Effects of a Behavior-Matching Tool on Behavior Adoption and Attrition in an eHealth

Intervention Focused on Fruit and Vegetable Consumption

by

Kelly Cosgrove

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Graduate Supervisory Committee:

Christopher Wharton, Chair
Marc Adams
Tyler DesRoches
Carola Grebitus
Carol Johnston

ARIZONA STATE UNIVERSITY

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ABSTRACT

Tools designed to help match people with behaviors they identify as likely to lead
to a successful behavioral outcome remain under-researched. This study assessed the
effect of a participant-driven behavior-matching intervention on 1) the adoption of a new
behavior related to fruit and vegetable (F&V) consumption, 2) study attrition, and 3)
changes in F&V consumption. In this two-arm randomized controlled trial, 64 adults who
did not meet standard F&V recommendations were allocated to an intervention (n=33) or
control group (n=31). Participants in the intervention group ranked 20 F&V-related
behaviors according to their perceived likelihood of engagement in the behavior and their
perception of the behavior's efficacy in increasing F&V consumption. Participants in the
intervention group were subsequently shown the list of 20 behaviors in order of their
provided rankings, with the highest-ranked behaviors at the top, and were asked to
choose a behavior they would like to perform daily for 4 weeks. The control group chose
from a random-order list of the same 20 behaviors to adopt daily for 4 weeks. During the
study period, text messages were sent to all participants 90 minutes before their reported
bedtime to collect Yes/No data reflecting successful behavior engagement each day. The
binary repeated-measures data collected from the text messages was analyzed using
mixed-effects logistic regression, differences in attrition were assessed using log-rank
analysis, and change scores in F&V consumption were compared between the two groups
using the Man-Whitney U test. P<0.05 indicated significance. The rate of successful
behavior adoption did not differ significantly between the two groups (b=0.09, 95%CI= -
0.81, 0.98, p=0.85). The log rank test results indicated that there was no significant
difference in attrition between the two groups (χ^2=2.68, df=1, p=0.10). F&V consumption

increased significantly over the 4 weeks in the total sample (Z=-5.86, p<0.001), but no differences in F&V change scores were identified between the control and intervention groups (Z=-0.21, p=0.84). The behavior-matching tool assessed in this study did not significantly improve behavior adoption, study attrition, or F&V intake over 4 weeks.

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CHAPTER 1

INTRODUCTION

Diet and other lifestyle behaviors have been widely recognized as major risk factors for noncommunicable diseases associated with high rates of morbidity and mortality, such as cardiovascular disease, type 2 diabetes mellitus, and certain cancers (GBD 2016 Risk Factors Collaborators, 2017; Ley et al., 2014; Pan et al., 2018). Therefore, interventions targeting these health behaviors constitute an important research focus. A wide range of interventions aimed at improving diet and lifestyle behaviors have been developed and assessed, demonstrating varying degrees of efficacy.

The ubiquitous use of technology has given rise to a new class of health-promotion interventions, referred to as eHealth interventions, which place a strong focus on digital tools, such as web portals for health information dissemination, informational websites, mobile apps, and wearable devices and technologies. eHealth interventions offer many benefits, including the potential for wide reach, minimal barriers to implementation, improved efficacy, efficiency, wide accessibility, and opportunities for personalization (Escriva Boulley et al., 2018; Hewitt et al., 2020; Jiang et al., 2019; E. Murray et al., 2016; Wongvibulsin et al., 2021). As the collection and processing of data from digital tools continues to improve, opportunities for intervention optimization are arising. For example, interventions that are tailored to people's specific characteristics and behaviors are becoming more popular given the greater capacity to gather and process complex behavioral data and intervene almost in real time to tailor interventions (Hardeman et al., 2019).

In addition to tailoring interventions in response to real-time data, interventions can be tailored to a wide variety of characteristics that are specific to an individual. For example, previous research has indicated that tailoring interventions according to the most important psychosocial determinants or mediators of a behavior can increase intervention efficacy (Guillaumie et al., 2010). Many of these psychosocial determinants or behavioral mediators are central constructs of Social Cognitive Theory (SCT). These constructs include motivation, beliefs about competency, and outcome expectancies (Bandura, 1998; Guillaumie et al., 2010).

Previous research has mainly focused on interventions aimed at modifying these behavioral determinants, for example, by increasing motivation or competence through educational interventions or coaching (Aktaç et al., 2019; Chad-Friedman et al., 2018; Dhandevi & Jeewon, 2015; Steptoe et al., 2004). However, only an underdeveloped body of literature exists focusing on interventions that match individuals with behaviors for which they already report favorable behavioral determinants. Some research has been conducted on interventions that are tailored to certain characteristics of individuals, such as their stage of change according to the transtheoretical model and their real-time reactions to interventions that can allow for the implementation of adaptive interventions (de Freitas et al., 2020; de Melo Ribeiro et al., 2020; Fiedler et al., 2020; Nakabayashi et al., 2020). Expanding this area of research by exploring more ways to effectively tailor interventions to specific individuals and their circumstances has potential to increase the effectiveness of new and existing interventions. For example, interventions could be more effective if they are able to match individuals with specific supportive behaviors they already feel competent, motivated, and likely to adopt.

Outcome expectancy, in particular, is an important determinant of behavior and intention and a construct of SCT that can be integrated into behavior change interventions. An individual's perception of the outcome that can be expected from engaging in a behavior has a strong influence on their motivation and intention to engage in the behavior in question (Huttunen-Lenz et al., 2018). If an individual does not expect a behavior to result in a meaningful outcome, this can have a negative influence on their motivation to engage in the behavior (Schwarzer et al., 2011). Outcome expectancies are subjective and vary among individuals, and they constitute another important factor that can be influenced through education and training. However, there is also a possibility that encouraging people to adopt behaviors for which they already have favorable outcome expectancies could lead to more successful behavior uptake.

Another SCT construct that has a strong evidence base regarding its influence on behavior is self-efficacy. Self-efficacy has been demonstrated to be very important in the field of health behavior due to its associations with a wide range of behaviors and outcomes (Jerusalem & Schwarzer, 1992). There are many examples in the literature of the association of self-efficacy with various health behaviors and outcomes. In general, intervention studies tend to focus on increasing self-efficacy through education and counselling rather than leveraging existing levels of self-efficacy associated with various behaviors.

In addition to these constructs of SCT that have been shown to influence behavior, another important component of behavior uptake is salience. It has been shown that making behaviors more salient can increase behavioral engagement in a variety of contexts, such as improving learning outcomes among students, making favorable dietary

choices, and engaging in pro-environmental behaviors (Bauer & Reisch, 2019; Bettinger et al., 2021; Byerly et al., 2018). The studies in this area have indicated the potential of salience-focused interventions for behavior change. Interventions that focus on increasing saliency of behaviors for which people already have favorable behavioral determinants have the potential to result in meaningful behavior change without the need to invest resources into education and counseling to improve these determinants, such as motivation, self-efficacy, and attitude. These types of tailored interventions can be particularly useful when targeting dietary behaviors, which are already notoriously difficult to change due to biological, cultural, and other factors.

Considering that there are many specific behaviors that can lead to a desired outcome (e.g., increased fruit and vegetable consumption or increased physical activity), there is an opportunity to utilize a tailored approach when determining which specific target behavior will be the focus of an intervention. Targeting behaviors associated with lower resistance that can result in a desired outcome could be more effective than designing an intervention in which all people are tasked with adopting the same target behavior that is likely associated with different promotors and barriers for each individual (Lucan et al., 2010).

Another potential influencer of behavior that could have an effect in behavior change interventions is the mere-measurement effect. The mere-measurement effect is the phenomenon in which asking participants questions about specific behaviors could increase engagement in the target behavior (Morwitz & Fitzsimons, 2004). Several studies have shown that simply asking questions about a behavior can lead to changes in subsequent behavior (Williams et al., 2006). This phenomenon has been observed in

various disciplines, including consumer research, public health, and environmental conservation (Schmidt, 2014), and has been referred to as the mere-measurement effect, self-generated validity, the self-erasing error of prediction, and the self-prophecy effect (Feldman & Lynch, 1988; Morwitz & Fitzsimons, 2004; Sherman, 1980; Spangenberg & Greenwald, 2001).

The digital behavior-matching tool that was the focus of the present study aims to facilitate the adoption and maintenance of health behaviors by taking advantage of the aforementioned behavioral determinants and influencers. The tool asks individuals about their likelihood of engaging in a behavior as well as the efficacy of the behavior for increasing fruit and vegetable consumption. The use of the behavior-matching tool could lead to higher behavioral adoption by taking advantage of existing self-efficacy and outcome expectancies associated with a specific behavior, as well as the mere-measurement effect.

This matching process could be applied in a wide range of intervention settings to increase the adoption of variety of target behaviors, including health behaviors such as improvements in dietary intake. Diet constitutes an important focus of health promotion, and optimizing interventions aimed at improving diet is an important priority in the context of public health and is the focus of the present study. In the United States, poor diet was identified as the leading cause of death in an analysis of 2016 Global Burden of Disease Study data (The US Burden of Disease Collaborators, 2018). Adequate fruit and vegetable consumption is as an important component of diet quality (Slavin & Lloyd, 2012). The consumption of fruits and vegetables has been linked to a reduced risk of many chronic diseases, including heart disease, type 2 diabetes mellitus, certain cancers,

stroke, Alzheimer's disease, and cataracts (Liu, 2004; Slavin & Lloyd, 2012; Willett, 2002). In 2017, it was estimated that worldwide, 3.9 million deaths were attributed to inadequate fruit and vegetable consumption (World Health Organization, 2019).

Fruits and vegetables are rich in many health-promoting compounds and nutrients such as vitamin C, phytochemicals, and dietary fiber, which are not found in large amounts in other food sources, such as meat, fish, dairy, and refined grains (Craig, 1997). Vitamin C is an important antioxidant that has been associated with many health benefits including reduced risks of many age-related and degenerative conditions, such as cancer and cardiovascular disease (Li & Schellhorn, 2007). As another health-promoting component of fruits and vegetables, dietary fiber plays an important role in healthy digestion and reduces the risk and symptoms associated with many diseases related to metabolism and inflammation, such as cardiovascular disease, obesity, diabetes, colorectal cancer, and inflammatory bowel disease (Kasubuchi et al., 2015). Moreover, it has been found that the gut microbiome utilizes soluble fiber found in fruits and vegetables to generate short-chain fatty acids through fermentation (S. Zhang et al., 2021). Short-chain fatty acids derived from soluble fiber have been shown to play important roles in many health-promoting processes. For example, short-chain fatty acids act as an energy source for colonocytes and the gut microbiome, reduce pH to prevent pathogen growth in the gastrointestinal tract, increase mineral absorption, increase glucose utilization, prevent neurodegeneration, and promote regeneration (Alexander et al., 2019).

Despite the importance of and health benefits associated with fruit and vegetable consumption, in the United States, individuals in all age groups consistently fall short of

fruit and vegetable intake recommendations, indicating a missed opportunity for health promotion and disease prevention and an important focus of impactful interventions (Slavin & Lloyd, 2012). A multitude of factors are involved in the dietary choices that lead most people to fall short of the fruit and vegetable intake recommendations. Studies have examined the barriers to meeting fruit and vegetable recommendations and have indicated that the barriers include lack of time, perception of guidelines being unachievable, availability of many other foods, and high cost and limited availability of fresh fruits and vegetables (Livingstone et al., 2020). As can be inferred from the variety of barriers, a multipronged, individualized approach is likely needed to elicit a meaningful increase in fruit and vegetable consumption at the population level.

Dietary interventions can fail to lead to changes in behavior because it can be challenging to create an intervention that is relevant and effective for a variety of people given the individual differences in characteristics and barriers and promotors of the target behavior. This could be an explanation as to why despite the development and assessment of a wide range of interventions aimed at increasing fruit and vegetable consumption, fruit and vegetable intake remains consistently below the recommended level across population groups. This indicates the importance of identifying new approaches to encourage fruit and vegetable consumption at the population level that can be applied in a variety of population subgroups.

The present study aims to examine the effects of the use of a behavior-matching tool designed to match participants with a specific behavior for which they report high likelihood of engagement and favorable outcome expectancy; the matching process is designed to increase engagement in a behavior related to increased fruit and vegetable

consumption. To the best of the author's knowledge, this is the first intervention assessing the effect of matching individuals with specific behaviors related to fruit and vegetable consumption according to their self-reported likelihood of engagement and perception of behavioral efficacy. The research question guiding this study is as follows: Does the use of a behavior-matching tool that rank suggested behaviors according to a) an individual's reported likelihood of engagement in each behavior and b) the perceived efficacy of each behavior for increasing fruit and vegetable consumption lead to more consistent engagement in the target behavior over a four-week intervention?

The aims and corresponding hypotheses of this study are as follows:

Aim 1. **Determine whether the use of the behavior-matching tool leads to differences in the adoption of a target behavior over 4 weeks compared to choosing a behavior without the use of the matching tool.**

H1: Participants using the behavior-matching tool will have a higher frequency of adoption of the target behavior over 4 weeks than control participants choosing a behavior from a random-order list.

Aim 2. **Determine whether the use of the behavior-matching tool leads to differences in attrition over 4 weeks compared to choosing a behavior without the use of the matching tool.**

H2: Participants using the behavior-matching tool will have a lower rate of attrition over 4 weeks than control participants choosing a behavior from a random-order list.

Aim 3. **Assess differences in change in fruit and vegetable consumption between the behavior-matching tool (intervention) group and the unordered list (control) group.**

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H3: Participants using the behavior-matching tool will increase the number of servings of fruits and vegetables they consume per week to a greater extent than participants choosing a behavior from a random-order list.

CHAPTER 2

REVIEW OF LITERATURE

eHealth Dietary Interventions

Noncommunicable diseases, such as cardiovascular disease, type 2 diabetes mellitus, and certain cancers, are the leading causes of morbidity and mortality in the United States (GBD 2016 Risk Factors Collaborators, 2017). These diseases have important lifestyle-related risk factors and are often preventable through lifestyle adaptation (C. J. L. Murray et al., 2020). The high prevalence and societal burden associated with these lifestyle-related diseases indicate the importance of developing and implementing techniques that can lead to meaningful, population-level changes in the behaviors associated with these diseases, including poor diet and inadequate physical activity.

The rapid development of communication technologies in the past decade has facilitated the swift introduction and evolution of health-focused digital tools and interventions (Cotie et al., 2018). The use of such digital tools and interventions, including web portals for health information dissemination, mobile apps, educational websites, and wearable devices and technologies, in the field of health promotion has led to the development of 'eHealth' as a particular area of interest. eHealth interventions have seen a dramatic increase in implementation and popularity due to the ubiquitous use of digital tools, such as smartphones and computers, as well as advances in cyberinfrastructure that have allowed big data to be stored and organized efficiently (E. W. J. Lee et al., 2022). eHealth interventions offer new opportunities for scalable approaches to health promotion. Interventions utilizing digital tools allow for a large

number of participants to be reached without requiring excessive resources in many cases.

Not only can these methods of information dissemination be more efficient, but it has also been shown that computer-tailored nutrition education is more effective in inducing dietary shifts than the provision of general information (Cheung et al., 2019). In fact, eHealth interventions have become a research area of particular interest in the field of nutrition. A meta-analysis that assessed the effects of eHealth interventions on fruit and vegetable (F&V) consumption included 19 studies and a total of 6,894 participants (Patricia et al., 2019). The analysis revealed a small effect size overall (0.26, P<0.001); however, tailored interventions, computer-based interventions, and interventions utilizing at least seven behavior-change techniques exhibited larger effect sizes (0.27, 0.44, and 0.42, respectively, all P<0.001).

A feasibility study was conducted to examine the effects and acceptability of an eHealth intervention among pregnant women to promote a healthy lifestyle and prevent excess weight gain in pregnancy (Huang et al., 2020). The intervention program was web based and provided personalized weight-management advice, dietary education, a session with a dietitian, weekly text messages, and a goal-development guide. The intervention retention rates were 73.7%, 64.9%, and 55.8% at the end of the 12-week intervention, at birth, and 3 months after birth, respectively. While no differences were observed in gestational weight gain or birth size between the intervention and routine antenatal care groups, the intervention was associated with an increase in the score of perceived confidence of dietary change (1.2±0.46, p=0.009) and the score of readiness to exercise (1.21±0.51, p=0.016). Moreover, at the three-month follow-up, infants in the intervention

group weighed less (5405 vs. 6193 g, p=0.008) and had a lower ponderal index (25.2±3.0 vs. 28.8±4.0 kg/m^3).

In a randomized, controlled trial assessing the acceptability, feasibility, and effectiveness of an eHealth intervention referred to as 'MyPlan,' 155 adults were randomly allocated to a control group, 158 to a physical activity group, 161 to a fruit intake group, and 48 to a vegetable intake group (Plaete et al., 2015). In the intervention groups, three modules were made available to participants. In the first module, participants completed a questionnaire regarding their awareness of and motivation to engage in the target health behavior, and based on their answers, personalized feedback was provided. For example, the participant's engagement in the target behavior was compared to health norms. Moreover, the module included prompts to create an action plan. In module two, participants answered questions about the target behavior once again, received feedback, and were provided guidance regarding adapting their action plan. Finally, module three was made available one month after module two was finished and was identical to module two. At the one-month follow-up, the fruit intake group exhibited significantly increased fruit intake (F=9.5, P=0.003), but no effect was observed for vegetable intake in the vegetable intake group. Only 48% of participants completed the one-week follow-up module, and 24% of participants completed the one-month follow-up module. The authors indicated the need to adapt the content of the interventions further, with a stronger focus on motivating participants to complete the follow-up activities.

The format in which eHealth interventions are administered has also been suggested to have an important impact on intervention efficacy. A pilot study examined

the effect of a weight-management intervention delivered via smartphone app, website, or paper diary (Carter et al., 2013). All of the interventions provided similar self-monitoring components that incorporated goal setting and feedback. The trial retention rates were 93% in the smartphone group, 55% in the website group, and 53% in the diary group at six months. Additionally, diet record adherence was significantly higher in the smartphone group than in the website and paper diary groups (mean (standard deviation): 92 (67) days, 35 (44) days, and 29 (39) days, respectively, p<0.001).

A randomized controlled trial of an eHealth intervention based on social cognitive theory in which parents of toddlers were given access to a website that provided educational materials and tips for creating a healthy food and eating environment along with activities, recipes, and opportunities for collaboration was conducted, with an intervention period of six months (Røed et al., 2021). Vegetable intake was found to be increased at the first follow-up but not at the second follow-up, indicating the lack of persistence of the intervention effect. The authors suggested the implementation of tailoring approaches as a possibility for optimizing the intervention to improve long-term persistence of the increased vegetable consumption.

Tailored Health Interventions

Although many eHealth interventions have shown a promising ability to elicit dietary behavior changes, there is an opportunity to improve these interventions to further improve outcomes and increase intervention adherence. One promising approach is the use of tailoring techniques. eHealth interventions provide many opportunities to tailor interventions at the individual level due to the associated data collection and processing capabilities. Because a large amount of data can be collected and processed in real time,

digital tools have been developed to provide tailored feedback to individuals according to their current state. This has many important implications because tailored interventions have the potential to result in more meaningful outcomes.

