 0.22$, $F(5, 419) = 20.3$			
Regression Model #4— Engagement vs. Mean IVR-reported weight loss (in lbs.) and Overall comprehension levels***			
Constant	3.5	3.6	1.0
Choice vs. RCT	-0.1	1.2	-0.1
Age	-0.1	0.1	-1.4
Comprehension level	0.1	1.5	0.1
Health literacy level	-1.5	1.8	-0.8
Engagement	-0.6	0.1	-5.5
$R^2 = 0.13$, $F(5, 419) = 14.9$			
Regression Model #5—Engagement vs. Mean IVR-reported percent weight loss and Overall comprehension levels*****			
Constant	2.1	1.4	1.4
Choice vs. RCT	0.2	0.5	0.5
Age	-0.04	0.02	-2.1
Comprehension level	0.2	0.6	0.3
Health literacy level	-0.6	0.8	-0.8
Engagement	-0.2	0.04	-5.9
$R^2 = 0.15$, $F(5, 418) = 17.4$			

*p<0.05, **p<0.01, ***p<0.001

Discussion

Consistent with other types of implemented interventions, programs that provide techniques and strategies to enhance knowledge attainment and information uptake are necessary, especially in the early phases of diabetes prevention programs (Negarandeh, Mahmoodi, Noktehdan, Heshmat, & Shakibazadeh, 2013; Strecher et al., 2008; Williamson et al., 2010). This may be due to the fact that many participants have high levels of anxiety, fear and overwhelming thoughts regarding their health status and the need for them to reduce their type 2 diabetes risk (Atlantis, Vogelzangs, Cashman, & Penninx, 2012; Kahl et al., 2015; Taylor, Keim, Sparrer, Van Delinder, & Parker, 2004). Providing techniques that enhance information uptake, regardless of health literacy levels, may reduce cognitive load by enhancing working memory levels (Baker, D.W., et al., 2011; Baker, M.K., et al., 2011; Kim, Love, Quistberg, & Shea, 2004).

Similar to our observations, recent studies evaluating executive functioning, defined as the set of mental processes that are needed to promote concentration to avoid instinctive behaviors that wouldn't be recommended, have seen these effects and their role on behavior uptake and intervention engagement (Burgess & Simons, 2005; Butryn et al., 2019; Espy et al., 2004; Miller & Cohen, 2001). The Butyrn et. al. study (2019) was able to suggest that better executive processing conducted in the prefrontal cortex of the brain can predict the likelihood of greater objectively-evaluated aerobic physical activity that could enhance weight loss outcomes (Butryn et al., 2019). This remains consistent with a 2004 *Science* review that stated that the medial frontal cortex evaluates performance monitoring, while the lateral and orbitofrontal divisions of the prefrontal

cortex makes the adjustments to improve the performance (Ridderinkhof, Van Den Wildenberg, Wery, Segalowitz, & Carter, 2004). Teach-back and teach-to-goal may play upon those two regions of the brain to enhance capacity of completing the behavior by reinforcing the correct information.

Interestingly, these processing tasks may improve over time which coincides with what our call-by-call reported behavioral and weight loss data showed with the exception of fruit and vegetable intake where LHL participants have been observed to struggle obtaining high quantities of the healthier food option, also seen in previous research conducted by several members of our research team (Zoellner et al., 2011). Throughout the intervention, LHL participants had greater levels of aerobic physical activity and muscle strengthening, as well as, LOC participants over their counterparts—an unexpected finding. However, HOC participants still lost a significantly greater amount of weight.

The gap in overall question performance reduced over time as indicated in chapter 2 of this dissertation between LHL and HHL participants. Those LHL participants reaching call #12 and later had greater reported weight loss percentages, even though the averages in magnitude and percent weight loss between the LHL and HHL groups was nearly equal. Even in the light of answering IVR review questions incorrect, as in the case of LOC, or being of LHL, it is possible that those participants retained the reinforced information through the teach-back mechanism to encourage those folks to greater uptake in aerobic physical activity and muscle strengthening.

Conclusions

Diabetes prevention programs that facilitate opportunities for greater educational reinforcement, especially early in the intervention, may encourage greater long-term engagement by reducing cognitive load placed upon the individual through teach-back and teach-to-goal health literacy techniques (see Figure 8 below).

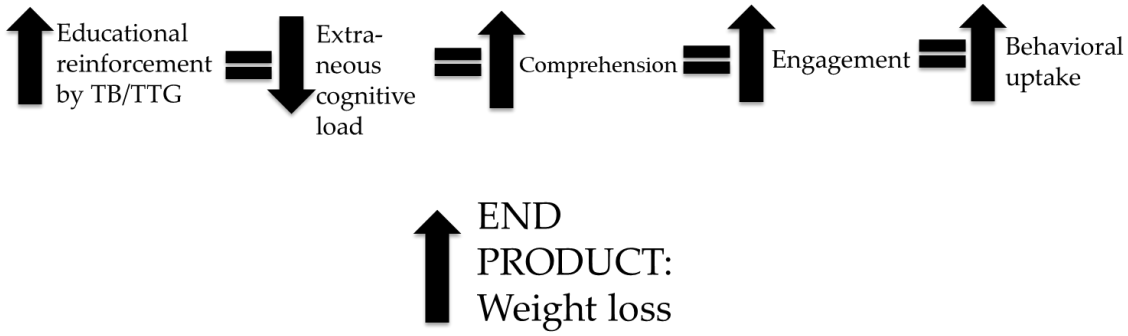


Figure 8 Causal pathway of teach-back/teach-to-goal to behavioral uptake and weight loss