Tailored health interventions have been shown to be effective in increasing health-promoting behaviors across various populations (Lustria et al., 2013). The idea that the same generic health messaging and public health programs can encourage shifts in behavior in all population groups and under various circumstances has greatly limited the effectiveness of many health-promotion attempts (Lustria, 2017; Stellefson et al., 2008). It has been shown that failure to consider individual needs or relevance when providing health information can dramatically limit health behavior change (Noar et al., 2009; Sahin et al., 2019; Schwartz et al., 2020; Suggs & McIntyre, 2009; Te Poel et al., 2009).

Intervention tailoring is a method that integrates individualized messages or approaches according to variables or characteristics at the individual level that are associated with the target behavior (Kreuter et al., 2000; Lustria et al., 2009). Tailoring increases the relevance of health information and messaging, thereby increasing the impact of interventions (Hawkins et al., 2008). Moreover, interventions that use tailoring approaches have been suggested to increase participant attention, reduce processing effort, increase perceived relevance of the message, and increase perceived message salience (Ken Resnicow et al., 2008). However, many interventions and programs continue to utilize less-individualized approaches because these types of interventions tend to be lower cost, require less time, and require less training and personnel (Lairson et al., 2011).

Previous studies have demonstrated the efficacy of tailored interventions. For example, one study examined the results of 88 tailored health interventions targeting smoking cessation, physical activity, diet, and breast cancer screening and demonstrated that the tailored interventions resulted in a significant but small mean effect size (g=0.17) (Krebs et al., 2010). A study assessing the effect of a transtheoretical model-based tailored intervention aimed at improving adherence to the DASH diet was conducted with 533 individuals with uncontrolled hypertension (Rodriguez et al., 2019). At 6 months, the tailored intervention group exhibited a significant increase in DASH score compared to the usual care group, whereas a non-tailored intervention group did not demonstrate a significant difference when compared to the usual care group.

A qualitative study examined themes related to lifestyle change implementation in low socio-economic status populations (Coupe et al., 2018). The researchers observed community-run weight-loss groups and then interviewed 11 group facilitators and 14 group members in a low-socioeconomic region in northwest England. Two themes were identified in the interviews: managing diversity and environment. The discussions of managing diversity centered around challenges faced when attempting to deliver a generic intervention to a population that is diverse in regard to knowledge, language and literacy skills, and culture. The concepts related to environment included differences in cost and access and availability of food and leisure activities. The authors stressed the importance of tailoring interventions to account for these important differences among individuals that impact the efficacy of programs and interventions.

In a four-week study examining goal-setting techniques aimed at reducing stress, 65 individuals were randomized to an easy goal group, a difficult goal group, or an

adaptive goal group (Konrad et al., 2015). The easy goal group maintained easy goals throughout the study period, the difficult goal group maintained difficult goals throughout the study period, and the goals in the adaptive goal group were modified according to previous performance. For example, if an individual met their goal one day, they would be given a more difficult goal for the following day. Compared to their baseline values, the Depression, Anxiety, and Stress Scale scores decreased significantly only in the adaptive goal group (mean differences: -2.25, -2.64, and -9.47 points in the easy, difficult, and adaptive goal groups, respectively, P<0.001). The findings indicated that the adaptive goal system resulted in more positive effects on stress because it was able to find a balance in the degree of challenge of the goals.

Behavioral Persistence

One of the major pitfalls of many health-related interventions, especially in the field of eHealth, is the lack of persistence of behavior change. Successful behavior-change programs consider two important phases of behavior change: behavior adoption and behavior maintenance (Voils et al., 2014). Behavior-change interventions have traditionally placed a strong focus on the adoption of a new behavior, while neglecting the maintenance phase of behavior change (Lawler et al., 2014). In fact, typically, engagement in a target behavior tends to decrease or end entirely once the intervention ends, leading to decreases in behavioral gains over time (Judah et al., 2013).

This concept of poor behavioral persistence is particularly notable in the field of eHealth interventions, which are associated with poor behavior adoption and attrition (Springer et al., 2018). In fact, nearly 50% of individuals who identified as having used an eHealth application at some point reported that they no longer use it (Krebs & Duncan,

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2015). There are two important components of eHealth intervention persistence: behavior adoption and intervention attrition. Challenges associated with both of these components must be addressed to increase the impact of eHealth interventions.

Behavior Adoption

Behavior adoption is described in the literature as the initiation of a new behavior in which an individual does not already participate regularly (Buis et al., 2013). Behavior adoption is an important primary focus of behavior-change interventions—an individual must adopt a behavior before the behavior can be maintained (Marcus et al., 2000). Therefore, a substantial amount of effort in behavior-change interventions goes towards encouraging and facilitating behavior adoption.

Attrition

Attrition is the phenomenon of ceasing engagement in an intervention and not returning over time (Eysenbach, 2005). Although attrition is oftentimes considered a 'fixed cost' in the delivery of interventions, attrition can be assessed, characterized, and reduced (Springer et al., 2018). The acknowledgement of the importance and influenceability of attrition has led to studies focusing specifically on the reasons for attrition in intervention trials.

In one such study, individuals with bipolar disorder were recruited to participate in an online education program, and a sample of those who did not complete the program were interviewed and characteristics were compared between intervention completers and non-completers (Nicholas et al., 2010). Young age, male gender, and clinical recruitment setting were significant predictors of attrition ($F_{7,330}$=8.08, P<0.001). The qualitative findings of the study suggested that some of the main factors underlying attrition were

not wanting to think about one's illness and program-related factors, such as the provided information being too general and not tailored at the individual level.

Theoretical Framework

The behavior-matching tool assessed in this study was not informed by a specific theoretical model. However, given the possible mechanisms of action of the tool on target behavior adoption, social cognitive theory (SCT) can provide a theoretical framework in which the results of the study can be contextualized. SCT is a widely used theory of motivation based on the idea that internal processes are precursors to behavioral outcomes (Schunk & DiBenedetto, 2020). SCT is widely applied in diverse contexts, such as emotional disorders, mental and physical health, and career choice (Luszczynska & Schwarzer, 2015). The digital tool assessed in the current study was informed by some of the central constructs of SCT: self-efficacy, attitudes, and outcome expectancy.

Self-efficacy

Many behavior models and theories include some construct that reflects an individual's perceived capability to engage in a behavior in question. These constructs have been demonstrated to be very important in the field of health behavior due to their associations with a wide range of behaviors and outcomes (Jerusalem & Schwarzer, 1992). As constructs reflecting an individual's perceived ability to engage in a behavior, perceived competence and self-efficacy are often used interchangeably. However, there are some important distinctions between the two. Perceived competence is included as a construct in Self-Determination Theory, and self-efficacy is included as a construct in SCT (Rodgers et al., 2014). Perceived competence is a person's perception of their basic ability to engage in a behavior, while self-efficacy has been shown to be more complex in

that it reflects an individual's confidence in their ability to engage in a behavior in a variety of circumstances, including challenging ones (Rodgers et al., 2014).

There are many examples in the literature of the association of self-efficacy with various health behaviors and outcomes. A previous study showed that high levels of perceived health self-efficacy predicted nutrition- and health-related information seeking (Marks & Lutgendorf, 1999). Breast cancer patients exhibiting difficulty accessing information related to their cancer diagnosis were found to have lower levels of self-efficacy (Arora et al., 2002). Moreover, among dialysis patients, self-efficacy was associated with better protocol adherence (Christensen et al., 1996).

Similarly, an intervention based on SCT that used tailored information and self-regulation strategies to improve nutrition-related behaviors showed that the intervention led to greater consumption of F&Vs and that physical outcome expectations mediated the effect of self-efficacy on nutrition outcomes, indicating that many of these theory-based constructs had synergistic effects on health outcomes (Anderson et al., 2001). As evidenced by the existing literature on the important role of self-efficacy in health behavior across a wide range of behaviors and populations, self-efficacy may be an important construct to consider when developing interventions with the aim of changing health behaviors. However, in general, studies tend to focus on increasing self-efficacy through education and counselling rather than leveraging existing levels of self-efficacy associated with various behaviors by making high-impact behaviors for which individuals already have a high level of self-efficacy more salient.

Attitudes

The definition of *attitude* varies slightly among fields of study. However, across research areas, an attitude is typically considered an evaluative predisposition towards an idea, object, issue, or behavior (Fishman et al., 2021). Louis Thurstone developed a method to assess attitudes by pairing statements with numerically scaled response options. These scales allowed for the assessment of the degree to which an individual judged an issue favorably or unfavorably (R. C. Peterson & Thurstone, 1932).

Martin Fishbein and Icek Ajzen extended this idea of attitude to the realm of behavior in particular, defining one's attitude toward a behavior as a result of an evaluation of a behavior that predisposed the individual either favorably or unfavorably towards engaging in the behavior (Ajzen & Fishbein, 1977). According to this logic, the belief that engaging in a behavior would have mostly positive consequences would lead to a supportive attitude in favor of engaging in the behavior in question. Previous studies have demonstrated that attitudes towards a behavior can predict engagement in a behavior through the mediator behavioral intention. In order to successfully predict a behavior using measures of attitude, it has been found that it is important to measure attitudes toward the specific behavior of interest rather than attitudes toward more general concepts, such as groups of behaviors, policies, people, and objects; this importance of specific measurement has been termed the *principle of correspondence* (Albarracín et al., 2014; Fishbein & Ajzen, 1977; Valois & Godin, 1991). The principle of correspondence is important because it has been found that attitudes can vary according to specific behaviors (Presseau et al., 2019).

Outcome Expectancy

As described previously as an often-important determinant of attitude, outcome expectancy (i.e., the outcome that one expects if they engage in a certain behavior) has also received attention as a determinant or predictor of behavior in the context of SCT. Outcome expectancies are people's beliefs about the potential consequences of their behaviors (Luszczynska & Schwarzer, 2015). It has been found that outcome expectancy has a strong influence on the types of goals people set for themselves: people commit to goals that they perceive achieving as being desirable and feasible (Lehmann et al., 2019).

Mere-Measurement Effect

The mere-measurement effect is another potential mechanism through which the digital tool that is the focus of the present study could operate. It has been found that simply asking participants questions about specific behaviors could increase engagement in the behavior due to the mere-measurement effect (Morwitz & Fitzsimons, 2004). Several studies have shown that simply asking questions about a behavior can lead to changes in subsequent behavior (Williams et al., 2006). The mere-measurement effect has been described as "a strengthened relationship between latent intentions and behavior due to the measurement of intentions" (Schmidt, 2014). This phenomenon has been observed in various disciplines, including consumer research, public health, and environmental conservation (Schmidt, 2014), and has been referred to as the mere-measurement effect, self-generated validity, the self-erasing error of prediction, and the self-prophecy effect (Feldman & Lynch, 1988; Morwitz & Fitzsimons, 2004; Sherman, 1980; Spangenberg & Greenwald, 2001).

A mechanism that has been suggested to underly this effect is as follows. First, it has been proposed that pre-existing intentions could become mentally more accessible as a result of answering a question related to the behavior, and this higher mental accessibility of intentions may make behaviors more consistent with previous intentions (Voigt et al., 2020). While the mere-measurement effect can cause problems related to confounding in market research studies aimed at assessing the likelihood of purchasing a product, it is possible that the mere-measurement effect can be utilized to encourage the adoption of health-promoting behaviors in the context of health interventions by asking individuals about their future participation in a health-promoting behavior.

Fruit and Vegetable Consumption

Diet is an important focus of health-promotion interventions, and this study focuses specifically on the adoption of behaviors associated with improving the intake of F&Vs. The importance of consuming adequate F&Vs in support of a healthy lifestyle has been widely discussed in scientific literature and government reports and recommendations, making F&V consumption an ideal target of eHealth interventions (Galland, 2010; Holder, 2019; Jansen et al., 2021a; Produce for Better Health Foundation, 2015; Slavin & Lloyd, 2012; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2020). The consumption of F&Vs has been linked to a reduced risk of many chronic diseases, including heart disease, type 2 diabetes mellitus, certain cancers, stroke, Alzheimer's disease, and cataracts (Adams et al., 2019; Neuhouser, 2019; R. Ng et al., 2020; Schulze et al., 2018). In the United States, poor diet was identified as the leading cause of death in an analysis of 2016 Global Burden of Disease Study data (The US Burden of Disease Collaborators, 2018). In 2017, it was

estimated that worldwide, 3.9 million deaths were attributed specifically to inadequate F&V consumption (World Health Organization, 2019).

Despite the overwhelming evidence indicating the health benefits associated with consuming F&Vs, people generally fail to consume the recommended number of servings for each, indicating an important opportunity for diet optimization and health promotion. The 2020 Dietary Guidelines for Americans recommend the consumption of at least 4.5 cup-equivalents of F&Vs each day according to a 2,000-calorie diet (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2020). However, according to the most recent data from the National Health and Nutrition Examination Survey (NHANES), people in the United States consume an average of 2.32 cup-equivalents of F&Vs each day, indicating marked underconsumption of these important food groups (Economic Research Service & U.S. Department of Agriculture, 2021).

Differences in the consumption of F&Vs according to certain demographic characteristics, such as gender, race, ethnicity, age, urban/rural residence, and socioeconomic factors, have been reported (Drisdelle et al., 2020; Dubowitz et al., 2008; C. Lee & Pena-y-Lillo, 2022; Savoca et al., 2009). While these disparities in F&V consumption require further exploration to determine the best methods to close the gap in F&V consumption between these populations, it is important to note that F&V consumption has consistently been low in all subpopulations and that effective interventions are urgently needed to increase F&V consumption among all population subgroups in the United States. A recent study assessed differences in the proportions of individuals meeting the F&V recommendations according to sex, age, rural/urban residence, and the area-level disadvantage index (Livingstone et al., 2020). In the overall

population, only 7% of participants reported meeting the F&V intake recommendations. Females and older individuals were found to be significantly more likely to meet the recommendations, but the proportions of individuals meeting the recommendations in these subgroups were still low, at 10.1% and 11.8%, respectively. In this study, the area-level disadvantage index, a proxy measure of socioeconomic status, was associated only with the prevalence of meeting the recommendations for fruit intake, not the combined F&V intake recommendation. Similarly, a cross-sectional study of 270,612 adults in the United States estimated that approximately 9% of people consumed F&Vs five times per day, and no significant relationship between income inequality and daily F&V consumption frequency was identified (Horino et al., 2020).

F&V intake adequacy has also been assessed in other vulnerable populations. A recent study examined health behaviors among pregnant women in the United States using data from NHANES from 2007–2014 (Francis et al., 2021). Data from 248 pregnant women were analyzed, revealing that 35.4% of women consumed adequate F&Vs, demonstrating differences according to race/ethnicity and education level. The percentage of women meeting the F&V recommendations ranged from 14.72% among non-Hispanic black women to 37.82% among non-Hispanic white individuals and from 11.47% among high school graduates to 70.6% among those who completed some college. Although these percentages are higher than those reported in the general population, the overall prevalence of pregnant women achieving the recommended F&V intake is still low, which is concerning because of the importance of healthy behaviors during pregnancy due to their associations with health outcomes of both mothers and their infants (Herzog-Petropaki et al., 2022).

Barriers to Fruit and Vegetable Consumption

The low rate of achievement of F&V consumption recommendations among Americans likely results from a host of issues, including a variety of barriers to F&V intake that occur in different contexts. A mixed-methods study was conducted to explore such barriers among 13,788 individuals from the general population of Greater Bendigo, Australia through quantitative analysis and in a subgroup of 5,649 of these individuals through qualitative analysis (Livingstone et al., 2020). Only 7% of participants met the F&V intake recommendations. A number of main barriers to F&V consumption were identified, including lack of time, perception of unachievable guidelines, availability of a wide variety of other foods, and high cost and limited availability of F&Vs. The barriers were also assessed in subgroups, and the main barriers in each group included taste among males, lack of appetite among females, lack of time among young to middle aged adults, lack of appetite among older adults, and cost and availability of F&Vs among rural and disadvantaged participants. The main barriers were considered those that were reported at the greatest frequency among participants.

Another study investigated the barriers to F&V access at the community level (Haynes-Maslow et al., 2013). This research revealed that there were 6 major barriers: cost, transportation, quality, variety, changing food environment, and changing societal norms as they relate to food. A study conducted with a sample of participants in a farmers' market incentive program identified cost, spoilage, knowledge of F&V preparation methods, and lack of thought about F&Vs when hungry as the main barriers to F&V consumption (Singleton et al., 2018). Pinho et al. (2018) identified lack of

willpower, time constraints, and taste preferences as barriers that were most strongly associated with dietary behaviors.

Health Benefits of Fruit and Vegetable Consumption

Chronic Disease Risk

Higher F&V consumption has been associated with a lower risk of a multitude of chronic diseases, many of which are leading causes of mortality and disability in the United States (Murphy et al., 2021). The most widely researched chronic diseases and syndromes in the context of F&V consumption include cardiovascular disease, type 2 diabetes, cancer, depression, and metabolic syndrome, which will be discussed in detail below.

Cardiovascular Disease

A study examined the associations between F&V intake and prevalent coronary heart disease using National Health and Nutrition Examination Survey (NHANES) data from 1999 to 2014 (Conrad et al., 2018). The researchers found an inverse linear relationship between vegetable intake variety and prevalent coronary heart disease (P for trend=0.032) and between vegetable consumption amount and coronary heart disease (P for trend=0.026) in the sample of 38,981 adults. A systematic review and meta-analysis of prospective cohort studies assessing the associations of fruit and vegetable intake with incident cardiovascular outcomes among individuals free of disease at baseline revealed decreased disease and mortality risk (Zurbau et al., 2020). The risk ratios (95% confidence intervals) were 0.93 (0.89–0.96) for cardiovascular disease, 0.88 (0.83–0.92) for coronary heart disease, and 0.82 (0.77–0.88) for stroke.

A number of factors contribute to the development of cardiovascular disease. However, inflammation has been shown to be a particularly important component of the pathogenesis of cardiovascular disease, and inflammatory markers, such as IL-6, have demonstrated strong correlations with cardiovascular disease development (Silveira Rossi et al., 2022). The association between F&V consumption and inflammatory biomarkers was assessed in a sample of 233 older adults (Papaioannou et al., 2022b). It was found that vegetable intake was inversely associated with the inflammatory marker IL-6.

Type 2 Diabetes

Type 2 diabetes is associated with a substantial socioeconomic burden due to its high prevalence and associated health problems and quality of life impairments (Cannon et al., 2018). An important risk factor for type 2 diabetes is poor diet quality, including inadequate F&V consumption (Kahleova et al., 2019). An analysis of participants of the DOrtmund Nutritional and Anthropometric Longitudinally Designed (DONALD) study indicated that higher intake of flavonoids from F&Vs during adolescence was associated with improved insulin sensitivity and a lower pro-inflammatory score in early adulthood (P for trend <0.001 and 0.02, respectively) (Penczynski et al., 2019). Additionally, an analysis of the 11-year incidence of type 2 diabetes among 3704 individuals recruited from the general population in Norfolk, England, showed that comparing the high tertile with the low tertile, vegetable consumption was inversely associated with type 2 diabetes (hazard ratio 0.76 (95% confidence interval 0.60-0.97)) (Cooper et al., 2012).