Through repetition of information, executive processing in the frontal cortex is strengthened due to greater intrinsic cognitive load and working memory capacity lending to shorter executive processing time. More resources can be dedicated towards internalizing all schema related to diabetes prevention, and storage of this information can fuel greater personal control of the behaviors. In time, this can lend to greater self-efficacy of the behavior, ultimately lending to greater behavioral uptake. While a plateau effect may occur in weight loss after a certain amount of time, maintenance of these behaviors beyond initial levels pre-intervention should encourage weight loss and/or control (Butryn et al., 2019).

Our call-by call data suggested this trend mentioned above starting around calls #8 or 9. While our teach-back and teach-to-goal methods were only provided to those

completing the calls and not those that disengaged, we believe lesson and review question assessment became more conducive suggesting more comfort with their status of their health through greater self-awareness, improved knowledge of lifestyle habits or their willingness to learn and retain information about habits necessary to reduce diabetes risk. This sort of cognitive success, if applied amongst a specific population experiencing a certain health condition, especially those at risk for type 2 diabetes, can only enhance engagement numbers, like ours did which may improve the collective effectiveness of the intervention. Future studies should look to incorporate and evaluate educational reinforcement mechanisms to improve the likelihood of engagement of all behaviors lending to weight loss, regardless of health literacy levels, and account for the effects of attrition, which was a limitation of our study.

Table 14 Secondary outcomes according to CDC DPP engagement categories by overall comprehension levels

	Low Comprehension[b,c]								High Comprehension[d]							
		DVD[e, f]			Class[e, f]		LHL[h]	HHL[h]		DVD[e, g]			Class[e, g]		LHL[h]	HHL[h]
	Overall	LHL[i, j, k]	HHL[i, j, k]	Overall	LHL[i, j, k]	HHL[i, j, k]			Overall	LHL[i, l]	HHL[i, l]	Overall	LHL[i, l]	HHL[i, l]		
Patient engagement category (PEC)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)
Completed 1-3 Calls[a]	n=34	n=8	n=26	n=27	n=4	n=23	n=12	n=49	n=5	n=2	n=3	n=5	n=0	n=5	n=2	n=8
Aerobic physical activity	49.3 (56.3)	82.7 (80.0)	39.0 (43.8)	42.2 (42.7)	58.5 (66.4)	39.3 (38.7)	74.6 (73.6)	39.2 (41.0)	120.0 (141.9)	185.0 (247.6)	76.7 (51.3)	18.7 (11.2)	--	18.7 (11.2)	185.0 (247.0)	40.4 (41.5)
Muscle strengthening	18.9 (24.0)	19.8 (18.9)	18.6 (25.7)	13.1 (16.2)	17.5 (14.9)	12.3 (16.6)	19.0 (17.0)	15.7 (21.9)	56.0 (91.3)	105.0 (148.5)	23.3 (40.4)	5.0 (7.1)	--	5.0 (7.1)	105.0 (148.5)	11.9 (24.2)
Fruit and vegetable intake	2.6 (1.4)	2.2 (1.5)	2.7 (1.4)	2.1 (1.5)	2.1 (2.)	2.1 (1.5)	2.2 (1.6)	2.4 (1.5)	2.3 (2.8)	0.6 (0.3)	3.4 (3.2)	1.9 (0.9)	--	1.9 (0.9)	0.6 (0.3)	2.4 (2.0)
Completed 4-16 Calls[a]	n=50	n=6	n=44	n=51	n=8	n=43	n=14	n=87	n=30	n=3	n=27	n=28	n=2	n=26	n=5	n=53
Aerobic physical activity	16.3 (11.5)	20.2 (13.2)	15.7 (11.3)	17.5 (14.3)	23.2 (20.7)	16.4 (12.8)	21.9 (17.3)	16.1 (12.0)	12.6 (7.9)	16.2 (9.6)	12.2 (7.8)	12.2 (8.0)	14.3 (9.3)	12.1 (8.1)	15.4 (8.3)	12.1 (7.8)
Muscle strengthening	8.1 (18.7)	10.0 (5.6)	7.9 (19.8)	5.5 (6.4)	9.8 (9.1)	4.8 (5.6)	9.9 (7.5)	6.3 (14.6)	4.0 (3.4)	2.4 (1.4)	4.2 (3.5)	2.5 (2.1)	1.2 (0.8)	2.6 (2.1)	1.9 (1.3)	3.4 (3.0)
Fruit and vegetable intake	3.1 (1.6)	2.5 (1.9)	3.1 (1.5)	2.9 (1.2)	2.6 (1.3)	3.0 (1.2)	2.6 (1.5)	3.0 (1.4)	3.2 (1.2)	3.4 (1.8)	3.2 (1.1)	3.2 (1.3)	2.9 (1.4)	3.2 (1.4)	3.2 (1.4)	3.2 (1.2)
Completed 17-21 Calls[a]	n=4	n=1	n=3	n=2	n=2	n=0	n=3	n=3	n=28	n=5	n=23	n=29	n=5	n=24	n=10	n=48
Aerobic physical activity	7.7 (5.7)	3.6	9.0 (6.1)	7.4 (6.0)	7.4 (6.0)	--	6.1 (4.8)	9.0 (6.1)	7.6 (5.6)	9.4 (4.2)	7.2 (5.8)	8.0 (5.6)	7.4 (5.4)	8.2 (5.7)	8.4 (4.7)	7.5 (5.8)
Muscle strengthening	2.3 (0.8)	2.2	2.3 (0.9)	3.3 (2.4)	3.3 (2.4)	--	3.0 (1.8)	2.3 (0.9)	2.2 (2.6)	2.9 (1.7)	2.0 (2.8)	3.1 (3.7)	1.5 (0.9)	3.4 (4.0)	2.2 (1.5)	2.7 (3.4)
Fruit and vegetable intake	3.2 (1.3)	3.1	3.2 (1.6)	3.4 (0.8)	3.4 (0.8)	--	3.3 (0.6)	3.2 (1.6)	3.7 (1.1)	3.1 (1.2)	3.8 (1.1)	3.5 (1.3)	2.6 (1.4)	3.7 (1.2)	2.8 (1.3)	3.7 (1.3)
Completed all 22 calls[a]	n=6	n=6	n=0	n=4	n=2	n=2	n=8	n=2	n=60	n=6	n=54	n=60	n=15	n=45	n=21	n=99
Aerobic physical activity	6.9 (2.7)	6.9 (2.7)	--	5.2 (8.4)	6.7 (3.5)	3.7 (2.7)	6.8 (2.7)	3.7 (3.7)	9.0 (5.2)	12.4 (6.7)	8.6 (4.9)	9.4 (4.8)	9.3 (3.3)	9.5 (5.3)	10.2 (4.6)	9.0 (5.1)
Muscle strengthening	3.5 (2.5)	3.5 (2.5)	--	4.3 (3.2)	5.3 (3.6)	3.9 (3.6)	3.9 (2.7)	3.2 (3.6)	2.5 (1.9)	4.9 (3.7)	2.2 (1.4)	2.7 (1.9)	2.9 (1.3)	2.6 (2.1)	3.5 (2.3)	2.4 (1.8)
Fruit and vegetable intake	3.4 (1.7)	3.4 (1.7)	--	3.8 (1.6)	2.5 (1.0)	5.0 (0.4)	3.2 (1.6)	5.0 (0.4)	4.2 (1.5)	3.6 (1.1)	4.2 (1.5)	3.9 (1.4)	3.8 (1.4)	3.9 (1.4)	3.8 (1.3)	4.1 (1.5)