A study was conducted to determine the long-term effects of a low-carbohydrate Mediterranean diet (characterized by high F&V intake) compared with the effects of a low-fat diet in overweight middle-aged men and women with newly diagnosed type 2

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diabetes (Esposito et al., 2014). Participants were randomized to either the low-carbohydrate Mediterranean diet group or the low-fat diet group. All participants required drug treatment for diabetes after 6.1 years and 8.1 years of follow-up in the low-fat diet and low-carbohydrate Mediterranean diet groups, respectively, indicating a delay in medication requirement in the Mediterranean diet group. Moreover, the rate of remission (partial or complete) was 14.7% (13.0-16.5%) in the first year and 5.0% (4.4-5.6%) in the sixth year in the Mediterranean diet group compared with 4.1% (3.1-5.0%) in the first year and 0% in the sixth year in the low-fat diet group.

Cancer

Several observational studies have shown that higher F&V intake is associated with a lower risk of certain cancers, such as prostate cancer, pancreatic cancer, lung cancer, and colorectal cancer (Albanes & Hartman, 2019; Chan et al., 2005; Myneni et al., 2021; Rowles III & Erdman Jr, 2020). An analysis of data from the Nurses' Health Study showed that higher consumption of total F&Vs, particularly cruciferous and yellow/orange vegetables, was associated with significantly lower breast cancer risk among US female registered nurses (>5.5 vs. ≤2.5 servings/day: hazard ratio=0.89, 95% confidence interval=0.83-0.96, P for trend=0.006) (Farvid et al., 2019). Additionally, gastric cancer risk was found to be inversely associated with vegetable consumption but not fruit consumption in a study with a mean follow-up of 7.2 years (hazard ratio of 0.56 (95% confidence interval 0.34-0.93) for the consumption of ≥2.5 servings/day compared to <1 serving/day) (Larsson et al., 2006).

A study conducted in Canada using data from the Canadian Community Health Survey that collected data from the general population examined the current attributable

and future avoidable cancer burden associated with low F&V consumption (Poirier et al., 2019). The researchers used data on cancer incidence, exposure prevalence, and risk effects to estimate the population attributable risk for cancers related to low F&V consumption. The estimation revealed that the population attributable risks for colon cancer associated with low intake of fruit and low intake of vegetables were 6.1% and 2.2%, respectively. It was estimated that a one-serving increase in fruit consumption per week could prevent 20,710 cases of colorectal cancer cumulatively through 2042.

Depression

A meta-analysis of observational studies assessing the association between fruit and vegetable consumption and depression risk revealed pooled relative risks (95% confidence intervals) for depression in the highest versus the lowest category of fruit intake of 0.83 (0.71–0.98) in cohort studies and 0.76 (0.63–0.92) in cross-sectional studies and revealed pooled relative risks (95% confidence intervals) for depression in the highest versus lowest category of vegetable consumption of 0.86 (0.71–0.98) in cohort studies and 0.75 (0.62–0.91) in cross-sectional studies (Saghafian et al., 2018). Additionally, a study conducted with adults aged 60 years or older compared individuals with depression to those without depression in regard to F&V consumption (Payne et al., 2012). The researchers found that individuals in the depression group reported lower levels of fruit (P=0.0227) and vegetable (P=0.0323) intake than individuals in the control group.

Metabolic Syndrome

Metabolic syndrome is defined as a cluster of metabolic factors, including elevated waist circumference, elevated triglycerides, reduced high-density lipoprotein

cholesterol, elevated blood pressure, and elevated fasting plasma glucose (P. M. Nilsson et al., 2019). A study investigating trends in the prevalence of metabolic syndrome using NHANES data revealed that from 2011 to 2016, the prevalence of metabolic syndrome increased significantly among individuals aged 20 to 30 years (from 16.2% to 21.3%, P for trend=0.02), women (from 31.7% to 36.6%, P for trend=0.04), Asian individuals (from 19.9% to 26.2%, P for trend=0.008), and Hispanic individuals (from 32.9% to 40.4%) (Hirode & Wong, 2020). Due to the increasing prevalence of metabolic syndrome in these groups along with the increased risks of serious chronic diseases associated with metabolic syndrome, the prevention of metabolic syndrome has become an important research focus.

A recent study revealed that lower F&V consumption was significantly associated with a higher prevalence of metabolic syndrome in a sample of 93 men and 152 women aged 65-70 years (odds ratio: 1.23, 95% confidence interval: 1.03-1.47) after controlling for various covariates (Papaioannou et al., 2022a). A prospective study was conducted in which 5,688 individuals aged 40-69 years without metabolic syndrome at baseline were recruited and followed for eight years to identify factors associated with the development of metabolic syndrome (Lim & Kim, 2020). The study revealed that individuals who consumed ≥4 servings of fruit per day had a lower risk of developing metabolic syndrome than individuals who consumed <1 serving of fruit per day (hazard ratio (95% confidence interval) = 0.55 (0.44-0.67), P<0.0001 for men and 0.57 (0.47-0.70), P for trend <0.0001 for women). Additionally, frequent fruit consumption exhibited inverse associations with abdominal obesity, hypertriglyceridemia, and elevated blood pressure.

However, frequent vegetable consumption was inversely associated with the risk of hyperglycemia only in men (hazard ratio (95% confidence interval)= 0.65 (0.44-0.96)).

Mortality

A previous study showed a 27% lower cardiovascular disease mortality rate among individuals who consumed F&Vs at least three times per day than among those who consumed F&Vs only one time per day; the study also demonstrated inverse correlations of F&V intake with stroke mortality, cardiovascular disease mortality, coronary heart disease mortality, and all-cause mortality (Bazzano et al., 2002).

A recent analysis of two prospective cohort studies and a meta-analysis of 26 cohort studies revealed nonlinear inverse associations between F&V consumption and total mortality, as well as cancer-, cardiovascular disease-, and respiratory disease-related mortality (all P values <0.001) (Wang et al., 2021). The analysis compared the associations of consuming approximately 5 servings of F&Vs per day versus only 2 servings per day with all-cause and disease-specific mortality. The following hazard ratios (95% confidence intervals) were obtained: 0.87 (0.85–0.90) for all-cause mortality, 0.88 (0.83–0.94) for cardiovascular disease-related mortality, 0.90 (0.86–0.95) for cancer mortality, and 0.65 (0.59–0.72) for respiratory disease-related mortality.

Weight Control

Nearly one-third of the world's population is now classified as either overweight or obese (Network, 2017). This phenomenon represents a significant threat to public health because obesity increases the risks for diabetes mellitus, cardiovascular disease, several types of cancers, musculoskeletal disorders, and poor mental health (Chooi et al.,

2019). Lifestyle factors, including diet, have been identified as important factors in the development of obesity (Kopp, 2019).

Several clinical trials have been conducted in which F&Vs are integrated into energy-controlled or liberal diets to promote weight loss or prevent weight gain, with inconsistent results that indicated that promoting increased F&V consumption alone might not be sufficient to induce weight loss but that diets higher in F&Vs are associated with healthier weight status (Kaiser et al., 2014; Mytton et al., 2014; Tohill et al., 2004). One such prospective study examining changes in body mass index and weight in relation to F&V intake revealed that a 100-g increase in F&V consumption was associated with a 211-g decrease in weight and 0.94 kg/m^2 decrease in BMI only among men (B=-2.11, 95% confidence interval= -3.34 to -0.89, P<0.001; B=-0.94, 95% confidence interval -1.36 to -0.46, P<0.001, respectively), with nonsignificant findings among women (S. Yuan et al., 2018).

Wellbeing and Cognitive Performance

An analysis of baseline data from an intervention study showed that F&V consumption was associated with better sleep (Jansen et al., 2021b). Specifically, men with better sleep quality and shorter time to fall asleep reported higher F&V consumption (a 1.12-serving/day (95% confidence interval: 0.48-1.75) difference between high- and low-quality sleep and a 0.52-serving/day (95% confidence interval: 0.15-0.90) difference between those with the shortest time to fall asleep and those with the longest).

Existing research suggests that F&V intake is also associated with well-being, but this area of research is relatively new, indicating the need for additional work in this area (Holder, 2019). One intervention study demonstrated that participants who increased

consumption of vegetables for eight weeks exhibited increased mean Subjective Happiness Scale Scores (De Leon et al., 2022). In a study in which participants were followed over 3 waves of data collection from 2010 to 2017, it was found that mental well-being measured by the 12-item General Health Questionnaire exhibited a dose-response association with the quantity and frequency of F&V consumption, indicating that as people consumed more F&Vs, their scores for mental well-being increase (Ocean et al., 2019).

Additionally, the consumption of whole vegetables, excluding potatoes, was significantly associated with better cognitive performance on multiple cognitive tests (quintile 5 compared with quintile 1: digit symbol substitution test (DSST), mean difference of 2.84 (95% confidence interval 0.93-4.75, P for trend <0.01; Stroop test, mean difference of -2.87 (95% confidence interval -4.24 to -1.50, P for trend <0.01) (Mao et al., 2019). A study conducted with 27,842 men in which F&V consumption was assessed with a food frequency questionnaire every 4 years between 1986 and 2002 obtained similar results (C. Yuan et al., 2019). Higher intakes of vegetables, fruits, and fruit juice were significantly associated with lower odds of moderate or poor subjective cognitive function. Specifically, the odds ratio (95% confidence interval) for poor subjective cognitive function was 0.66 (0.55-0.80) for vegetable intake when the highest quintile was compared to the lowest quintile.

Health-Promoting Components of Fruits and Vegetables

Many health-promoting compounds in F&Vs have been identified that likely contribute to the host of benefits noted above. For example, F&Vs are rich in many health-promoting compounds and nutrients such as vitamin C, dietary fiber, and

phytochemicals, which are not found in large amounts in other food sources, such as meat, fish, dairy, and refined grains (Yahia et al., 2019).

Dietary Fiber

Despite the widely acknowledged health-promoting effects of fiber, Americans typically consume only approximately 15 grams of fiber per day, which is substantially less than the recommended adequate intake of approximately 25 grams (Frampton et al., 2021). This low intake is likely due to the fact that most commonly consumed foods are low in fiber. In American diets, the major sources of dietary fiber are white flour and potatoes (Slavin, 2008).

F&Vs tend to have low energy density due to their high fiber and water content, which has important implications in the context of weight control (Nour et al., 2018; Slavin & Lloyd, 2012). The satiating properties of F&Vs have been suggested to underlie the mechanism through which F&V consumption leads to reduced consumption of energy-dense and nutrient-poor foods to ultimately reduce overall calorie intake (Howarth et al., 2001; Rolls, 2009).

In addition to the effects on satiety and weight loss, dietary fiber from F&V could contribute to decreased cardiovascular disease risk (Dayib et al., 2020). It has been suggested that dietary fiber can decrease the risk of cardiovascular disease due to its effects on glucose control and serum cholesterol (Gao et al., 2021). In a study including 107,377 individuals, the consumption of soluble fiber was found to be associated with a reduced risk of cardiovascular disease (hazard ratio (95% confidence interval)= 0.80 (0.66-0.98), P for trend=0.01) (Partula et al., 2020).

Dietary fiber also plays an important role in healthy digestion and reduces the risks for and symptoms associated with many diseases related to metabolism and inflammation, such as cardiovascular disease, obesity, diabetes, colorectal cancer, and inflammatory bowel disease (Kasubuchi et al., 2015). Moreover, it has been found that the gut microbiome utilizes soluble fiber found in F&Vs to generate short-chain fatty acids through fermentation (Zhang et al., 2021). Short-chain fatty acids derived from soluble fiber have been shown to play important roles in many health-promoting processes. For example, short-chain fatty acids act as an energy source for colonocytes and the gut microbiome, reduce pH to prevent pathogen growth in the gastrointestinal tract, increase mineral absorption, increase glucose utilization, prevent neurodegeneration, and promote regeneration (Alexander et al., 2019).

Vitamin C

Vitamin C is an important antioxidant that has been associated with many health benefits including reduced risks of many age-related and degenerative conditions, such as cancer and cardiovascular disease (Li & Schellhorn, 2007). Because F&Vs are the primary sources of vitamin C, the low consumption of F&Vs usually results in suboptimal vitamin C intake (Brauchla et al., 2021). This is a particular concern because vitamin C plays important roles in many health-related processes due to its potent antioxidant and cofactor functions (Nancy Selvamary et al., 2020).

Phytochemicals

In addition to being a good source of various macro- and micronutrients, F&Vs have been shown to be rich in many other bioactive compounds, such as phytochemicals, which can reduce the risk of many major chronic diseases (Liu, 2013). The most

important groups of dietary phytochemicals include phenolics, alkaloids, phytosterols, and carotenoids (Otles & Bakirci, 2021). Flavonoids, a group of phenolic compounds, are found in high levels in many F&Vs and other plant foods; they have been associated with reduced risks of many chronic diseases, including heart disease, stroke, diabetes, cancer, Alzheimer's disease and cataracts (Hilliard et al., 2020; Maaliki et al., 2019; Parmenter et al., 2020). Moreover, flavonoid consumption has been shown to be inversely correlated with coronary heart disease mortality and myocardial infarction incidence (Micek et al., 2021; Perez-Vizcaino & Fraga, 2018). Flavonoid intake has also been shown to be inversely correlated with low-density lipoprotein cholesterol and total cholesterol concentrations (Fardoun et al., 2020). Carotenoids are also widely present in many F&Vs and are well-known for their provitamin and antioxidant functions (Liu, 2004).

Antioxidants and other phytochemicals are thought to prevent low-density lipoprotein oxidation, which could be one of the underlying mechanisms in preventing or delaying the progression of cardiovascular disease (Garcia & Blesso, 2021; Q. Zhang et al., 2019). Antioxidants and phytochemicals have also been shown to reduce platelet aggregation, impact cholesterol synthesis and lipid absorption, reduce blood pressure, and decrease inflammation. Another important function of the phytochemicals found in F&Vs is cancer prevention. The cancer-prevention effect is expected to be explained by the protective effects against DNA oxidation and modulation of signal transduction pathways that control cell apoptosis and proliferation (Liu, 2004).

Synergistic Properties

Interestingly, these health-promoting compounds found in F&Vs have been hypothesized to have synergistic effects when consumed as part of a whole food rather

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than in an isolated form in a supplement. In fact, some studies have shown that when consumed in an isolated form rather than as part of a food, individual antioxidants and phytochemicals do not show consistent beneficial effects; moreover, some of these compounds have even been shown to be harmful when consumed in an isolated form (Lippman et al., 2009; Omenn et al., 1996; The Alpha-Tocopherol Beta Carotene Cancer Prevention Study Group, 1994; Yusuf et al., 2000). This indicates the importance of identifying ways to increase F&V consumption because potential health benefits might often not be replicated through the use of supplements and fortification.

Assessment of Fruit and Vegetable Intake

Accurately assessing and quantifying F&V intake is necessary for surveillance, intervention, and epidemiological research (Thompson et al., 2002). Various dietary assessment methods are available, including 24-hour recalls, food diaries, food frequency questionnaires, and more recently, digital tools such as online interfaces and smart phone apps. When deciding which assessment method to utilize for a given study, it is important to consider each method's strengths and weaknesses. For example, food diary assessment methods tend to result in more accurate and detailed information, are associated with an increased participant burden because they require a lot of time to complete, require a certain level of participant literacy, and might not reflect an individual's usual intake, especially if completed for only one day (Kenneth Resnicow et al., 2000).

Reducing participant burden is an important consideration in research, especially in large-scale studies with large sample sizes or repeated measures. Some diet assessment methods, such as food frequency questionnaires, have been validated and been shown to accurately reflect dietary intake in a variety of contexts (Kenneth Resnicow et al., 2000).

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Furthermore, studies focused on particular consumption patterns or food groups can adopt abbreviated versions of some of these measures to further reduce participant burden (K. E. Peterson et al., 2008).

Many older studies of F&V consumption have utilized food frequency questionnaires to assess changes in F&V intake (Bertoia et al., 2015; Butler et al., 2004; Esfahani et al., 2014; Halkjær et al., 2009; He et al., 2004). A previous study assessed the associations of serum carotenoid levels with four F&V assessment methods: three food frequency questionnaires (two items, seven items, and 36 items) and a 24-hour recall (Kenneth Resnicow et al., 2000). The study showed that the 36-item food frequency questionnaire and a single 24-hour recall exhibited similar correlations with the serum carotenoid level (r=0.35 and r=0.37, respectively, both P<0.01). The two-item food frequency questionnaire exhibited a weaker correlation with serum carotenoids, but the correlation was still significant (r=0.22, P<0.01). Two-item food frequency questionnaires for the assessment of F&V consumption are associated with a very minimal participant burden and can reflect general intake of F&Vs; therefore, they have been used in several studies to assess F&V consumption cross-sectionally as well as longitudinally to reflect changes in F&V consumption (Campbell et al., 2009; Cappuccio et al., 2003; Jansen et al., 2021a).

A shift towards the use of digital tools for dietary data collection has been observed in recent years. Digital tools utilize information and communication technologies, including smartphone apps, patient mortals, and other internet-based programs or software (Adesina et al., 2022). Digital tools offer many benefits in the context of dietary data collection. For example, they are often more convenient for

participants than pencil-and-paper methods due to the ubiquity of technological devices. Individuals usually have a technological device within close proximity, which can overcome the barrier of pencil-and-paper diet logs requiring individuals to remember to bring the physical log with them wherever they go on the days they are recording their intake (Sharp & Allman-Farinelli, 2014).

Additionally, digital methods of dietary data collection offer other possibilities to decrease participant burden, such as the use of images to collect dietary data rather than recording a list of all foods consumed along with their ingredients (Gemming et al., 2015). Moreover, these digital methods have been shown to have good agreement with the traditional 24-hour dietary recall method. For example, a study was conducted with 80 university students in which participants used a diet-record app to record their dietary intake for five consecutive days and also completed three 24-hour dietary recalls during this period (Rangan et al., 2015). No significant difference was found between the app data and the 24-hour recalls related to mean nutrient and energy intake.

Current Study

Despite the impressive health-promoting properties of F&Vs, most people in the United States consistently fail to meet the F&V intake recommendations. Many interventions targeting F&V consumption have been reported in the literature, and many of them have resulted in increased consumption of F&Vs. However, as evidenced by the continued failure of the population to meet the F&V intake recommendations, there continues to be a need to develop new interventions targeting F&V consumption or optimize existing interventions to result in meaningful improvements in F&V consumption on a large scale.

Digital tools afford the possibility to optimize interventions by making them more engaging, scalable, and tailored at the individual level. Tailored interventions have been shown to be effective at inducing behavior change and can thus be beneficial when targeting F&V consumption. Tailoring interventions according to known behavioral determinants, such as perceived competence and outcome expectancies, could be a promising approach to changing behavior at a meaningful scale. Therefore, the present study proposes to assess the effect of behavior-matching tool designed to match individuals with a behavior associated with increased F&V consumption. The use of the behavior-matching tool is hypothesized to influence behavior by leveraging the mere-measurement effect by asking participants to rate the target behaviors; by allowing for behavioral determinants including perceived competence, attitudes, and outcome expectancies to be considered at the individual level; and by increasing the salience of the behaviors with the highest self-report rankings on these behavioral determinants. If found to be effective, this tool has the potential to be applied in conjunction with other interventions to make behaviors for which individuals perceive fewer barriers and higher efficacy more salient.