**Note: Physical activity and muscle strengthening represents average minutes/week. Fruit and vegetable intake were average daily servings.

[a]p<0.001, PEC, All 3 behaviors; [b]p<0.01, PEC/LOC, PA and MS; [c]p<0.05, PEC/LOC, F/V; [d]p<0.001, PEC/HOC, All 3 behaviors; [e]p<0.001, CL/Modality, All 3 behaviors; [f]p<0.05, LOC/Modality, All 3 behaviors; ; [g]p<0.001, HOC/Modality, All 3 behaviors; [i]p<0.001, CL/Modality/PEC/HL , All 3 behaviors; ; [j]p<0.001, LOC/Modality/HL/PEC, PA;[k]p<0.05, LOC/Modality/HL/PEC, MS/FV;[l]p<0.05, HOC/Modality/HL/PEC,All 3 behaviors

Table 15 Weight and percent change (in lbs.) by call where participant disengaged

	LOC (N=179)[a]												HOC (n=246)[a]											
	DVD (n= 95)[b]						Class (n= 84)[b]						DVD (n=124)[b]						Class (n= 122)[b]					
		LHL (n= 21)[c]			HHL (n= 74)[c]			LHL (n= 16)[c]			HHL (n= 68)[c]			LHL (n= 16)[c]			HHL (n= 108)[c]			LHL (n= 22)[c]			HHL (n= 100)[c]	
Call #	n	μ (SD) (in lbs.)	% (SD)	n	μ (SD) (in lbs.)	% (SD)	n	μ (SD) (in lbs.)	% (SD)	n	μ (SD) (in lbs.)	% (SD)	n	μ (SD) (in lbs.)	% (SD)	n	μ (SD) (in lbs.)	% (SD)	n	μ (SD) (in lbs.)	% (SD)	n	μ (SD) (in lbs.)	% (SD)
Call			0.8			-0.7						-1.4			-0.8		-0.3	‘-0.2						-1.4
#1	2	-1.6 (16.4)	(7.3)	5	-1.7 (2.2)	(1.0)	1	-7.2	-3.7	8	-2.6 (3.0)	(1.6)	2	-2.4 (4.8)	(1.7)	3	(1.8)	(0.9)	--	--	--	4	-3.0 (0.2)	(0.1)
Call			-2.0			-2.8						-1.1	-											
#2	5	-4.8 (4.1)	(1.4)	10	-7.9 (9.0)	(2.8)	1	-0.4	-0.2	9	-3.0 (6.0)	(2.4)	-	--	--	--	--	--	--	--	--	--	--	--
Call						-1.5						-1.7	-											
#3	1	-0.2	-0.1	12	-3.7 (5.3)	(2.2)	2	5.7	2.3	6	-3.7 (2.6)	(1.3)	-	--	--	--	--	--	--	--	--	1	-6.8	-3.5
Call	-				-6.6	-2.7			-1.4			-2.7	-											
#4	-	--	--	9	(11.2)	(4.7)	4	-2.5 (1.0)	(0.6)	5	-6.3 (7.7)	(3.2)	-	--	--	--	--	--	--	--	--	--	--	--
Call			-1.7			-3.2	-				-10.3	-4.5	-											
#5	2	-3.4 (2.5)	(1.3)	5	-7.3 (5.2)	(1.8)	-	--	--	7	(12.3)	(5.5)	-	--	--	--	--	--	--	--	--	--	--	--
Call						-3.2	-					-1.9	-											
#6	1	-5.0	-2.1	8	-6.8 (5.7)	(2.8)	-	--	--	4	-3.7 (8.1)	(3.3)	-	--	--	--	--	--	--	--	--	--	--	--
Call						-1.2	-					-1.2	-											
#7	1	-0.6	-0.3	5	-2.9 (6.5)	(2.6)	-	--	--	6	-2.4 (9.8)	(4.7)	-	--	--	1	-0.2	-0.1	--	--	--	--	--	--
Call	-				-12.4	-5.5			-0.1			1.3						3.3						-1.4
#8	-	--	--	4	(7.1)	(3.1)	2	-0.5 (6.1)	(3.1)	5	2.1 (4.3)	(2.8)	1	0.2	0.1	2	5.4 (1.1)	(1.0)	--	--	--	2	-3.8 (2.5)	(0.7)
Call	-					-1.5	-					-2.5	-				-3.5	-1.6						-1.7
#9	-	--	--	6	-2.8 (7.0)	(2.8)	-	--	--	5	-5.4 (4.5)	(2.1)	-	--	--	4	(7.0)	(3.0)	--	--	--	7	-3.4 (6.1)	(3.1)
Call	-					1.2						-1.9					-6.3	-3.0						-2.9
#10	-	--	--	2	4.0 (11.9)	(4.8)	1	5.6	2.3	4	-4.5 (8.9)	(3.7)	1	-17.0	-6.5	3	(3.6)	(1.7)	--	--	--	2	-6.3 (3.5)	(2.0)
Call					-15.6	-4.6						-3.0	-				-14.3	-5.7						-3.5
#11	1	-21.2	-9.1	2	(10.7)	(2.7)	1	-0.8	-0.5	3	-8.3 (4.8)	(0.9)	-	--	--	3	(19.4)	(6.9)	--	--	--	7	-6.7 (8.8)	(4.1)
Call	-									-			-				-16.3	-6.6						
#12	-	--	--	--	--	--	1	-2.6	-0.9	-	--	--	-	--	--	3	(12.6)	(4.6)	--	--	--	1	-8.0	-3.1
Call	-						-					1.0	-				-16.6	-6.8						-2.5
#13	-	--	--	1	-6.4	-3.8	-	--	--	1	2	(0.1)	-	--	--	2	(6.8)	(4.3)	--	--	--	3	-6.7 (2.6)	(1.0)
Call	-						-			-														
#14	-	--	--	--	--	--	-	--	--	-	--	--	1	2	1.1	1	12.2	6.0	--	--	--	1	-9.2	-5.1
Call	-				-11.2	-4.8	-					-3.7	-				-10.7	-4.1					-14.9	-6.4
#15	-	--	--	2	(2.3)	(0.4)	-	--	--	3	-7.9 (4.3)	(2.0)	-	--	--	4	(4.6)	(1.2)	1	-11.8	-6.4	2	(19.7)	(8.2)
Call							-			-			-				-6.5	-2.4						
#16	1	-10.2	-5.4	--	--	--	-	--	--	-	--	--	-	--	--	4	(14.9)	(5.8)	1	18.6	8.2	1	-18.8	-8.3
Call							-			-			-				-21.6	-8.7					-10.8	-4.3
#17	1	-7.6	-3.6	--	--	--	-	--	--	-	--	--	-	--	--	5	(15.3)	(5.4)	--	--	--	7	(10.6)	(3.6)
Call	-									-							-18.5	-8.4					-12.2	-5.5
#18	-	--	--	--	--	--	1	-2.6	-0.9	-	--	--	1	-10.2	-4.2	5	(9.8)	(4.6)	1	-10.4	-5.4	5	(8.5)	(3.3)
Call	-						-			-			-				-11.8	-5.3					-15.5	-7.2
#19	-	--	--	1	-27.8	-8.7	-	--	--	-	--	--	-	--	--	2	(3.1)	(1.5)	1	-14.6	-5.2	2	(12.9)	(5.6)
Call	-									-					0.5		-23.9	-10.4					-4.6	-1.2
#20	-	--	--	1	-1.8	-0.8	1	-4.0	-2.5	-	--	--	2	0.9 (1.3)	(0.6)	5	(18.0)	(6.8)	1	-9.8	-5.3	2	(17.8)	(8.4)
Call	-						-			-				-10.4	-4.9		-12.7	-4.9			-2.8		-20.3	-7.9
#21	-	--	--	1	-6.2	-2.4	-	--	--	-	--	--	2	(18.1)	(8.6)	7	(14.2)	(4.6)	2	-6.8 (11.3)	(4.8)	8	(12.3)	(4.5)
Call			7.9					-21.8	-11.7			-6.2		-15.7	-6.6		-12.1	-5.4	1	-17.6	-7.5		-16.0	-6.8
#22	6	-9.0 (5.1)	(10.4)	--	--	--	2	(10.5)	(3.7)	2	-9.0 (5.1)	(4.1)	6	(13.3)	(5.7)	54	(14.4)	(6.3)	5	(22.2)	(8.9)	45	(17.7)	(6.8)