CHAPTER 3

METHODS

Setting and Participants

Individuals who were 18 years of age or older, resided in the United States, were

comfortable reading and writing in English, had access to and were comfortable using a

cellphone, had an email account that they checked daily Monday-Friday, made their own

food purchasing and consumption decisions, reported eating fewer than 5 servings of

fruits and vegetables per day and had a desire to increase their fruit and vegetable

consumption were eligible for inclusion in this study. The exclusion criteria included

chronic diseases that are not managed in a stable state, initiation of a new medication

within the last 3 months, allergies to any fruits or vegetables, irritable bowel disease, and

diagnosed eating disorders. The study was conducted remotely, with all correspondence

and data collection conducted online, allowing individuals residing anywhere in the

United States to participate.

Participants were recruited through word of mouth, social media, and online

listservs. All participants provided informed consent prior to participating in the study,

and the study was approved by the Arizona State University Institutional Review Board

(IRB ID: STUDY00017123, Appendix A).

Experimental Design

This study was designed as a two-group, parallel, randomized controlled trial. The

study assessed the effect of behavior-matching tool on multiple primary and secondary

outcome variables over the course of four weeks. The complete study design is shown in

Figure 1.

Figure 1. Study design
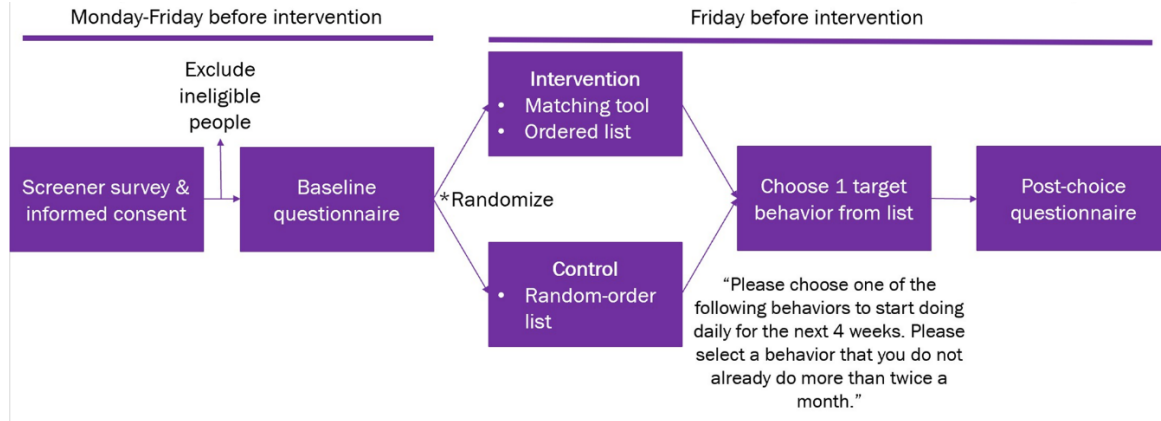
Potential participants completed a screening questionnaire administered through Qualtrics, comprising items related to the inclusion and exclusion criteria. Those who met these criteria were then asked to provide informed consent via the Qualtrics survey. Eligible participants then completed the baseline questionnaire, including items assessing F&V consumption, height, weight, demographics, and F&V consumption self-efficacy. All participants who completed the baseline questionnaire were then randomized to the intervention or control group in the Qualtrics survey:

- The intervention group rated 20 behavior options (described below) in terms of their perception of the efficacy of the behavior to lead to increased fruit and vegetable consumption ('not effective' (-8) to 'very effective' (8)) as well as their perception of the likelihood that they will engage in the behavior ('not likely to do' (-8) to 'likely to do' (+8)). Once participants rated all 20 behaviors on both scales, a Qualtrics survey was sent via email asking participants to choose a target behavior with the behaviors listed in descending order according to their matching score (calculated as 2x likelihood score + efficacy score). The following text was

placed above the list of behaviors: "Please choose one of the following behaviors to start doing every day for the next four weeks. **Please select a behavior that you do not already do more than twice a month**. The behaviors are listed in order of your 'behavior-matching' score, with the best options for you shown at the top of the list."

- The control group was given a link to a Qualtrics survey that showed them a list of the same 20 behaviors but in a random order. The following text was placed above the list of behaviors: "Please choose one of the following behaviors to start doing every day for the next four weeks. **Please select a behavior that you do not already do more than twice a month**."

Participants in both groups chose the behavior they wanted to adopt for the following four weeks from the list and submitted their choice via the Qualtrics survey (Appendix B). After choosing their target behavior, participants were informed that the four-week behavior adoption period would begin the following Monday and received a brief overview regarding the format of the informational emails and data-collecting text messages that they would receive throughout the study period.

During the four-week study period, participants in both groups received emails every Monday and Friday (eight emails in total) with information about the benefits of fruit and vegetable consumption. The schedule of the four-week study period is shown in Figure 2. All participants in the study (intervention and control groups) received the same emails and the same data-collection text messages throughout the study period (Appendix C).

Figure 2. Study schedule

Week 1	• Fruit and vegetable e-mail bulletin sent Monday and Friday • Daily data-collection text
Week 2	• Fruit and vegetable e-mail bulletin sent Monday and Friday • Daily data-collection text
Week 3	• Fruit and vegetable e-mail bulletin sent Monday and Friday • Daily data-collection text
Week 4	• Fruit and vegetable e-mail bulletin sent Monday and Friday • Daily data-collection text

Behavior-Matching Tool

The behavior-matching tool asks participants to rate specific behaviors according to their perception of the efficacy of the behavior in facilitating the achievement of a goal (in this case, increasing fruit and vegetable intake) as well as their perception of the likelihood that they would engage in the behavior. All behavior options the participants could choose from in this study were daily behaviors related to increasing fruit and vegetable consumption. Screenshots from an example behavior-matching tool are shown in Figure 3.

Figure 3. Screenshots of an example behavior-matching tool
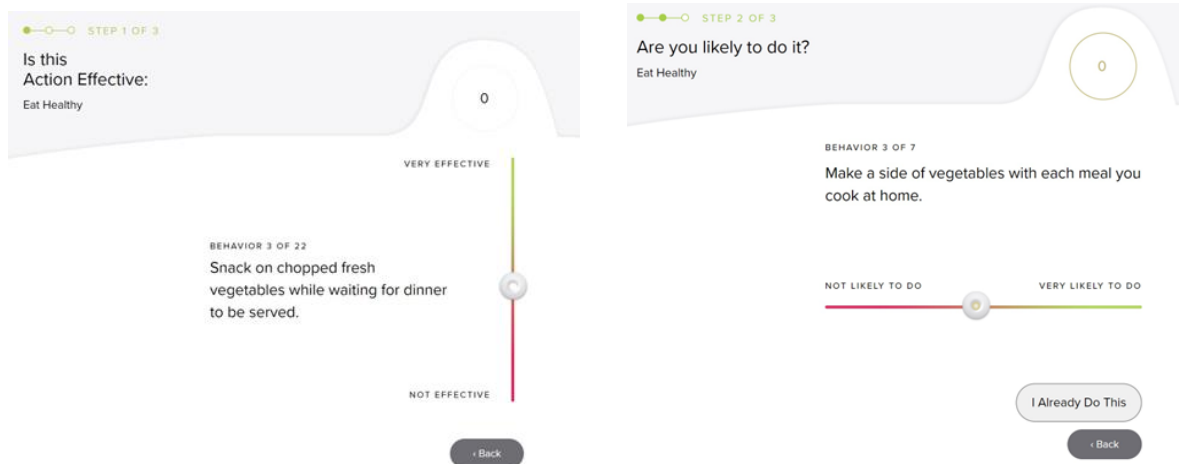
Behavior Options

The list of behaviors from which participants could choose were developed based on lists of fruit-and vegetable-focused behaviors provided as resources by the Academy of Nutrition and Dietetics and the American Heart Association (Academy of Nutrition and Dietetics, 2014; American Heart Association, 2017). Twenty behaviors from these resources were aggregated to form a preliminary behavior list (see Appendix D). These 20 behaviors were rated using the matching tool by 20 people prior to the start of the study to determine whether any of the behaviors were consistently rated among all individuals either abnormally high or abnormally low on perceived likelihood or efficacy. Histograms were created for each of the behavior options to allow for a visual inspection of the distributions of ratings. If the majority of the behavior options exhibited a similar pattern while certain behavior options exhibited different distributions on the histogram based on visual inspection, the two-sample Kolmogrov-Smirnov test would be conducted to compare the potential outlier with one of the behavior options that exhibits the similar-pattern distribution to determine whether the distributions are significantly different. Any items deemed to have outlier response distributions were excluded from the list used in the study.

Fruit and Vegetable Email Bulletin

Emails were sent to all participants each Monday and Friday during the four-week study period. The same emails were sent to all participants. Emails contained brief information about the health benefits of fruits and vegetables. The email content was based on information typically provided by the Academy of Nutrition and Dietetics, the American Heart Association, the American Diabetes Association, and other national

health associations. Previous studies have shown that educational materials sent via email can be an effective means of providing health-related information with the aim of changing behavior (Zahid & Reicks, 2019). This component of the intervention was identical between the control and intervention conditions.

Descriptive Data and Outcome Measures

The following demographic data were collected from all participants: age, gender, income, closest grocery store, and education level. Height, weight, physical activity, and the typical frequency of engaging in the chosen target behavior in the previous month were also reported by participants at baseline. The primary outcome was whether or not the participant engaged in their chosen behavior. This was assessed as a binary variable (yes or no). Secondary outcomes included fruit and vegetable consumption, the automaticity of the target behavior, and fruit and vegetable consumption self-efficacy.

Assessment of the primary outcome

Target behavior adoption was assessed through a simple question that was asked daily for 4 weeks via text message (i.e., "Did you [insert target behavior here] today? Reply Y or N"). The automatic text messaging service Simple Texting (Denver, CO, USA) was used to send text messages to participants at the same time every day and to collect data from the participants' text message responses. Participants were asked in the baseline questionnaire what time they typically go to sleep at night, and the automated text message was scheduled to be sent to each participant 90 minutes before their reported bedtime. If participants did not provide an answer within 45 minutes, they received a reminder message. If participants failed to respond to the reminder message, their data were considered missing for that day. Previous studies have shown that when

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text messages are used to gather repeated measures data in longitudinal studies, participants are more likely to provide information in real time, resulting in data that are more reliable and complete and minimizing recall bias (Shimoni et al., 2020).

Assessment of secondary outcomes

- **Attrition**

A conservative indicator of attrition that has been used in similar studies was adopted for use in this study (Springer et al., 2018). A participant was considered to have dropped out of the study after missing five consecutive daily datapoints, i.e., if they have not responded to a text message to indicate whether they had completed their target behavior that day five days in a row. A previous study found that variance was generally low for participants who missed one to four days in a row of data collection, suggesting that they usually completed the remainder of the study after their missed data streak. However, around a miss streak of 5, the variance increased substantially, suggesting that these participants were less likely to return to participate in the study (Springer et al., 2018).

An additional analysis was conducted based on attrition defined as a complete lack of response beginning at least 5 days prior to the end of the study period. This analysis allowed for the inclusion of participants with more erratic engagement in the study protocol, which can reflect real-world situations in which people participate in an intervention, discontinue participation for a time, and then return to participate in the intervention.

- **Fruit and vegetable consumption**

    Participants completed a validated two-question measure of fruit and vegetable consumption at baseline and after the four-week intervention. The two questions are as follows (Prochaska & Sallis, 2004):

Q1. In the past week, on a typical day, how many servings of fruit did you eat? A serving is equal to:

  o   1 medium piece of fresh fruit

  o   ½ cup of fruit salad

  o   ¼ cup of raisins, apricots, or other dried fruit

  o   6 oz. of 100% orange, apple, or grapefruit juice

(Do not count fruit punch, lemonade, Gatorade, Sunny Delight or fruit drink)

Q2. In the past week, on a typical day, how many servings of vegetables did you eat? A serving is equal to:

  o   1 medium carrot or other fresh vegetable

  o   1 small bowl of green salad

  o   ½ cup of fresh or cooked vegetables

  o   ¾ cup of vegetable soup

(Do not count French fries, onion rings, potato chips, or fried okra)

- **Fruit and vegetable consumption self-efficacy**

  A measure of dietary self-efficacy was also be completed by participants at baseline and after the four-week study period to see if using the behavior-matching tool resulted in higher overall fruit and vegetable consumption self-efficacy. Perceived dietary self-efficacy was measured by two items rated on a six-point scale. The two items are "I am confident that I can eat five servings of fruits and vegetables a day" and "I am confident that I can eat enough fruit and vegetables daily, even when there are no attractive shopping opportunities." (Kreausukon et al., 2012)

- **Behavioral automaticity**

  The Self-Report Habit Index (SRHI) was completed by participants after they chose their target behavior and again after the four-week study period to assess whether the target behavior became more automatic during the study period. The validated 12-item SRHI is as follows (Verplanken & Orbell, 2003):

  [Insert target behavior here] is something…

    1. I do frequently.

    2. I do automatically.

    3. I do without having to consciously remember.

    4. That makes me feel weird if I do not do it.

    5. I do without thinking.

    6. That would require effort not to do.

    7. That belongs to my (daily, weekly, monthly) routine.

    8. I start doing before I realize I'm doing it.

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9. I would find hard not to do.

10. I have no need to think about doing.

11. That's typically "me."

12. I have been doing for a long time.

The above items were rated on a 7-point scale anchored by *agree/disagree*.

Statistical Analyses

All analyses were conducted using R statistical software (R Core Team, 2021) and Excel (Microsoft Corporation, 2018). Data are reported as the mean ± standard deviation or median (interquartile range). Participant characteristics were described using descriptive statistics. The outcome variables were tested for normality using Q-Q plots and histograms, and non-normally distributed variables were logarithmically transformed to achieve a normal distribution where possible. When it was not possible to achieve a normal distribution through transformation, non-parametric tests were used. Homogeneity was assessed using Levene's test, and sphericity was assessed using Mauchly's test of sphericity.

Whether or not a participant engaged in their chosen behavior each day over the 28-day study period was assessed as a binary variable (0=no, 1=yes) and was the primary outcome of the study. This outcome was assessed for all participants daily, with 28 possible data points for each participant over the study period (daily assessment of binary outcome for 28 days). This binary outcome variable will be modeled using logistic regression. To account for individual differences in intervention response as well as the clustering of repeated-measures data from each participant, a mixed-effects logistic regression will be used, with participant as a random effect and group assignment as a

fixed effect. A power analysis conducted using PROC GLIMMIX indicated that the sample of 64 participants provided approximately 80% power to detect an odds ratio of 2.25, indicating a medium effect size, with an alpha value of 0.05.

The secondary outcomes were analyzed as follows. Continuous outcome variables that were normally distributed were compared as change scores between groups using t tests, whereas Mann-Whitney U tests were used for data that were nonnormally distributed. Five participants did not complete the post-study survey and were excluded from the analyses incorporating the post-study data. Baseline characteristics were compared between groups using the chi-square test for nominal variables and t tests or Mann-Whitney U tests for normally distributed and nonnormally distributed continuous variables, respectively. Text message response frequency was compared between the two groups using the chi-square test, and the Fisher exact test was used to compare the frequency of behavior choices between the groups. A survival analysis was conducted to compare attrition rates between groups. A log rank test was used to compare survival curves.

CHAPTER 4

RESULTS

Participant Characteristics

      Individuals were screened for eligibility using the online eligibility survey. Participants who met the inclusion criteria were then emailed a link to the baseline survey. All participants who completed the baseline survey were randomized to the control or intervention group using the randomization feature in Qualtrics, and these individuals comprised the randomized sample, which included 114 individuals. Participants who subsequently successfully selected a target behavior that they did not already report doing frequently comprised the analytic sample, which included a total of 64 participants (Figure 4).

Figure 4. CONSORT flow diagram of participant inclusion
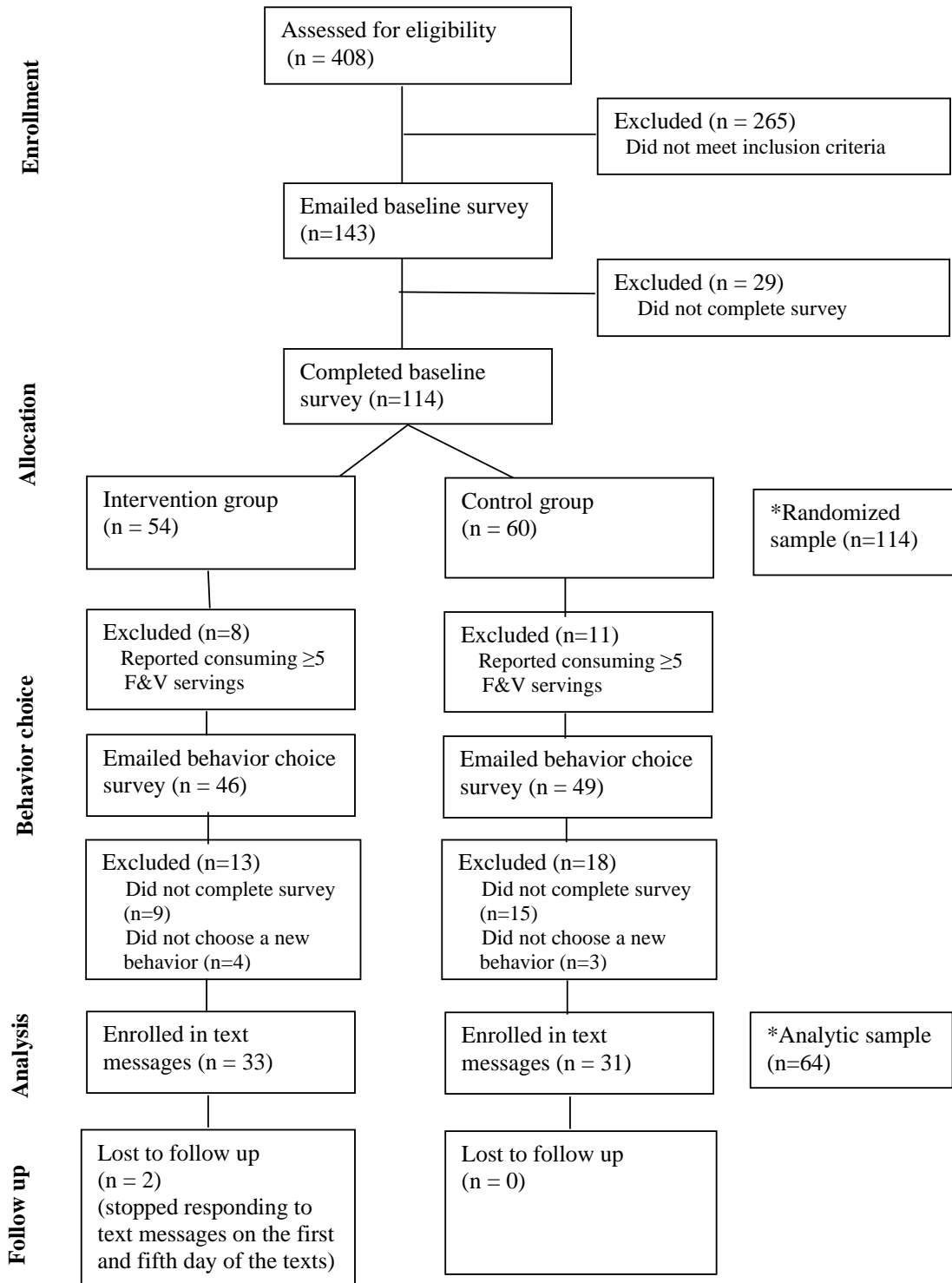
The characteristics of all participants who were randomized as a result of completing the baseline survey (randomized sample) and those of participants who successfully chose a target behavior and enrolled in the daily text messages (analytic sample) are shown in Table 1. None of the characteristics differed between the randomized sample and the analytic sample (p>0.05). The characteristics of the participants in the analytic sample are shown according to group allocation in Table 2. None of the characteristics differed between the control and intervention groups in the analytic sample (p>0.05).