[a]p<0.001, CL, Both variables; [b]p<0.001, CL/Modality, All 4 categories, Both variables; [c]p<0.001, CL/Modality, All 8 categories, Both variables

Table 16 Mean IVR-reported weekly aerobic physical activity during intervention by call where participant disengaged

	Low Overall Comprehension (N=179)[a]								High Overall Comprehension (n=246)[a]							
	DVD (n= 95)[b]				Class (n= 84) [b]				DVD (n=124) [b]				Class (n= 122) [b]			
	LHL (n= 21)[d]		HHL (n= 74) [d]		LHL (n= 16) [d]		HHL (n= 68) [d]		LHL (n= 16) [d]		HHL (n= 108) [d]		LHL (n= 22) [d]		HHL (n= 100) [d]	
Call #	n	PA- μ (SD)	n	PA- μ (SD)	n	PA- μ (SD)	n	PA- μ (SD)	n	PA- μ (SD)	n	PA- μ (SD)	n	PA- μ (SD)	n	PA- μ (SD)
Call #1	2	187.5 (53.0)	5	68 (72.6)	1	36	8	55.0 (47.5)	2	185.0 (247.5)	3	76.7 (51.3)	--	--	4	17.5 (12.6)
Call #2	5	57.3 (49.9)	10	36.0 (43.4)	1	157.5	9	25.8 (27.1)	--	--	--	--	--	--	--	--
Call #3	1	0	12	26.3 (21.8)	2	20.3 (2.0)	6	38.6 (39.1)	--	--	--	--	--	--	1	23.3
Call #4	--	--	9	24.1 (12.0)	4	39.0 (17.7)	5	13.7 (11.2)	--	--	--	--	--	--	--	--
Call #5	2	22.8 (18.7)	5	12.8 (12.4)	--	--	7	31.3 (18.6)	--	--	--	--	--	--	--	--
Call #6	1	29.8	8	14.7 (9.5)	--	--	4	16.1 (9.6)	--	--	--	--	--	--	--	--
Call #7	1	9.2	5	12.3 (14.8)	--	--	6	12.5 (11.0)	--	--	1	23.5	--	--	--	--
Call #8	--	--	4	16.7 (11.2)	2	8.2 (0.6)	5	12.9 (9.1)	1	23.3	2	14.3 (13.9)	--	--	2	5.5 (7.0)
Call #9	--	--	6	17.3 (11.5)	--	--	5	19.0 (13.0)	--	--	4	10.6 (8.0)	--	--	7	13.3 (7.8)
Call #10	--	--	2	13.2 (4.5)	1	11.8	4	13.7 (6.9)	1	20	3	12.7 (3.4)	--	--	2	16.2 (11.8)
Call #11	1	30.7	2	4.8 (1.9)	1	1.2	3	11.0 (5.4)	--	--	3	17.5 (11.7)	--	--	7	13.3 (8.6)
Call #12	--	--	--	--	1	0	--	--	--	--	3	8.5 (1.4)	--	--	1	1.5
Call #13	--	--	1	9.7	--	--	1	6.7	--	--	2	18.4 (4.3)	--	--	3	9.0 (9.1)
Call #14	--	--	--	--	--	--	--	--	1	5.3	1	2.5	--	--	1	16.9
Call #15	--	--	2	8.1 (3.0)	--	--	3	8.0 (1.4)	--	--	4	11.4 (9.8)	1	20.8	2	9.1 (9.5)
Call #16	1	6.3	--	--	--	--	--	--	--	--	4	8.3 (5.9)	1	7.7	1	20
Call #17	1	3.6	--	--	--	--	--	--	--	--	5	3.1 (1.9)	--	--	7	5.7 (5.2)
Call #18	--	--	--	--	1	11.6	--	--	1	11.7	5	13.0 (6.2)	1	8.3	5	12.1 (7.6)
Call #19	--	--	1	15.4	--	--	--	--	--	--	2	7.7 (5.2)	1	1.4	2	13.4 (5.4)
Call #20	--	--	1	8.3	1	3.2	--	--	2	7.3 (6.6)	5	5.8 (4.3)	1	5.7	2	5.7 (6.0)
Call #21	--	--	1	3.4	--	--	--	--	2	10.5 (3.0)	7	6.8 (6.6)	2	10.7 (7.5)	8	7.2 (3.5)
Call #22	6	6.9 (2.7)	--	--	2	6.7 (3.5)	2	3.7 (3.7)	6	12.4 (6.7)	54	8.6 (4.9)	15	9.3 (3.3)	45	9.5 (5.3)

[a]p<0.001, CL; [b]p<0.001, CL/Modality, All 4 categories; [c]p<0.001, CL/Modality/HL Level, All 8 categories; [d]p<0.01, HOC/Modality/HL Level

Table 17 Mean IVR-reported minutes of weekly muscle strengthening during intervention by call where participant disengaged

	Low Overall Comprehension (N=179)[a]								High Overall Comprehension (n=246)[a]							
	DVD (n= 95)[b]				Class (n= 84)[b]				DVD (n=124)[b]				Class (n= 122)[b]			
	LHL (n= 21)[c]		HHL (n= 74)[c]		LHL (n= 16)[c]		HHL (n= 68)[c]		LHL (n= 16)[c, d]		HHL (n= 108)[c, d]		LHL (n= 22)[c, d]		HHL (n= 100)[c, d]	
Call #	n	MS- μ (SD)	n	MS- μ (SD)	n	MS- μ (SD)	n	MS- μ (SD)	n	MS- μ (SD)	n	MS- μ (SD)	n	MS- μ (SD)	n	MS- μ (SD)
Call #1	2	37.5 (31.8)	5	44.0 (45.1)	1	0	8	16.1 (20.7)	2	105.0 (148.5)	3	23.3 (40.4)	--	--	4	6.3 (7.5)
Call #2	5	16.8 (10.1)	10	17.5 (19.5)	1	33.8	9	14.2 (17.5)	--	--	--	--	--	--	--	--
Call #3	1	0	12	7.5 (7.2)	2	18.1 (9.8)	6	4.5 (4.7)	--	--	--	--	--	--	1	0
Call #4	--	--	9	23.5 (40.9)	4	15.6 (9.2)	5	4.2 (5.3)	--	--	--	--	--	--	--	--
Call #5	2	12.4 (5.1)	5	3.9 (4.8)	--	--	7	10.1 (11.0)	--	--	--	--	--	--	--	--
Call #6	1	17.1	8	3.9 (5.6)	--	--	4	4.6 (3.4)	--	--	--	--	--	--	--	--
Call #7	1	6.1	5	2.1 (1.9)	--	--	6	2.8 (1.2)	--	--	1	1	--	--	--	--
Call #8	--	--	4	7.7 (9.4)	2	7.0 (3.3)	5	4.8 (3.9)	1	2.3	2	3.6 (2.3)	--	--	2	2.4 (1.8)
Call #9	--	--	6	2.8 (1.3)	--	--	5	3.2 (0.9)	--	--	4	5.6 (7.1)	--	--	7	3.5 (2.7)
Call #10	--	--	2	5.8 (6.3)	1	1.4	4	5.2 (4.5)	1	3.9	3	5.9 (3.2)	--	--	2	2.2 (2.0)
Call #11	1	9.1	2	2.1 (0.1)	1	0.3	3	2.6 (2.1)	--	--	3	4.4 (2.2)	--	--	7	2.6 (1.7)
Call #12	--	--	--	--	1	0	--	--	--	--	3	2.3 (2.4)	--	--	1	0
Call #13	--	--	1	2.3	--	--	1	3.5	--	--	2	7.7 (0.4)	--	--	3	2.4 (3.3)
Call #14	--	--	--	--	--	--	--	--	1	1	1	0.5	--	--	1	1.8
Call #15	--	--	2	3.5 (1.5)	--	--	3	1.7 (0.8)	--	--	4	3.8 (3.1)	1	0.6	2	2.5 (2.6)
Call #16	1	2.7	--	--	--	--	--	--	--	--	4	3.2 (2.1)	1	1.7	1	2
Call #17	1	2.2	--	--	--	--	--	--	--	--	5	0.6 (0.8)	--	--	7	3.1 (2.1)
Call #18	--	--	--	--	1	5	--	--	1	3.5	5	5.1 (4.7)	1	1.6	5	6.4 (8.1)
Call #19	--	--	1	1.8	--	--	--	--	--	--	2	1.3 (0.1)	1	0.2	2	2.7 (0.3)
Call #20	--	--	1	3.4	1	1.6	--	--	2	2.8 (3.0)	5	1.2 (0.4)	1	2.7	2	1.6 (1.6)
Call #21	--	--	1	1.7	--	--	--	--	2	2.6 (1.3)	7	1.5 (1.6)	2	1.6 (0.4)	8	2.3 (0.9)
Call #22	6	3.5 (2.5)	--	--	2	5.3 (3.6)	2	3.2 (3.6)	6	4.9 (3.7)	54	2.2 (1.4)	15	2.9 (1.3)	45	2.6 (2.1)