Table 1. Characteristics of the randomized sample and the analytic sample

	Randomized sample (N=114)	Analytic sample (n=64)
Age, yrs (median (IQR))	35 (30-47)	34 (29.75-44.5)
Gender (Male / Female)	23 (20.2%)/	13 (20.3%)/
	90 (78.9%)	51 (79.7%)
Income, USD (median (IQR))	$60,000 ($39,576-$86,250)	$54,500 ($37,250-$90,000)
Education		
Less than high school	1 (0.9%)	0 (0.0%)
High school	5 (4.4%)	3 (4.7%)
Associate's degree	18 (15.8%)	12 (18.8%)
Some college	9 (7.9%)	6 (9.4%)
Bachelor's degree	47 (41.2%)	23 (35.9%)
Graduate degree	33 (28.9%)	20 (31.3%)
Nearest grocery store		
Less than 1 mile	38 (33.3%)	20 (31.3%)
1-5 miles	65 (57.0%)	39 (60.9%)
5-10 miles	4 (3.5%)	3 (4.7%)
10 or more miles	6 (5.3%)	2 (3.1%)
Household size, n		
1	12 (10.5%)	4 (6.3%)
2	47 (41.2%)	26 (40.6%)

3	18 (15.8%)	12 (18.8%)
4	21 (18.4%)	13 (20.3%)
5+	15 (13.2%)	9 (14.1%)
BMI (median (IQR))	25 (23-30)	25 (22.75-30.25)

* Values shown are number (%) of participants, unless otherwise indicated

Table 2. Characteristics of the analytic sample by group

	Control (n=31)	Intervention (n=33)
Age, yrs (median (IQR))	39 (30-46.5)	33 (27-43)
Gender (Male / Female)	6 (19.4%)/	7 (21.2%)/
	25 (80.6%)	26 (78.8%)
Income, USD (median (IQR))	$60,000 ($41,652-$121,500)	$50,000 ($35,000-$70,000)
Education		
High school	1 (3.2%)	2 (6.1%)
Associate's degree	2 (6.5%)	10 (30.3%)
Some college	5 (16.1%)	1 (3.0%)
Bachelor's degree	11 (35.5%)	12 (36.4%)
Graduate degree	12 (38.7%)	8 (24.2%)
Nearest grocery store		
Less than 1 mile	7 (22.6%)	13 (39.4%)
1-5 miles	21 (67.7%)	18 (54.5%)
5-10 miles	1 (3.2%)	2 (6.1%)
10 or more miles	2 (6.5%)	0 (0.0%)
Household size, n		
1	2 (6.5%)	2 (6.1%)
2	12 (38.7%)	14 (42.4%)
3	4 (12.9%)	8 (24.2%)
4	8 (25.8%)	5 (15.2%)
5+	5 (16.1%)	4 (12.1%)
BMI (median (IQR))	25 (23-31.5)	25 (22-30)

* Values shown are number (%) of participants, unless otherwise indicated

The subsequent sections outline the results of the analyses conducted with the analytic sample.

Baseline Fruit and Vegetable Data

Thu number of servings of F&V eaten by participants on a typical day was assessed at baseline, and the results are shown for all participants and according to group allocation in Table 3. There were no significant differences between the groups ($p > 0.05$).

Table 3. Typical fruit + vegetable consumption at baseline

	Total (n=64)	Control (n=31)	Intervention (n=33)
0 servings	2 (3.2%)	1 (3.2%)	1 (3.1%)
1 serving	4 (6.3%)	2 (6.5%)	2 (6.3%)
2 servings	14 (22.2%)	7 (22.6%)	7 (21.9%)
2.5 servings	2 (3.2%)	0 (0.0%)	2 (6.3%)
3 servings	24 (38.1%)	12 (38.7%)	12 (37.5%)
4 servings	18 (28.6%)	9 (29.0%)	9 (28.1%)

* Values shown are number (%) of participants

Target Behavior Choice

Table 4 shows the frequency of selection of the chosen behaviors in the total sample, the intervention group, and the control group.

Table 4. Frequency of behavior selection

	Total (n=64)	Control (n=31)	Intervention (n=33)
Mix up a breakfast smoothie made with low-fat or non-dairy milk, frozen strawberries and a banana.	9 (14.0%)	2 (6.5%)	7 (21.2%)
Drink a small (6-ounce) glass of juice. Be sure it's 100% fruit or vegetable juice without excess sodium or sugar – not "fruit drink," "cocktail" or "punch."	7 (10.9%)	4 (12.9%)	3 (9.1%)
Have any type of fresh fruit as a snack with breakfast: grapes, apple, banana, orange, kiwi, etc.	7 (10.9%)	4 (12.9%)	3 (9.1%)
Snack on raw veggie sticks, such as green or red bell peppers, green beans, celery or carrots.	7 (10.9%)	7 (22.6%)	0 (0.0%)
Have fruit salad for dessert.	4 (6.3%)	1 (3.2%)	3 (9.1%)
Have a vegetable salad with dinner.	4 (6.3%)	2 (6.5%)	2 (6.1%)
Add a side of steamed or microwaved vegetables to dinner.	3 (4.7%)	1 (3.2%)	2 (6.1%)
Add bananas, raisins or berries to your cereal, yogurt, waffle, or other breakfast dish.	3 (4.7%)	3 (9.7%)	0 (0.0%)
Have a fruit or vegetable salad with lunch.	3 (4.7%)	2 (6.5%)	1 (3.0%)
Have a piece of fruit or raw veggie sticks instead of chips with lunch.	3 (4.7%)	1 (3.2%)	2 (6.1%)
"Sandwich" in fruits and vegetables. Add pizzazz to sandwiches with sliced pineapple, apple, peppers, cucumber and tomato as fillings.	2 (3.1%)	0 (0.0%)	2 (6.1%)
Add chopped up vegetables to your eggs or potatoes at breakfast. Try onions, celery, green or red bell peppers, or spinach.	2 (3.1%)	1 (3.2%)	1 (3.0%)
Add grated, shredded or chopped vegetables such as zucchini, spinach and carrots to lasagna, meat loaf, mashed potatoes, pasta sauce and rice dishes.	2 (3.1%)	0 (0.0%)	2 (6.1%)
Eat dried fruit, such as raisins, dates or dried apricots, as a snack at work.	2 (3.1%)	1 (3.2%)	1 (3.0%)
Stuff an omelet with vegetables. Turn any omelet into a hearty meal with broccoli, squash, carrots, peppers, tomatoes or onions with low-fat sharp cheddar cheese.	2 (3.1%)	0 (0.0%)	2 (6.1%)
Make a veggie wrap with roasted vegetables and low-fat cheese rolled in a whole-wheat tortilla.	1 (1.6%)	1 (3.2%)	0 (0.0%)
Make fruit your dessert: Slice a banana lengthwise and top with a scoop of low-fat frozen yogurt. Sprinkle with a tablespoon of chopped nuts.	1 (1.6%)	0 (0.0%)	1 (3.0%)

Microwave a cup of vegetable soup as a snack or with a sandwich for lunch.	1 (1.6%)	1 (3.2%)	0 (0.0%)
Put vegetables, such as cucumber, sprouts, tomato, lettuce or avocado, on your sandwich or other lunch dish.	1 (1.6%)	0 (0.0%)	1 (3.0%)
Eat crunchy vegetables instead of chips with your favorite low-fat salad dressing for dipping.	0 (0.0%)	0 (0.0%)	0 (0.0%)

*Values shown indicate the number (%) of participants that chose the target behavior

As can be seen from the table above, there were some noticeable differences between the groups regarding the frequency of selection of certain target behaviors, namely, the intervention group chose the breakfast smoothie behavior more often than the control group, and the control group chose the snack on raw veggie sticks behavior more often than the intervention group. Fisher's exact test indicated that the frequencies of behavior selection differed significantly between the two groups ($p<0.05$).

Figure 5 shows the findings related to the chosen behavior's placement on the selection list in the (a) control and (b) intervention groups. Interestingly, the intervention group was significantly more likely to choose a target behavior that appeared earlier in the list than the control group ($Z=3.45$, $p<0.001$). The median (IQR) ranking of the chosen behavior on the behavior option list was 5 (2-11) in the intervention group, whereas it was 15 (10-16.5) in the control group.

Figure 5. Histogram of frequency of list placement of selected behavior
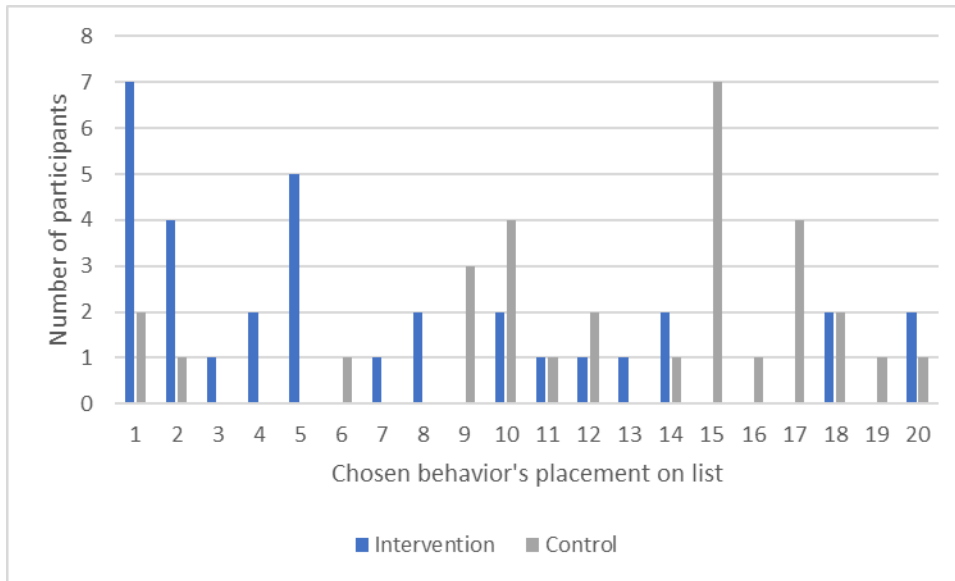
Target Behavior Adoption

Figure 6 shows the daily average target behavior adoption score in the control and intervention groups over the 28-day study period. The mixed-effect logistic regression analysis of target behavior adoption indicated that the effect of group allocation (intervention vs. control) was non-significant (b=0.09, 95%CI= -0.81, 0.98, p=0.85). The logistic mixed model was estimated using maximum likelihood and BOBYQA optimizer to determine whether group allocation was a predictor of daily behavior adoption. Additionally, participant ID was included in the model as a random effect to account for the within-participant nested nature of the repeated-measure data.

Figure 6. Daily average behavior adoption score by group (average of binary values: 0=did not engage in behavior, 1=engaged in behavior).
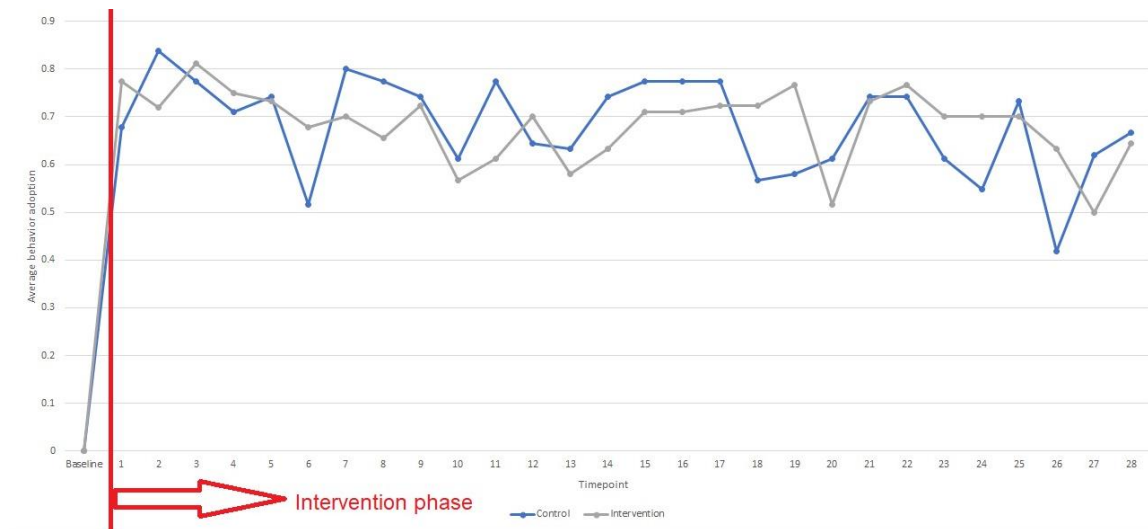
Note: The baseline value was derived from the following question on the baseline questionnaire: "How often do you typically do the target behavior that you selected?" with the options "Never," "Once a month," or "Twice a month."

Attrition rates

Kaplan-Meier survival curves were created to visualize the occurrence of attrition in the intervention and control groups during the study period (Figure 7). A log rank test was used to explore differences in attrition rates between the two groups. The results indicated that there was no significant difference in attrition between the two groups (χ^2=2.68, df=1, p=0.10).

Figure 7. Kaplan-Meier curve
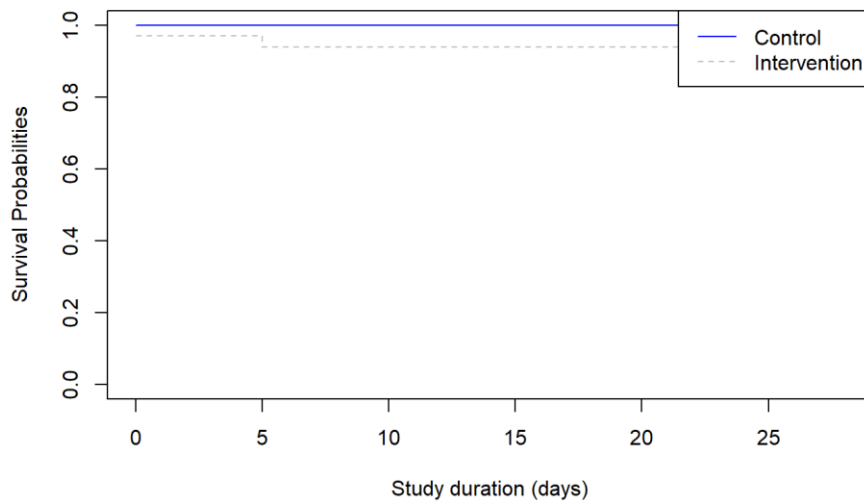
Changes in Fruit and Vegetable Consumption

Overall, the results for F&V consumption and the consumption of fruits and vegetables separately were similar. The statistical findings are outlined in detail below: the results indicated that improvements in F&V consumption occurred in the total sample, but there were no significant differences in change scores between the intervention and control groups.

Fruit consumption

Compared to the number of servings of fruit reported to be eaten by participants at baseline, the number of servings of fruit increased significantly in the total population after the four-week study period ($Z=-4.43$, $p<0.001$). However, there were no significant differences between the intervention and control groups in change in fruit consumption between baseline and post-intervention ($Z=-0.05$, $p=0.96$). The detailed data are shown in Table 5.

Table 5. Fruit consumption

	All Subjects (N=63)	Control (n=31)	Matching (n=32)
Baseline	1 (1-2)	1 (1-1.5)	1 (1-2)
Post-study	2 (1-3)	2 (1-3)	2 (1-3)
Change	1 (0-1)	1 (0-1)	1 (0-1)

* Values shown are median (IQR) numbers of servings consumed.

Vegetable consumption

        Self-reported vegetable consumption increased during the study period in the total sample (Z=-5.16, p<0.001), but no between-group differences in the vegetable consumption change score were identified (Z=0.10, p=0.92). The detailed data are shown in Table 6.

Table 6. Vegetable consumption

	All Subjects (N=63)	Control (n=31)	Matching (n=32)
Baseline	1.5 (1-2)	2 (1-2)	1 (1-2)
Post-study	2 (2-3)	3 (2-4)	2 (2-3)
Change	1 (0-2)	1 (0-2)	1 (0-1)

* Values shown are median (IQR) numbers of servings consumed.

F&V consumption

        Consistent with the findings of the analyses of fruit and vegetable consumption separately, the combined variable of F&V consumption showed significant increases between the baseline and post-study measurements (Z=-5.86, p<0.001), but no differences in F&V change scores were identified between the control and intervention groups (Z=-0.21, p=0.84). The detailed data are shown in Table 7.

Table 7. F&V consumption

	All Subjects (N=63)	Control (n=31)	Matching (n=33)
Baseline	3 (2-4)	3 (2-4)	3 (2-4)
Post-study	5 (3.25-6)	5 (4-6)	5 (3-6)
Change	2 (1-3)	2 (1-3)	1.75 (1-3)

* Values shown are the median (IQR) numbers of servings consumed.

Changes in Fruit and Vegetable Self-Efficacy

F&V self-efficacy did not exhibit any significant differences in the total sample during the course of the study (Z=-0.93, p=0.36), and no significant differences were identified between the control and intervention groups (Z=0.91, p=0.36).

Changes in Behavioral Automaticity

Similar to the findings regarding the changes in F&V consumption, the automaticity of the target behavior increased during the study period among the total sample (Z=-6.01, p<0.001), but no between-group differences were found in the change in automaticity (Z=-0.30, p=0.77).

Text Response Rates

Out of 1792 possible binary data points for the primary outcome of behavior adoption collected via text message, 1710 data points were collected over the study period in the total study sample, resulting in a response rate of 95.4%. The response rate differed significantly between the two groups, with the control group exhibiting a higher response rate than the intervention group (99.2% vs. 91.9%, χ^2=53.1, df=1, p<0.001).

Qualitative Findings

In the exit survey, participants were asked whether they fought they chose a good target behavior to adopt, whether they felt confident in their ability to choose a behavior they could successfully adopt during the study period, and whether they thought they would continue doing their chosen behavior after the study period. Additionally, they were asked to provide comments about their participation in the study if they chose to. The responses were similar between the groups, and the results are shown in Table 8.

Table 8. Findings related to behavior choice and continuation

	Total (n=59)	Control (n=29)	Intervention (n=30)
Good choice			
Yes	53 (89.8%)	26 (89.7%)	27 (90.0%)
No	6 (10.2%)	3 (10.3%)	3 (10.0%)
Confident in ability			
Yes	54 (91.5%)	26 (89.7%)	28 (93.3%)
No	5 (8.5%)	3 (10.3%)	2 (6.7%)
Continue			
Yes	47 (79.7%)	23 (79.3%)	24 (80.0%)
No	12 (20.3%)	6 (20.7%)	6 (20.0%)

*Values indicate the number (%) of participants

A total of 24 participants provided additional comments regarding their participation in the study; 16 comments were categorized as positive (9 intervention/7 control), 5 were categorized as negative (1 intervention/4 control), and 4 were categorized as neutral (4 intervention/0 control). The majority of the positive comments were related to the influence of the text message "check-in" each night and how it provided a sense of accountability and acted as a reminder. Some example quotes are as follows: "I really enjoyed it! And the daily check-in was a friendly reminder to keep it up

the following day. If I could subscribe to the daily check in beyond the study, I would!"
and "I found this incredibly helpful. The daily check-in was just what I needed to help
me do the behavior. I don't feel it's fully automatic yet, but hopefully as I continue to do
this behavior it will become second nature and I will no longer have to remind myself
each day."

Most of the negative comments were related to the need to engage in the same
behavior every day and expressed a desire for more variety in target behaviors. Some
examples of negative comments are as follows: "I didn't love eating the same thing every
day. I would have like to have a second option to be able to do as well." and "I hated
having to do the same behavior every night. It got boring and made eating veggies more a
chore than before. Would have been better to choose a different target behavior every
week."

The neutral comments typically did not relate to the intervention but rather
described how the schedule during the study period related to work or travel made it
difficult to engage in the target behavior consistently. Some examples of neutral
comments are as follows: "Throughout this study, there was a fair amount of travel mixed
in with my schedule which makes it a little more challenging to develop routine." and
"Because of daily activities varying, the timing of the chosen target behavior also
varied."

CHAPTER 5

DISCUSSION

The objective of this study was to determine whether the use of a behavior-matching tool prior to selecting a target behavior to adopt daily for four weeks would lead to differences in behavior adoption rates. Additionally, attrition rates and changes in F&V consumption and other secondary outcomes were compared between the intervention and control groups to determine whether the use of the matching tool affected these parameters. The major finding was that the use of the matching tool did not seem to have an impact on behavior adoption, attrition rates, or changes in F&V consumption.

The results obtained are valuable because the study was designed to assess the premise of an existing online tool aimed to aid in behavior adoption. The finding that the use of the tool did not lead to significant improvements in behavior adoption indicates that the tool may require modification if it is to provide value to consumers (S. A. Mummah et al., 2016). The results indicated that a tool of this nature could have some promise as a behavior adoption aid, but the use of the matching tool assessed in the present study did not lead to improvements in behavior adoption or F&V consumption. In an industry setting, it is highly important to obtain quality data to guide product development. In this case, exploring ways to improve the matching process is likely an important next step. In the subsequent sections, the specific results will be discussed in the context of the existing literature, potential reasons for the lack of a significant effect of the matching tool will be proposed, and opportunities for improvement of the tool will be discussed.

Behavior Adoption

As the primary outcome of the present study, behavior adoption was not found to be significantly improved by the use of the behavior-matching tool. The finding of an absence of effect of this intervention on behavior adoption is consistent with previous studies. Although many interventions developed and assessed to date have improved knowledge and increased intentions to adopt healthful behaviors, most interventions have either failed to result in behavior change or adoption or resulted in only short-term changes, highlighting the difficulty of developing interventions that lead to lasting engagement in health-related behaviors (Wood & Neal, 2016). A notable example is the introduction of the 5 A Day for Better Health Program that was developed by the National Cancer Institute and industry partners and launched in 1991. This campaign more than doubled the awareness of the F&V recommendations by 1997 (from 7% of the US population to 20%) (Stables et al., 2002). However, the percent of the population meeting these recommendations remained unchanged after the introduction of the initiative (Casagrande et al., 2007). A more recent national program launched in 2007 to increase F&V consumption also failed to increase the percentage of people meeting the 5-a-day recommendation (Moore & Thompson, 2015). Similar results have been obtained in more contemporary research assessing programs and tools aiming to improve health behaviors.

A systematic review that assessed studies investigating the use of mobile apps to change physical activity, diet, drug, and alcohol behaviors revealed similar results as those described in the present study: most studies included in the systematic review showed high study completion rates and positive ease-of-use ratings, but there was little

indication of success in increasing behavior adoption or improving health outcomes (Milne-Ives et al., 2020). An intervention that aimed to increase vegetable consumption through the use of a mobile app revealed a significant increase in vegetable consumption in the intervention group that used the app (S. Mummah et al., 2017). However, this study utilized a waitlist control group rather than an active control group. This could have contributed to the difference in the findings between the study by Mummah et al. and the present study since the present study utilized an active control group while the comparison group in the study by Mummah et al. did not receive any treatment.

Similarly, a study assessing the effects of a mobile app utilizing gamification principles to improve eating habits among overweight or obese adults demonstrated a significant improvement in healthy eating habits in the intervention group when compared to a waitlist control group (Blackburne et al., 2016). This study did not focus specifically on F&V consumption, but rather used a food frequency questionnaire assessing the frequency of consumption of healthy food groups, including F&V.

Another study investigated a decisional balance sheet approach to increase F&V consumption and physical activity (Geller et al., 2012). In this study, participants were randomized to either the F&V group or the physical activity group, and no control group was used. A decisional balance program was implemented in which participants were guided through discussions regarding the gains/losses that they would expect from increasing either F&V consumption or physical activity, depending upon their group allocation. Then, participants created their own decisional balance sheet in which they reflected on the goal to which they were assigned in terms of gains, losses, approvals, and disapprovals. After two weeks of follow-up, participants in the F&V group reported

eating less F&Vs than they did at baseline (4.89 vs. 5.63 servings), whereas the physical activity group reported engaging in more physical activity (50.95 vs. 18.76 minutes). The absence of effect could have been attributed to the high F&V consumption at baseline (5.63±3.25 servings), which was avoided in the present study by the requirement that participants did not currently meet the F&V recommendation. The results of the present study and the study investigating the effect of the decisional balance sheet highlight the difficulty of increasing F&V consumption solely through the use of cognitive approaches.

There are many explanations for the absence of an effect of the matching tool on behavior adoption in this study, several of which will be discussed in detail in the context of the existing literature. The matching tool could have failed to consider certain important determinants of behavior, making it less effective in matching people with optimal behaviors. Specifically, the matching tool assessed in the present study encompassed two important constructs of SCT (self-efficacy and outcome expectancy) but failed to include any questions related to the social constructs of the theory, which could explain the behavior tools' lack of effect on behavior adoption rates over four weeks. Additionally, the participants included in this study exhibited a high overall behavior adoption rate in both groups. Even participants in the control group achieved high behavior adoption rates, which led to the finding of no between-group differences since both groups improved significantly. Moreover, there are many predictors of behavior adoption that differ at the individual level and according to an individual's existing motivation and stage of the behavior adoption process. Perhaps the specific questions included in the matching tool would need to be tailored to individuals based on certain characteristics to provide meaningful guidance in the behavior selection process.

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Additionally, the duration of the study and sample size may have been insufficient to allow for the detection of a significant effect. These concepts are discussed in detail as follows.

Social aspects of behavior adoption

Although the intervention assessed in this study incorporated constructs from SCT, the intervention did not explicitly include any components related to the social constructs in this theory. Previous research has indicated the great importance of social aspects of behavior adoption. An experimental study examining the effect of homophily—similarity of social contacts—on health behavior adoption showed that homophily significantly increased the adoption of a new behavior (Centola, 2011). Another study showed that attitudes and actions of family members and friends exerted a strong influence on health behaviors (Sriram et al., 2018). A study that investigated the adoption of personalized prevention plan recommendations from their annual wellness visits revealed that subjective norms were the strongest determinant of intention to adopt the recommendations, while attitude and perceived behavioral control were weaker determinants of intention (Nelson et al., 2021). An analysis of the English Longitudinal Study of Ageing showed that people were significantly more likely to adopt a healthy behavior if their cohabitating partner was adopting the same habit (Jackson et al., 2015). The influence of the partners of the participants in the current study were not considered and could have influenced the success of behavior adoption.

Because of the importance of the social influences in the context of health behavior adoption, it is possible that the behavior-matching tool did not exert an

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influence on behavior adoption in the present study because no questions related to the social aspects of behavior adoption were included.

Other behavioral considerations

       There are many steps involved in the successful completion of a specific behavior, from increasing motivation to ensuring that an individual has the necessary skills, knowledge, and resources to engage in the target behavior. For example, if a participant chose to adopt the behavior of eating a salad every day at lunch but did not have the greens or vegetables at home to make a salad or lacked the skills to make or purchase a salad, then they would likely not be successful at adopting the behavior. Previous studies have emphasized the importance of intermediate behaviors in the successful adoption of healthy dietary behaviors. For example, recent studies have shown that cooking skills are associated with diet quality and healthy eating behaviors (Hagmann et al., 2020; Tani et al., 2020). Moreover, a 12-month study focused on providing education on healthy food budgeting, purchasing, and cooking skills, indicating the importance of these food-related variables in the successful adoption of behaviors associated with improved dietary intake (Hawley et al., 2021).

       The present study focused exclusively on behaviors related to the *consumption* of fruits and vegetables and did not address any of the specific steps that one would need to take to successfully carry out the chosen behavior. It is possible that when an individual was choosing their target behavior from the list that they would choose the behavior that aligns best with their existing skills, abilities, and plans, but a future study could investigate whether a behavior-matching tool can match people with non-consumption

related behaviors that target behaviors early in the behavior adoption process (e.g., behaviors related to purchasing or preparing fruits and vegetables).

<u>Active control</u>

The selection of a control condition in a study should be conducted with the aim of isolating the influence of the intervention to the greatest extent possible. In doing so, the control condition should mimic the intervention condition as much as possible, with the exception of the administration of the specific intervention being tested. A good control group will maintain similar positive beliefs of the influence of the 'intervention' in both groups, which will reduced the likelihood of the placebo effect influencing outcomes only in the intervention group if participants in the control group are well aware that they are not receiving the active intervention (Lane et al., 2021). Based on these considerations, an active control condition is often a good option to increase the likelihood that potential differences in outcomes between the control and intervention conditions can be attributed to the intervention rather than other factors that differed between the groups.

In the present study, because the control group exhibited significant improvements in most measures, it could have been difficult to demonstrate a positive result in the intervention group above and beyond that observed in the control group. This phenomenon has been described in the literature as an important consideration in controlled trials. In fact, a previous article focused on the potential explanations for observing improvements in both intervention and control groups and associated problems and potential remedies (Becker et al., 2003). The present study could have exhibited

effects of reactivity of measurement, in which participants in both groups improved their outcomes as a result of the outcome measures used in the study.

A study exploring chronic disease self-management failed to identify a significant difference in various outcomes of interest between the intervention and control groups, and the researchers posited that the reason for the lack of relative improvement could have been the improvements observed in both the intervention and control groups during the study period (Elzen et al., 2007). The authors specifically noted the possibility of the influence of the Hawthorne effect and reactivity of measurement on the results of the study.

Based on the text message response rates and some of the qualitative feedback obtained from the participants indicating that they enjoyed having a nightly check-in to provide a reminder as well as accountability regarding their behavior goal, it is possible that the text messaging alone acted as a successful intervention, which was administered to both the intervention and control groups, providing little opportunity for the matching tool to exert a positive influence above and beyond the effects of the text messages. This idea is substantiated by evidence provided in a review related to the success of reminders and accountability-focused methods in improving adherence (Salisbury et al., 2022). The review included 165 studies, 154 of which used reminders without accountability and 11 included an accountability component. In total, 51% of reminder-only studies demonstrated improved adherence in the intervention group compared with the control, whereas this figure was 91% in the studies investigating reminders paired with an accountability component. Because the text messages requested a response from participants in the present study, there was an aspect of accountability along with the

provision of a reminder, which has been shown to effectively improve adherence,

providing a potential explanation as to why both the control and intervention groups

exhibited high rates of behavior adoption during the study period.

Social desirability bias

        Moreover, because the behavior adoption variable was self-reported, social

desirability bias could have led to high reported rates of behavior adoption in both

groups, again, providing little opportunity for the matching tool to exert an additional

positive influence on the rate of behavior adoption as reflected in the self-report data.

Social desirability bias is widely reported as a limitation of studies using self-reported

dietary measures (Durward et al., 2019; Sanjeevi et al., 2019; Tang et al., 2022).

Moreover, a recent systematic review of studies assessed the validity of self-reported

dietary measures by comparing the energy intake data collected with these measures to

energy intake data collected using the objective measure of doubly labelled water

(Burrows et al., 2019). The study revealed that among the included studies, there was a

systematic underreporting of energy intake by participants.

Tailored matching tool

        Due to the complex nature of health behavior adoption and the individual

variation in factors influencing motivation and stage of the adoption process, it is possible

that the tool used to match people with their optimal behaviors would need to be tailored

according to these types of factors in order to have a meaningful effect. For example, it

could be useful in the future to assess individual predictors of motivation and stage of the

adoption process to be able to tailor the matching tool according to what is relevant and

drives the behavior adoption of the specific individual.

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Adopting new behaviors related to food intake can be particularly challenging, and often various unique factors influence behavior uptake. For this reason, the Determinants Of Nutrition and Eating (DONE) framework was created to outline the determinants of eating behaviors (Stok et al., 2017). The framework groups determinants into the following categories: individual, interpersonal, environment, and policy. Each of these categories have increasingly granular subcategories, such as biological, demographic, social, product, and industry. Taking into account how a specific target behavior is influenced by many of these predictors at an individual level could increase the efficacy of the behavior-matching process.

The idea of patient- or person-centered behavioral interventions and customizing interventions according to motive, preferences, values, goals, beliefs, characteristics or needs have gained increasing attention in the literature (Worawong et al., 2018). These factors could have an important influence on how effective a behavior-matching tool is in a general sample. Therefore, future research should consider the influence of other factors according to which a behavior-matching intervention could be tailored to increase the efficacy of a behavior-matching intervention.

Behavior options

Another possible explanation for the lack of effect of the behavior-matching tool on behavior adoption could be the behavior options used in the present study. The behaviors were all related to F&V consumption and were derived from suggestions of the American Academy of Nutrition and Dietetics and the American Heart Association to increase F&V consumption. There is a chance that the 20-item behavior list did not include options that were conducive to successful adoption for some participants or that

focusing on the adoption of the same daily behavior for the whole study period resulted in lower engagement in the intervention.

There are benefits to focusing efforts on the adoption of one specific behavior until it becomes a habit. Repetition of a behavior has been highlighted as an important aspect of habit formation (Gardner et al., 2022). However, it is also possible that some people could become bored with engaging in the same behavior over and over and would benefit from some variety in the target behavior. In fact, boredom has been studied in relation to a variety of behaviors and goal pursuit, and the importance of goal adjustment in the context of boredom has been highlighted (Bieleke et al., 2022; Wolff et al., 2020). According to the qualitative feedback that was received in the present study, some participants reported feeling unmotivated to engage in the same behavior every day. This indicates an opportunity to modify the tool assessed in the present study to improve the user experience.

For example, the customizability of the online tool lends itself to the implementation of adaptive intervention features, which have shown promise in the field of health behavior change (Hardeman et al., 2019). It could be beneficial to check in with participants at regular intervals to see how happy they are with their behavior selection and then allow them to re-rate the behavior options and choose a new target behavior whenever they report being bored of or unsatisfied with their current behavior. There is evidence that the use of adaptive interventions increases engagement with the intervention and can lead to higher rates of behavior adoption (Copeland et al., 2021).

Another possibility would be to provide ideas and resources for how to incorporate variety within the realm of a single behavior partway through the study, for

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example by giving participants a list of different raw vegetables that could make a good snack to have with lunch that they might not have tried before or providing new smoothie recipes to try. A strength of this approach would be that the variety in the single behavior could increase engagement and satisfaction in the participant but would still lend itself to the formation of a habit by allowing the participant to repeatedly engage in the same behavior (Keller et al., 2021). This is an important area of further investigation because habit formation is an essential focus of research on the adoption and maintenance of health behaviors (Gardner & Rebar, 2019).

Sample size

In the current study, the sample size of the analytic sample was adequate to detect a medium to large effect size between groups. Therefore, the study was underpowered to detect a small effect size. It is possible that a significant effect of the matching tool on behavior adoption would have been obtained had the sample size been large enough to detect a small effect size between the two study groups. The relatively small sample size and the analysis of a subset of the randomized sample resulted in threats to statistical conclusion validity (García-Pérez, 2012).

Study duration

The four-week duration of the study adoption period may have been insufficient for the emergence of a significant difference in behavior adoption between the groups. A four-week study period has been widely used in studies evaluating interventions aiming to increase F&V consumption (Hersey et al., 2015; Keller et al., 2018; A. H. Ng et al., 2022; Rodríguez-Rodríguez et al., 2022). However, as the persistence of new behaviors over time allowing for the formation of a habit has been consistently identified as a

challenge, a longer study period could have led to changes in behavior adoption rates that might have differed between the groups. A study evaluating the process of habit formation found that habit development plateaued at an average of 66 days post-baseline, and the time to plateau ranged from 18-254 days in the study sample (Lally et al., 2010). A longer study duration of at least 66 days could have provided a clearer picture of behavior-adoption and habit-formation success in the present study.

Behavior Selection

An interesting finding of the present study was the significant difference in the placement of the chosen behavior on the behavior option list between the two groups. A possible explanation of this finding is that participants in the intervention group took note of the text above the behavior choice list that read "The behaviors are listed in order of your 'behavior-matching' score, with the best options for you shown at the top of the list." If this is the case that participants read this statement and proceeded to be more likely to select a behavior that appeared earlier on the list, it would indicate that participants were receptive to receiving help with the decision-making process. This suggests that a behavior-matching tool could provide value to people making choices related to behavior adoption.

The concept of decision fatigue, in which individuals feel overwhelmed by the decision-making process and likely do not fully consider the available options or avoid making a decision altogether, is important in the context of dietary choices. The field of decision sciences has made progress in identifying ways to aid people in the decision-making process in a variety of contexts (Arvai et al., 2004; Bakitas et al., 2011; Kellon & Arvai, 2011). An important opportunity to help people make the best decisions for

themselves are to provide guidance in the form of a tailored recommendation. For example, in the present study, participants chose a target behavior for a list of 20 behaviors. This can be an overwhelming task because of the number of options, and providing a structure that can guide people though the decision-making process could be of some benefit.