[a]p<0.001, CL; [b]p<0.001, CL/Modality, All 4 categories; [c]p<0.001, CL/Modality/HL Level, All 8 categories; [d]p<0.01, HOC/Modality/HL Level

Table 18 Mean IVR-reported daily fruit and vegetable servings during intervention by call where participant disengaged

	Low Overall Comprehension (N=179)[a]								High Overall Comprehension (n=246)[a]							
	DVD (n= 95)[b]				Class (n= 84)[b]				DVD (n=124)[b]				Class (n= 122)[b]			
	LHL (n= 21)[c]		HHL (n= 74)[c]		LHL (n= 16)[c]		HHL (n= 68)[c]		LHL (n= 16)[c]		HHL (n= 108)[c]		LHL (n= 22)[c]		HHL (n= 100)[c]	
Call #	n	FV- μ (SD)	n	FV- μ (SD)	n	FV- μ (SD)	n	FV- μ (SD)	n	FV- μ (SD)	n	FV- μ (SD)	n	FV- μ (SD)	n	FV- μ (SD)
Call #1	2	1.1 (0.4)	5	2.4 (2.1)	1	1.4	8	2.6 (2.2)	2	0.6 (0.3)	3	3.4 (3.2)	--	--	4	1.9 (1.0)
Call #2	5	2.8 (2.7)	10	2.6 (1.5)	1	5	9	1.9 (1.2)	--	--	--	--	--	--	--	--
Call #3	1	1.7	12	2.6 (1.1)	2	1 (0.7)	6	1.7 (0.7)	--	--	--	--	--	--	1	1.6
Call #4	--	--	9	2.8 (1.1)	4	2.2 (1.6)	5	2 (1.1)	--	--	--	--	--	--	--	--
Call #5	2	1.8 (0.8)	5	2.2 (1.6)	--	--	7	3.5 (1.8)	--	--	--	--	--	--	--	--
Call #6	1	1.5	8	3.2 (1.1)	--	--	4	2.1 (0.7)	--	--	--	--	--	--	--	--
Call #7	1	0.8	5	3.7 (2.3)	--	--	6	3.3 (0.7)	--	--	1	2.6	--	--	--	--
Call #8	--	--	4	3.9 (0.9)	2	2.8 (1.1)	5	2.2 (0.8)	1	4.3	2	1.7 (0.6)	--	--	2	3.2 (0.7)
Call #9	--	--	6	2.9 (1.8)	--	--	5	3.3 (1.0)	--	--	4	3.5 (1.3)	--	--	7	2.9 (1.5)
Call #10	--	--	2	3.1 (0.1)	1	3.2	4	3.7 (0.9)	1	4.5	3	3.4 (0.9)	--	--	2	3.5 (0.6)
Call #11	1	6	2	2.0 (0.5)	1	3.7	3	3.5 (1.4)	--	--	3	2.9 (1.9)	--	--	7	3.1 (1.0)
Call #12	--	--	--	--	1	0	--	--	--	--	3	3.8 (1.7)	--	--	1	0.5
Call #13	--	--	1	5.6	--	--	1	1.3	--	--	2	3.8 (0.4)	--	--	3	2.8 (2.1)
Call #14	--	--	--	--	--	--	--	--	1	1.4	1	1.4	--	--	1	4.7
Call #15	--	--	2	4.2 (3.5)	--	--	3	3.5 (1.2)	--	--	4	3.4 (0.6)	1	3.9	2	4.3 (0.8)
Call #16	1	2.8	--	--	--	--	--	--	--	--	4	3.2 (0.9)	1	1.9	1	4.8
Call #17	1	3.1	--	--	--	--	--	--	--	--	5	3.4 (1.1)	--	--	7	3.4 (1.5)
Call #18	--	--	--	--	1	2.8	--	--	1	2.2	5	4.5 (1.1)	1	4.2	5	3.7 (1.1)
Call #19	--	--	1	5	--	--	--	--	--	--	2	3.3 (0.9)	1	1.1	2	3.7 (1.6)
Call #20	--	--	1	2.9	1	4	--	--	2	2.4 (0.4)	5	4.5 (1.0)	1	1.2	2	4.3 (0.5)
Call #21	--	--	1	1.8	--	--	--	--	2	4.4 (0.5)	7	3.1 (1.0)	2	3.2 (0.8)	8	3.8 (1.3)
Call #22	6	3.4 (1.7)	--	--	2	2.5 (1.0)	2	5 (0.4)	6	3.6 (1.1)	54	4.2 (1.5)	15	3.8 (1.4)	45	3.9 (1.4)

[a]p<0.001, CL; [b]p<0.001, CL/Modality, All 4 categories; [c]p<0.001, CL/Modality/HL Level, All 8 categories

Conclusion

Summary and Significance

The original Diabetes Prevention Program and its LI has come a long way since first being published in 2002. Many adaptations and educational formats have been developed and implemented across a wide variety of settings. However, many adapted LIs have failed to acknowledge health literacy differences amongst its wide variety of patients.