Attrition

Attrition is an important point of concern in all research involving human subjects and is an important consideration in longitudinal studies involving repeated measurements. An aim of the present study was to compare attrition rates between the two groups to determine whether the use of the behavior-matching tool caused participants to select a better behavior for them that caused them to remain engaged in the study process more than their control group counterparts. However, the attrition rate among participants who enrolled in the daily text messages was very low, with one participant unsubscribing from the text messages on the first day of data collection and another participant ceasing their responses after five days. Both of these participants were in the intervention group. However, considering that the number of attrition cases was so low overall, the results of the survival analysis comparing attrition rates between the two groups were not significant.

The attrition rate among participants who successfully enrolled in the nightly text messages was much lower than attrition rates reported in other eHealth studies. A review of studies that utilized apps to improve health behavior revealed that among the 27 included studies, the attrition rate ranged from 0% to 57%, with an average rate of 17% (Schoeppe et al., 2016). A study explored retention practices among longitudinal clinical

research studies to identify factors that were associated with high retention rates (>80%) (Abshire et al., 2017). The study revealed that the most common retention practices were study reminders, emphasizing study benefits, and employing contact/scheduling strategies. Additionally, teams involved in studies with low attrition rates tended to tailor their retention strategies to their participants and utilize personalized touches. In the present study, the nightly text messages could have been pivotal in making participants feel engaged in the study, acting as a regular reminder of their participation. Moreover, study correspondence was carried out with personalized touches and encouraged participants to reach out to the study team at any time with questions, with the aim of building rapport between participants and the study team.

The low attrition rate in this study could also be explained by the fact that many participants were excluded from the study at various points throughout the study enrollment process, which might have resulted in a final sample comprising only very committed participants. Many longitudinal studies employ a run-in period in which there is ample opportunity for non-committed participants to withdraw from the study prior to actual study initiation. This is considered a good practice in this type of research in order to avoid wasting resources enrolling participants who will likely drop out of the study and to prevent potential selection bias associated with differential rates of attrition between groups. In fact, a "run-in and withdrawal design" has been proposed specifically to reduce attrition rates and improve the validity of eHealth studies (Eysenbach, 2005). However, in the present study, the run-in period continued after participants were randomized, which constituted a limitation of the study that is discussed in more detail in a subsequent section.

Changes in Fruit and Vegetable Variables

        Although the primary interest in the present study was behavior adoption, because the behavior options were related to F&V consumption, it was also of interest to assess the effect of the intervention on the change in F&V consumption between baseline and the exit survey after the four-week study period. F&V consumption increased significantly in the total sample, but there was no difference in change in F&V consumption between the two groups. A study that assessed the use of newsletters tailored according to either demographics (control) or self-determination theory constructs (intervention) obtained very similar results to those of the current study (Ken Resnicow et al., 2008). The intervention and control groups both increased F&V consumption by approximately one serving per day without differences between the two groups. A systematic review of studies investigating the use of mobile health apps for increasing and self-monitoring F&V intake revealed that overall, the mobile health apps were beneficial (Mandracchia et al., 2019). However, similar to previously discussed studies, many of the studies included in the systematic review utilized either waitlist control or measurement-only control groups, precluding an accurate comparison with the results of the present study that utilized an active control.

Data Collection

<u>Dichotomous text message responses</u>

        The primary outcome in the present study was assessed through daily responses to the text message "Did you [insert behavior here] today? Reply Y or N." While this particular question and method of collecting daily dichotomous data to track behavior adoption over time has not been validated, yes/no questions and questionnaires have been

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validated and used to assess behavior engagement or adoption in a variety of contexts, including smoking cessation, fruit and vegetable consumption, physical activity, flood adaptation, and the adoption of new teaching methods (Morisky et al., 2008; Porter & Graham, 2016; Post et al., 2005; Risica et al., 2007; Valois et al., 2019; Washburn et al., 2000). However, as mentioned in a previous section, this self-reported measure of behavior adoption could have been associated with social desirability bias.

Additionally, there was no specific definition of successful engagement in the target behavior in the present study. There was no cutoff to represent successful completion of the daily behavior. While this is, in fact, a limitation of the study, this preliminary study testing this novel behavior-matching tool was primarily focused on the adoption of a new behavior over time. If consistent engagement in a behavior can be successfully achieved, then a subsequent study could focus on the specifics of the "dose" of the behavior.

Text message response rates

Text messaging as a tool for data collection has been assessed in recent years due to the ubiquitous use of cell phones and text messaging as a form of communication. Consistent with the findings of the present study, previous research has shown that the use of text messaging for data collection results in high response rates. A study investigating the use of text messaging for ecological momentary assessment (EMA) to collect data from college-age marijuana users over two weeks showed a high response rate of 89% (Phillips et al., 2014). Interestingly, the current study demonstrated an even higher response rate of 95.4% despite the fact that the data collection period was twice as long as that of the aforementioned study. The very high response rate in the present study

indicate the potential utility of the specific text messaging data collection protocol used. The participants were sent a short text message 90 minutes before their self-reported bedtime asking them to provide only a one-letter response (Y or N). If they did not respond to the first message, a reminder message was sent 45 minutes later. The use of a consistent schedule for data collection via text message that is anchored by each participant's self-reported bedtime along with the ease of response could have been factors that facilitated high response rates in the present study.

Previous studies have successfully utilized text messages for data collection with high response rates as well. A study examining irritable bowel syndrome symptoms utilized text messages to collect weekly symptom data and obtained a response rate of 100% among 38 participants over 8 weeks (Kew, 2010). In the field of consumer research, the use of text messages has been highlighted as an ideal option for contact and data collection because they provide an opportunity to connect with consumers on an individual level through a familiar and frequently used modality (Willcox et al., 2019). Moreover, text messages boast an open rate of 98% and a response rate that is two times higher than those of other contact modalities, such as email, phone, or social media (Willcox et al., 2019). These findings, along with those of the present study, indicate the utility of text messages in behavior adoption trials.

Repeated-measures behavior adoption data

The assessment of behavior adoption is often a challenge in behavior adoption research. Some researchers rely on the measurement of behavior intention or attitudes to determine whether a given intervention has had a meaningful effect (Chu & Liu, 2021; Everett et al., 2020; Lin & Roberts, 2020; Zhou et al., 2019). However, this approach is

often criticized because there is evidence that behavior intention is often not an accurate proxy for behavior adoption (D. Nilsson et al., 2019). Given this, it is important to identify methods to collect accurate behavior *adoption* data. The method used in the present study in which yes/no data about daily behavior completion were collected each night could be a promising approach to provide detailed information about the trajectory of the behavior adoption and maintenance processes. However, as previously mentioned, this specific data collection technique has not been formally validated, and research regarding the validity of the self-report responses of participants is needed.

Strengths

This study has several strengths. It assessed the use of a real-world digital tool for promoting behavior adoption. The assessment of existing tools provides valuable information regarding future tool development and updates. Another strength is the large amount of data that was collected from participants. Data collected on a daily interval paint a more comprehensive picture of the behavior adoption process than do pre-post measurements. Moreover, the high response rate to the text messages in this study further improved the data quality and quantity.

Not only was the response rate to the text messages high, but the primary outcome assessed via the text messages was behavior adoption rather than intention. This is an important strength as much behavior adoption research focuses on behavior intention as an outcome since it tends to be easier to measure. This has been highlighted in the literature as a shortcoming of this type of research, and the current study offers a potential approach for the collection of behavior adoption data that could be applied in other behavior adoption research.

Another strength of the study is that it addressed an important gap in the current health behavior adoption literature by exploring the use of a tool that is accessible, affordable, and able to be widely implemented due to the limited resource requirement. Previous research has indicated that the cost of implementing health behavior interventions tends to be a common prohibitive factor, which minimizes the reach and impact of interventions (Ribisl et al., 2014). Studies assessing the efficacy of tools and interventions aiming to optimize health behavior adoption are an important priority.

Limitations

Several limitations of this study warrant mentioning. The study population comprised a convenience sample, and therefore, the results are likely not generalizable to the general population or other specific populations of interest. Moreover, the sample was randomized at the end of the baseline survey. After completing the baseline survey, many individuals did not complete the subsequent behavior selection survey, chose a behavior they already did frequently, or reported consuming ≥5 servings of F&V, which precluded their participation in the study. This led to the analysis of a subset of the randomized sample rather than the entire randomized sample as would typically be done in an intention-to-treat analysis. This could have been avoided by using a different interface for survey administration that would calculate the behavior-matching score for each item in the intervention group and order the behavior option list according to the calculated score to allow participants to choose their target behavior as part of the baseline survey. In the present study, this process was done manually, which required the use of a separate behavior-selection survey after the behavior-matching scores were calculated.

Another limitation is the use of Qualtrics to ask questions from the behavior-matching tool rather than the interface of the existing behavior-matching tool. This could have influenced the impact of the matching tool due to the possibly-less-engaging interface of Qualtrics. However, this was a necessary first step in understanding the use of the matching tool because it is necessary to understand the impacts of the underlying constructs that are utilized in the matching tool before including the additional user experience-related variables such as aesthetics and design.

All data analyzed in the study were self-reported, and self-reported measures are associated with various biases, such as social-desirability bias. These biases likely impacted participants in each group equally but could have inflated the behavior adoption rates in both groups, decreasing the likelihood of identifying a superior effect in the behavior-matching group.

Future research

The findings of the present study indicate many opportunities for future research in the area of behavior matching and behavior adoption. A study similar to the present study could be conducted with additional resources, which would allow for a larger sample size and longer study duration, providing stronger evidence of a potential effect of the use of the behavior-matching tool. Additionally, this similar study would benefit from randomizing participants at the final stage of the study run-in period to ensure that the randomized sample is included in the analyses. This study would provide a foundation for future research in this area that could examine the behavior-matching process more closely and perhaps validate the self-reported measure of behavior completion in a subset

of participants by asking participants to send a photo showing them engaging in their behavior.

Another study could include a question in the matching tool that is related to the social aspects of behavior adoption. For example, the question "How much social support do you feel you have to engage in the following behaviors?" could be added to the matching tool to help participants prioritize the behaviors for which they have higher levels of social support. This could help integrate the social/environmental domain of social cognitive theory.

Future studies could benefit from addressing other steps in the behavior adoption process, such as food procurement and preparation, to determine whether the matching tool can successfully match people with these intermediate behaviors prior to attempting to match them with the behavior associated with consumption. There are also many factors associated with behavior adoption, such as facilitators and barriers, that could be integrated into an intervention. However, this would be outside the scope of the evaluation of the behavior matching tool.

CHAPTER 6

CONCLUSIONS

In the present study, the behavior-matching tool assessed did not have a significant effect on the successful adoption of a new F&V-related behavior over four weeks. However, this study resulted in some promising findings that can guide the further development of this tool or other tools aimed at increasing health behavior adoption. For example, individuals in the intervention group were more likely than those in the control group to choose a target behavior that was placed higher on the behavior option list. This suggests that participants likely paid attention to the statement appearing before the behavior option list that read "The behaviors are listed in order of your 'behavior-matching' score, with the best options for you shown at the top of the list." This statement was not shown to participants in the control group. The fact that participants in the intervention group more often chose behaviors appearing higher on the option list indicates that they read the provided statement and were amenable to the idea of receiving guidance in the behavior-selection process. However, because the intervention group did not exhibit higher behavior-adoption rates, it is possible that the tool used was not valuable in identifying optimal target behaviors for the participants in the study and that participants were able to identify the behavior that was the best match for them without the use of the behavior-matching tool.

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APPENDIX A

RECRUITMENT FLYER

APPENDIX B

IRB APPROVAL

APPROVAL: EXPEDITED REVIEW

Christopher Wharton
CHS: Health Solutions, College of
602/496-1727
Christopher.Wharton@asu.edu

Dear Christopher Wharton:

On 12/16/2022 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Effects of behavior matching on behavior adoption and attrition in an eHealth intervention focused on fruit and vegetable consumption: a randomized controlled trial
Investigator:	Christopher Wharton
IRB ID:	STUDY00017123
Category of review:	
Funding:	Name: Arizona State University (ASU)
Grant Title:	
Grant ID:	
Documents Reviewed:	• Baseline questionnaire, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Behavior list for control group, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Behavior list for intervention group, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Consent form, Category: Consent Form; • Eligibility questionnaire, Category: Screening forms; • Exit survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • IRB protocol, Category: IRB Protocol; • Kelly Cosgrove GCP certificate, Category: Other;

	• Point-by-point IRB responses.pdf, Category: Other; • Recruitment ad, Category: Recruitment Materials; • Study text and emails, Category: Participant materials (specific directions for them); • Wharton GCP CITI training, Category: Other;

The IRB approved the protocol effective 12/16/2022. Continuing Review is not required for this study.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc: Kelly Cosgrove
        Kelly Cosgrove

APPENDIX C

SCREENING SURVEY, BASELINE SURVEY, BEHAVIOR CHOICE SURVEY,
EXIT SURVEY

Screener survey

Thank you for your interest in the Fruit and Vegetable Study. Please answer the next questions to determine your eligibility for participation; this will take less than 5 minutes. If you have any questions about your eligibility please contact Kelly Cosgrove at kelly.cosgrove@asu.edu. If your questions are not answered, contact Christopher Wharton at cwharton@asu.edu.

Completion of this survey will indicate your consent to participate in this screening. This research has been reviewed and approved by the Social Behavioral IRB at Arizona State University. You may reach them at (480) 965-6788 if you have any questions or concerns.

Are you 18 years of age or older?

◯ No

◯ Yes

Do you currently reside in the United States?

◯ No

◯ Yes

Are you comfortable reading and writing in English?

◯ No

◯ Yes

Do you have access to a cell phone that can send and receive text messages?

○ No

○ Yes

Are you willing and able to receive and respond to daily text messages?

○ No

○ Yes

Do you have an email account that you check at least once a day Monday-Friday?

○ No

○ Yes

Do you make your own food purchasing and consumption decisions?

○ No

○ Yes

In the past week, **on a typical day**, how many servings of **fruits and vegetables** did you eat?

A serving is equal to: 1 medium carrot or other fresh vegetable1 small bowl of green salad 1/2 cup of fresh or cooked vegetables 3/4 cup of vegetable soup1 medium piece of fresh fruit ½ cup of fruit salad ¼ cup of raisins, apricots, or other dried fruit 6 oz. of 100% orange, apple, or grapefruit juice

- ○ 0

- ○ 1

- ○ 2

- ○ 3

- ○ 4

- ○ 5 or more

Do you want to start eating more fruits and vegetables?

- ○ No

- ○ Yes

Do you have any chronic diseases that are not managed in a stable state (e.g., uncontrolled diabetes or hypertension)?

- ○ No

- ○ Yes

Have you started taking a new medication in the last three months?

○ No

○ Yes

Are you allergic to any fruits or vegetables?

○ No

○ Yes

Do you have a chronic digestive condition (e.g., irritable bowel disease or Crohn's disease)?

○ No

○ Yes

Do you currently or have you ever had or been suspected of having an eating disorder (e.g., anorexia or bulimia)?

○ No

○ Yes

You are eligible to participate in our study! Please take your time to read the following statement and contact our research team if you have any questions.

Informed Consent Form
Investigators:
Christopher Wharton (PI), Arizona State University
Kelly Cosgrove, Arizona State University

This study is being conducted to explore ways to increase fruit and vegetable intake. This study includes surveys that will collect data on demographics, behaviors, and thoughts about food. The study duration is five weeks, with an anticipated active participation time (filling in surveys, reading emails, responding to text messages) of 2 hours (<5 minutes for the screener survey, 15-20 minutes for a baseline survey, 15 minutes for the exit survey (35-40 min total for all surveys), and 80 minutes for reading emails and responding to text messages over a four-week period). You must be 18 years of age or older to participate. You are free to decide whether you wish to participate in this survey or not. The risks associated with participation in this study include annoyance related to receiving daily text messages and two emails each week, and we cannot promise any benefits to you or others for taking part in this research. Your responses are confidential. For research purposes, a numeric participant ID will be assigned to your responses. However, for the duration of the five-week study period, your email address and phone number will be associated with your participant ID. However, upon completion of the exit survey, your email address and phone number will be deleted from all data files, ensuring that all of the retained data will be anonymous. Data collected in this study will be secure and password protected. The results of this study may be used in reports, presentations, and publications, but your name and your identifiable information will never be used. Upon completion of the study, you will be asked if you would like to receive an email outlining your results. De-identified data collected as a part of the current study may be shared with other investigators for future research purposes. A description of this clinical trial will be available on http://www.ClinicalTrials.gov. This Web site will not include information that can identify you. At most, the Web site will include a summary of the results. You can search this website at any time.

If you have questions, concerns, or comments, please contact Kelly Cosgrove at kscosgro@asu.edu.

This research has been reviewed and approved by the Social Behavioral IRB at Arizona State University. You may talk to them at (480) 965-6788 if
• Your questions, concerns, or complaints are not being answered by the research team.
• You cannot reach the research team.
• You want to talk to someone besides the research team.
• You have questions about your rights as a research participant.
• You want to get information or provide input about this research.

The following is an agreement of electronic consent. Clicking on the "Next" button below indicates that
• You have read the above information
• You voluntarily agree to participate
• You are at least 18 years of age
• You reside in the United States of America

If you disagree with these terms or do not wish to participate in this research study, feel free to close this window now.

Thank you,
Christopher Wharton,
PhD Principal Investigator Associate Professor, Nutrition Program Arizona State
University
cwharton@asu.edu

Thank you for agreeing to participate in this study! Please provide your email address and phone number for your cellphone that can send and receive text messages. We will be in touch with more information soon! The study period is scheduled to run from January 30 to February 26.

Email address

_____

Phone number

_____

Baseline survey

Thanks again for volunteering to participate in this study! Please complete the following survey. It should take about 15 minutes.

Please enter your phone number.

_____

How old are you? (Please enter your age in years)

_____

What is your gender?

○ Male

○ Female

○ Non-binary / third gender

○ Prefer not to say

What is your annual income before taxes? (In US dollars, include numbers only)

_____

What is the highest degree or level of school you have completed?

○ Some high school

○ High school graduate or equivalent

○ Some college but degree not received or is in progress

○ Associate's degree

○ Bachelor's degree

○ Graduate degree

How far away is the grocery store that is closest to your home?

○ Less than 1 mile

○ 1-5 miles

○ 5-10 miles

○ 10 or more miles

What time do you go to bed on a typical day?

_____

What is your time zone?

○ Pacific Standard Time (UTC-8)

○ Mountain Standard Time (UTC-7)

○ Central Standard Time (UTC-6)

○ Eastern Standard Time (UTC-5)

How many total people – adults and children – currently live in your household, including yourself?

○ 1

○ 2

○ 3

○ 4

○ 5 or more

How tall are you? (Please answer in <u>inches</u>)

_____

How much do you weigh? (Please answer in <u>pounds</u>)

_____

Think about all the **vigorous** activities that you did in the **last 7 days**. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

How much time did you usually spend doing **vigorous** physical activities on one of those days?

Minutes per day:

_____

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

How much time did you usually spend doing **moderate** physical activities on one of those days?

Minutes per day:

_____

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

○ 0

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ 7

How much time did you usually spend walking on one of those days?

Minutes per day:

_____

The question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

Minutes per day:

_____

On a typical day, how many servings of fruit do you eat?