The use of clear communication strategies was apparent in our study, as this, in our opinion, has been a lack of emphasis among other technology based DPP LI's (Mackert, Ball, & Lopez, 2011; Sudore & Schillinger, 2009). This could be because past research has failed to recognize the roles of all educational channels as another provider-patient like interaction. In our case, the DVD, workbook and IVR calls acted as the provider where messages were delivered in appropriate reading levels (i.e. 6th grade level) with the most important message strongly stated first in each lesson. Jargon was held to a minimum, and patient comprehension was evaluated. Also, the use of multiple learning channels (i.e. audio, visual, written and verbal) was to ensure clear reception of the same information amongst all of the various modalities, which, our team believes enhanced the effectiveness of our intervention. Future investigations should and will be evaluating our overall clear communication index of all communication strategies used in similar projects.

This dissertation was also the first to take a look at how to enhance comprehension and engagement through health literacy techniques known to influence

information uptake and overall comprehension levels. Over time, as hypothesized, participants would feel less anxious with the material and more receptive to the behavior changes suggested because it empowers all participants through cognitive and performance adjustments over time, regardless of health literacy levels (Baker et al., 1996; Parikh, Parker, Nurss, Baker, & Williams, 1996). While not specific to diabetes prevention, this observation has been reported by other prominent health literacy researchers in their interventions (Baker et al., 1996; Parikh et al., 1996).

All three studies observed changes among both high and low health literacy participants from both a cross-sectional and longitudinal spectrum. Key to note is that the gap in performance disparities amongst the two groups was reduced over time suggesting the techniques applied worked as hypothesized. These techniques also contributed to the degree of engagement, which over time, was greater amongst the low health literacy group—reaching a population desperately needing assistance with improving their health outcomes. This finding also parallels a 2011 Agency for Healthcare Research and Quality review suggesting it is possible to enhance elements influential upon health literacy levels in low health literacy patients (Berkman et al., 2011).

Finally, study #3 observed that engagement led to greater behavior uptake and weight loss. Overall comprehension performance predicted weight loss. By having additional rounds of reinforcement, participants could have the opportunity to reinforce any learning materials assessed ensuring the participant would understand what the

program suggests. The research team believes this to be the first study to evaluate the changes that occur with teach-back and teach-to-goal longitudinally, regardless of the type of health care intervention, and its influence on the degree of weight loss.

Limitations

While this dissertation "pushed the needle" forward amongst diabetes prevention programs, there are several limitations that need to be noted. Of utmost concern, the design of the parent study didn't account for a control treatment group that would have received the IVR intervention without teach-back and teach-to-goal. Therefore, it is hard to ascertain the degree of difference in how the techniques truly impacted the degrees of comprehension, engagement and weight loss.

Secondly, while the parent study was pragmatically designed to be delivered through technology-based channels, this dissertation, through the performance measures, could really only account for functional health literacy and less so, interactive and critical health literacy. This is largely due to the fact that questions were assessed, behavior was tracked either objectively (i.e. aerobic physical activity through an accelerometer) or subjectively (i.e. IVR-reported aerobic exercise, muscle strengthening and fruit and vegetable consumption) and the direct link between knowledge attainment, reinforcement and application of proper behaviors couldn't be ascertained without a self-efficacy measurement relative to each relevant behavior, which our parent study didn't implement (Almeida et al., 2014).

A common saying amongst health literacy researchers is, "Health literacy can be a state, not a trait." While participants could ask for ideal times to receive the IVR phone calls, it is possible that due to various life circumstances that participants could be in a state of cognitive dysfunction when receiving the phone calls or their delivery could be at inconvenient times. When necessary, participants could call in to change their times to better enhance their engagement in the intervention.

Applications

Consistent with the dissertation hypotheses, low health literacy participants were able to improve immediate comprehension rates; however, the research team didn't expect for high health literacy participants to improve from initial comprehension rates over the short-term, as well as the long-term, in the manner they did. These improvements in both populations suggests the need to include education reinforcements measures, regardless of the type of health education intervention. Also, interestingly, if health literacy measures are enacted in any intervention, the need to evaluate engagement measures by health literacy level becomes extremely relevant.

While this study primarily evaluated quantitative outcomes, future research should include exploring participant's experiences and feedback provided regarding their experiences with the study and its staff, the IVR system and the curriculum framed upon the original DPP. Any mixed-methods approach would provide a more holistic evaluation of the program provided, and identify gaps needing addressing in future projects for all parties involved—researcher, staff, providers referring patients and those participants.

As this dissertation reported, it was observed that approximately 64% of the intervention had better engagement rates by LHL participants. One last thought—the DVD/IVR had slightly better outcomes than the class/IVR groups, across the board. This suggests the need for researchers to continue to invest in technology-enhanced interventions due to the ease of replication, low long-term costs and their reviewability by patients.

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