 A serving is equal to: 1 medium piece of fresh fruit ツス cup of fruit salad   ツシ cup of raisins, apricots, or other dried fruit   6 oz. of 100% orange, apple, or grapefruit juice (Do not count fruit punch, lemonade, Gatorade, Sunny Delight or fruit drink)

_____

On a typical day, how many servings of vegetables do you eat?

 A serving is equal to: 1 medium carrot or other fresh vegetable   1 small bowl of green salad ツス cup of fresh or cooked vegetables ツセ cup of vegetable soup (Do not count French fries, onion rings, potato chips, or fried okra)

_____

I am confident that I can eat five servings of fruits and vegetables a day.

○ Strongly disagree

○ Somewhat disagree

○ Neither agree nor disagree

○ Somewhat agree

○ Strongly agree

I am confident that I can eat enough fruit and vegetables daily, even when there are no attractive shopping opportunities.

○ Strongly disagree

○ Somewhat disagree

○ Neither agree nor disagree

○ Somewhat agree

○ Strongly agree

Thank you for your responses! Be on the lookout for an email from us with a list of goals focused on fruit and vegetable intake for you to choose from to continue your participation in the study!

One of the biggest challenges in designing for change is picking actions that will work for you. This last part of the survey will help you to sort through high-impact habits to help you increase your fruit and vegetable intake.

Rank each of the following actions according to **how effective you think they are** for increasing your fruit and vegetable intake.

Mix up a breakfast smoothie made with low-fat or non-dairy milk, frozen strawberries and a banana.

	Not effective		Very effective
	-8	0	8

Make a veggie wrap with roasted vegetables and low-fat cheese rolled in a whole-wheat tortilla.

	Not effective		Very effective
	-8	0	8

Eat crunchy vegetables instead of chips with your favorite low-fat salad dressing for dipping.

	Not effective		Very effective
	-8	0	8

Stuff an omelet with vegetables. Turn any omelet into a hearty meal with broccoli, squash, carrots, peppers, tomatoes or onions with low-fat sharp cheddar cheese.

	Not effective		Very effective
	-8	0	8

"Sandwich" in fruits and vegetables. Add pizzazz to sandwiches with sliced pineapple, apple, peppers, cucumber and tomato as fillings.

	Not effective		Very effective
	-8	0	8

(slider control)

Microwave a cup of vegetable soup as a snack or with a sandwich for lunch.

Not effective		Very effective
-8	0	8

(slider control)

Add grated, shredded or chopped vegetables such as zucchini, spinach and carrots to lasagna, meat loaf, mashed potatoes, pasta sauce and rice dishes.

Not effective		Very effective
-8	0	8

(slider control)

Make fruit your dessert: Slice a banana lengthwise and top with a scoop of low-fat frozen yogurt. Sprinkle with a tablespoon of chopped nuts.

Not effective		Very effective
-8	0	8

(slider control)

Add bananas, raisins or berries to your cereal, yogurt, waffle, or other breakfast dish.

	Not effective	Very effective
	-8	0	8

- -

Drink a small (6-ounce) glass of juice. Be sure it's 100% fruit or vegetable juice without excess sodium or sugar – not "fruit drink," "cocktail" or "punch."

	Not effective	Very effective
	-8	0	8

- -

Add chopped up vegetables to your eggs or potatoes at breakfast. Try onions, celery, green or red bell peppers, or spinach.

	Not effective	Very effective
	-8	0	8

- -

Have a fruit or vegetable salad with lunch.

	Not effective	Very effective
	-8	0	8

Put vegetables, such as cucumber, sprouts, tomato, lettuce or avocado, on your sandwich or other lunch dish.

	Not effective		Very effective
	-8	0	8

Have a piece of fruit or raw veggie sticks instead of chips with lunch.

	Not effective		Very effective
	-8	0	8

Snack on raw veggie sticks, such as green or red bell peppers, green beans, celery or carrots.

	Not effective		Very effective
	-8	0	8

Eat dried fruit, such as raisins, dates or dried apricots, as a snack at work.

	Not effective		Very effective
	-8	0	8

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Have any type of fresh fruit as a snack with breakfast: grapes, apple, banana, orange, kiwi, etc.

	Not effective	Very effective
	-8	0	8

Have a vegetable salad with dinner.

	Not effective	Very effective
	-8	0	8

Have fruit salad for dessert.

	Not effective	Very effective
	-8	0	8

Add a side of steamed or microwaved vegetables to dinner.

Not effective   Very effective

-8   0   8

Rank each of the following actions according to **how likely you think you are** to do the action every day.

Mix up a breakfast smoothie made with low-fat or non-dairy milk, frozen strawberries and a banana.

Not likely to do		Likely to do
-8	0	8

Make a veggie wrap with roasted vegetables and low-fat cheese rolled in a whole-wheat tortilla.

Not likely to do		Likely to do
-8	0	8

Eat crunchy vegetables instead of chips with your favorite low-fat salad dressing for dipping.

Not likely to do		Likely to do
-8	0	8

Stuff an omelet with vegetables. Turn any omelet into a hearty meal with broccoli, squash, carrots, peppers, tomatoes or onions with low-fat sharp cheddar cheese.

Not likely to do   Likely to do

-8   0   8

"Sandwich" in fruits and vegetables. Add pizzazz to sandwiches with sliced pineapple, apple, peppers, cucumber and tomato as fillings.

Not likely to do   Likely to do

-8   0   8

Microwave a cup of vegetable soup as a snack or with a sandwich for lunch.

Not likely to do   Likely to do

-8   0   8

Add grated, shredded or chopped vegetables such as zucchini, spinach and carrots to lasagna, meat loaf, mashed potatoes, pasta sauce and rice dishes.

	Not likely to do		Likely to do
	-8	0	8

Make fruit your dessert: Slice a banana lengthwise and top with a scoop of low-fat frozen yogurt. Sprinkle with a tablespoon of chopped nuts.

	Not likely to do		Likely to do
	-8	0	8

Add bananas, raisins or berries to your cereal, yogurt, waffle, or other breakfast dish.

	Not likely to do		Likely to do
	-8	0	8

Drink a small (6-ounce) glass of juice. Be sure it's 100% fruit or vegetable juice without excess sodium or sugar – not "fruit drink," "cocktail" or "punch."

	Not likely to do		Likely to do
	-8	0	8

Add chopped up vegetables to your eggs or potatoes at breakfast. Try onions, celery, green or red bell peppers, or spinach.

	Not likely to do		Likely to do
	-8	0	8

Have a fruit or vegetable salad with lunch.

	Not likely to do		Likely to do
	-8	0	8

Put vegetables, such as cucumber, sprouts, tomato, lettuce or avocado, on your sandwich or other lunch dish.

	Not likely to do		Likely to do
	-8	0	8

Have a piece of fruit or raw veggie sticks instead of chips with lunch.

	Not likely to do	Likely to do

| | -8 | 0 | 8 |

Snack on raw veggie sticks, such as green or red bell peppers, green beans, celery or carrots.

Not likely to do   Likely to do

-8   0   8

Eat dried fruit, such as raisins, dates or dried apricots, as a snack at work.

Not likely to do   Likely to do

-8   0   8

Have any type of fresh fruit as a snack with breakfast: grapes, apple, banana, orange, kiwi, etc.

Not likely to do   Likely to do

-8   0   8

Have a vegetable salad with dinner.

	Not likely to do		Likely to do
	-8	0	8

Have fruit salad for dessert.

	Not likely to do		Likely to do
	-8	0	8

Add a side of steamed or microwaved vegetables to dinner.

	Not likely to do		Likely to do
	-8	0	8

Behavior choice survey-behavior matching group

Please enter your phone number.

_____

Please choose one of the following NEW behaviors to start doing every day for the next four weeks.

Please select a NEW behavior that you do not already do more than two times a month.

The behaviors are listed in order of your 'behavior-matching' score, with the best options for you shown at the top of the list.

○ [Behavior options will be included here in order according to the participant's responses to the behavior-rating step]

○ Click to write Choice 2

○ Click to write Choice 3

How often do you typically do the target behavior that you selected?
(If it's more than twice a month, please go back and choose a different target behavior)

○ Daily

○ 4-6 times a week

○ 2-3 times a week

○ Once a week

○ Twice a month

○ Once a month

○ Never

The target behavior that you chose is something that

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
You do frequently.	○	○	○	○	○
You do automatically.	○	○	○	○	○
You do without having to consciously remember.	○	○	○	○	○
Makes you feel weird if you do not do it.	○	○	○	○	○
You do without thinking.	○	○	○	○	○
Would require effort not to do.	○	○	○	○	○
Belongs to your (daily, weekly, monthly) routine.	○	○	○	○	○
You start doing before you realize you're doing it.	○	○	○	○	○
You would find hard not to do.	○	○	○	○	○
You have no need to think about doing.	○	○	○	○	○

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Is typically "you."	○	○	○	○	○
You've been doing for a long time.	○	○	○	○	○

Behavior choice survey-control group

Please enter your phone number.

_____

Please choose one of the following NEW behaviors to start doing every day for the next four weeks.

 Please select a NEW behavior that you do not already do more than two times a month.

◯ Mix up a breakfast smoothie made with low-fat or non-dairy milk, frozen strawberries and a banana.

◯ Make a veggie wrap with roasted vegetables and low-fat cheese rolled in a whole-wheat tortilla.

◯ Eat crunchy vegetables instead of chips with your favorite low-fat salad dressing for dipping.

◯ Stuff an omelet with vegetables. Turn any omelet into a hearty meal with broccoli, squash, carrots, peppers, tomatoes or onions with low-fat sharp cheddar cheese.

◯ "Sandwich" in fruits and vegetables. Add pizzazz to sandwiches with sliced pineapple, apple, peppers, cucumber and tomato as fillings.

◯ Microwave a cup of vegetable soup as a snack or with a sandwich for lunch.

◯ Add grated, shredded or chopped vegetables such as zucchini, spinach and carrots to lasagna, meat loaf, mashed potatoes, pasta sauce and rice dishes.

◯ Make fruit your dessert: Slice a banana lengthwise and top with a scoop of low-fat frozen yogurt. Sprinkle with a tablespoon of chopped nuts.

◯ Add bananas, raisins or berries to your cereal, yogurt, waffle, or other breakfast dish.

◯ Drink a small (6-ounce) glass of juice. Be sure it's 100% fruit or vegetable juice without excess sodium or sugar – not "fruit drink," "cocktail" or "punch."

◯ Add chopped up vegetables to your eggs or potatoes at breakfast. Try onions, celery, green or red bell peppers, or spinach.

◯ Have a fruit or vegetable salad with lunch.

◯ Put vegetables, such as cucumber, sprouts, tomato, lettuce or avocado, on your sandwich or other lunch dish.

○ Have a piece of fruit or raw veggie sticks instead of chips with lunch.

○ Snack on raw veggie sticks, such as green or red bell peppers, green beans, celery or carrots.

○ Eat dried fruit, such as raisins, dates or dried apricots, as a snack at work.

○ Have any type of fresh fruit as a snack with breakfast: grapes, apple, banana, orange, kiwi, etc.

○ Have a vegetable salad with dinner.

○ Have fruit salad for dessert.

○ Add a side of steamed or microwaved vegetables to dinner.

How often do you typically do the target behavior that you selected?
(If it's more than twice a month, please go back and choose a different target behavior)

○ Daily

○ 4-6 times a week

○ 2-3 times a week

○ Once a week

○ Twice a month

○ Once a month

○ Never

The target behavior that you chose is something that

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
You do frequently.	○	○	○	○	○
You do automatically.	○	○	○	○	○
You do without having to consciously remember.	○	○	○	○	○
Makes you feel weird if you do not do it.	○	○	○	○	○
You do without thinking.	○	○	○	○	○
Would require effort not to do.	○	○	○	○	○
Belongs to your (daily, weekly, monthly) routine.	○	○	○	○	○
You start doing before you realize you're doing it.	○	○	○	○	○
You would find hard not to do.	○	○	○	○	○
You have no need to think about doing.	○	○	○	○	○

Is typically "you."	○	○	○	○	○
You've been doing for a long time.	○	○	○	○	○

Exit survey

Thank you so much for participating in this study. This survey is the final step in your participation and will take about 15 minutes to complete. Thank you!

Please enter your phone number.

_____

In the past week, on a typical day, how many servings of fruit did you eat?
 A serving is equal to: 1 medium piece of fresh fruit
        ½ cup of fruit salad   ¼ cup of raisins, apricots, or other dried fruit
        6 oz. of 100% orange, apple, or grapefruit juice   (Do not count fruit punch, lemonade, Gatorade, Sunny Delight or fruit drink)

_____

In the past week, on a typical day, how many servings of vegetables did you eat?
 A serving is equal to: 1 medium carrot or other fresh vegetable   1 small bowl of green salad   ½ cup of fresh or cooked vegetables   ¾ cup of vegetable soup   (Do not count French fries,

onion rings, potato chips, or fried okra)

_____

I am confident that I can eat five servings of fruits and vegetables a day.

○ Strongly disagree

○ Somewhat disagree

○ Neither agree nor disagree

○ Somewhat agree

○ Strongly agree

I am confident that I can eat enough fruit and vegetables daily, even when there are no attractive shopping opportunities.

○ Strongly disagree

○ Somewhat disagree

○ Neither agree nor disagree

○ Somewhat agree

○ Strongly agree

How often do you typically do the target behavior that you selected?

   ○ Daily

   ○ 4-6 times a week

   ○ 2-3 times a week

   ○ Once a week

   ○ Twice a month

   ○ Once a month

   ○ Never

The target behavior that you chose is something that

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
You do frequently.	○	○	○	○	○
You do automatically.	○	○	○	○	○
You do without having to consciously remember.	○	○	○	○	○
Makes you feel weird if you do not do it.	○	○	○	○	○
You do without thinking.	○	○	○	○	○
Would require effort not to do.	○	○	○	○	○
Belongs in your (daily, weekly, monthly) routine.	○	○	○	○	○
You start doing before you realize you're doing it.	○	○	○	○	○
You would find hard not to do.	○	○	○	○	○
You have no need to think about doing.	○	○	○	○	○

Is typically "you."	○	○	○	○	○
You've been doing for a long time.	○	○	○	○	○

Think about all the **vigorous** activities that you did in the **last 7 days**. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

Page Break

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How much time did you usually spend doing **vigorous** physical activities on one of those days?

Minutes per day:

_____

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

Page Break ─────────────────────────────────

How much time did you usually spend doing **moderate** physical activities on one of those days?

Minutes per day:

_____

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

○ 0

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ 7

How much time did you usually spend walking on one of those days?

Minutes per day:

_____

The question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

Minutes per day:

_____

Do you think you chose a good target behavior to do during the study period?

○ Yes

○ No

Did you feel confident in your ability to choose a behavior your could successfully adopt during the study period?

○ Yes

○ No

Do you think you will continue doing your chosen behavior now that the study is over?

○ Yes

○ No

If you have any comments about your participation in the study, please share them here:

_____

_____

_____

_____

_____

APPENDIX D

EMAILS AND EXAMPLE TEXT MESSAGE

Daily text message
"Did you [insert behavior here] today? Reply Y or N"

Weekly emails
Email January 30
Subject: Day one of the Fruit and Vegetable Study!
Good morning!

Did you know that eating more fruits and vegetables is associated with a lower risk of death? In fact, a study found that eating seven or more servings of fruits and vegetables each day was associated with a 42% lower risk of death from all causes! Check out this article if you'd like to learn more.

Email February 3
Subject: Fruits and vegetables are rich in vitamins and minerals
Good morning!
Did you know that fruits and vegetables can be a great source of many vitamins and minerals? Many fruits and vegetable are high in
- Potassium: can help maintain a healthy blood pressure
- Folate: important for a healthy pregnancy and growth
- Vitamin C: important for immune function and healing and helps keep teeth and gums healthy
- Vitamin A: helps keep eyes and skin healthy and is important for immune function

Check out this article if you'd like to learn more about the nutrients found in fruits and vegetables.

Email February 6
Subject: Fruits and vegetables are an excellent source of fiber
Good morning!
Did you know that fruits and vegetables are an excellent source of fiber? Fiber important for digestion, and it has also been found that higher levels of fiber intake can reduce the risks of many diseases and maintain a healthy gut bacteria!
Check out this article if you'd like more information about the health effects of fiber.

Email February 10
Subject: Fruits and vegetables are low in calories
Good morning!
Did you know that fruits and vegetables are low in calories? This means that eating more fruits and vegetables instead of other higher-calorie foods can help you maintain a healthy weight.

Check out this article if you'd like more information on achieving or maintaining a healthy weight by eating more fruits and vegetables.

Email February 13
Subject: Fruits and vegetables protect against heart disease
Good morning!
Did you know that eating more fruits and vegetables can reduce your risk of heart disease? Eating 5 servings of fruits and vegetables each day has been suggested to reduce the risk of heart attack and stroke!
Check out this article if you'd like more information on how fruits and vegetables impact heart health.

Email February 17
Subject: Fruits and vegetables help decrease inflammation
Good morning!
Did you know that eating fruits and vegetables has anti-inflammatory benefits? Long-term inflammation can lead to many different health problems, such as arthritis, heart disease, and cancer. Fruits and vegetables contain lots of anti-inflammatory compounds that help keep inflammation in check.
Check out this article if you'd like to learn more about anti-inflammatory fruits and vegetables that are currently in season.

Email February 20
Subject: Fruits and vegetables can add yummy variety to your diet
Good morning!
Did you know that there are more than 200 varieties of fruits and vegetables? Eating more fruits and vegetables is an opportunity to add tasty variety to your diet.
Check out this article if you'd like to find out more about the wide variety of fruits and vegetables that exist

Email February 24
Subject: Fruits and vegetables can protect against cancer
Good morning!
Did you know that studies have shown that eating a diet rich in fruits and vegetables lowers your risk of cancer? In addition to the health-promoting vitamins and minerals that are found in fruits and vegetables, fruits and vegetables contain high amounts of phytochemicals, which have been shown to have anti-cancer effects.
Check out this article if you'd like to find out more about the cancer-fighting effects of eating fruits and vegetables.

APPENDIX E

BEHAVIOR OPTION LIST

Behavior options:

add a side of steamed or microwaved vegetables to dinner

add bananas, raisins or berries to your breakfast dish

add chopped up vegetables to your eggs or potatoes at breakfast

add grated, shredded or chopped vegetables to lasagna, meat loaf, mashed potatoes, pasta sauce or a rice dish

drink a small glass of juice

eat dried fruit as a snack at work

have a fruit or vegetable salad with lunch

have a piece of fruit or raw veggie sticks instead of chips with lunch

have a vegetable salad with dinner

have any type of fresh fruit as a snack with breakfast

have fruit salad for dessert

make a veggie wrap with roasted vegetables

make fruit your dessert

microwave a cup of vegetable soup with lunch

mix up a breakfast smoothie

put vegetables on your sandwich or other lunch dish

"sandwich" in fruits and vegetables

snack on raw veggie sticks

stuff an omelet with vegetables

try crunchy vegetables instead of chips with your favorite low-fat salad dressing for dipping