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The Effects of Tailoring Knowledge Acquisition on Colorectal Cancer Screening Self-Efficacy

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Abstract

Interventions tailored to psychological factors such as personal and vicarious behavioral experiences can enhance behavioral self-efficacy, but are complex to develop and implement. Information seeking theory suggests tailoring acquisition of health knowledge (without concurrent psychological factor tailoring) could enhance self-efficacy, simplifying the design of tailored behavior change interventions. To begin to examine this issue, the authors conducted exploratory analyses of data from a randomized controlled trial, comparing the effects of an experimental colorectal cancer (CRC) screening intervention tailoring knowledge acquisition with the effects of a non-tailored control on CRC screening knowledge and self-efficacy in 1159 patients comprising three ethnicity/language strata (Hispanic/Spanish 23.4%, Hispanic/English 27.2%, non-Hispanic/English 49.3%) and five recruitment center strata. Adjusted for study strata, the mean post-intervention knowledge score was significantly higher in the experimental group versus control. Adjusted experimental intervention exposure (B = 0.22, 95% CI [0.14, 0.30]), pre-intervention knowledge (B = 0.11, 95% CI [0.05, 0.16]), and post-intervention knowledge (B = 0.03, 95% CI [0.01, 0.05]) were independently associated with subsequent CRC screening self-efficacy ($p < .001$ all associations). These exploratory findings suggest tailoring knowledge acquisition may enhance self-efficacy, with potential implications for tailored intervention design, but require confirmation in studies specifically designed to examine this issue.

Colorectal cancer (CRC) screening is under-utilized (Klabunde et al., 2003), despite its ability to reduce CRC mortality (U.S. Preventive Services Task Force, 2008). CRC screening rates are particularly low among Hispanic persons, largely due to language barriers (Jerant, Fenton, & Franks, 2008). For example, in analyses of national data in 2008, only 39% of Hispanics were up-to-date with CRC screening, compared with 57% of non-Hispanic whites (Klabunde et al., 2011). These observations indicate the need to develop approaches to motivate more individuals to undergo CRC screening and lessen ethnic screening disparities.

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Research indicates that self-efficacy, or confidence in one's ability to carry out the tasks or steps required to reach a goal, is a precursor of various salutary health behaviors, including CRC screening behavior (Hawley et al., 2012; McQueen et al., 2007; Strecher, DeVellis, Becker, & Rosenstock, 1986; Wiggers et al., 2005). Research also suggests that individually tailored interventions tend to be more effective than non-tailored interventions in bolstering patient self-efficacy for health behaviors, and in fostering adoption of the behaviors, including CRC screening (Basch et al., 2006; Dietrich et al., 2007; Fiscella et al., 2011; Fjeldsoe, Marshall, & Miller, 2009; Jerant et al., 2007; Krebs, Prochaska, & Rossi, 2010; Manne et al., 2009; Marcus et al., 2005; Noar, Benac, & Harris, 2007; Walsh et al., 2010; Wanyonyi, Themessl-Huber, Humphris, & Freeman, 2011). However, a question not previously addressed empirically is whether tailoring patient knowledge acquisition can enhance self-efficacy for health behaviors, including CRC screening behavior. The current study begins to address this question, which has practical implications for the design of tailored health behavior change interventions.

Health Information Seeking, Tailoring Knowledge Acquisition, and Self-Efficacy

To date, nearly all tailored health behavior change interventions primarily have been informed by theories that derive from the field of behavioral psychology, such the Expanded Health Belief Model, Social Cognitive Theory, the Transtheoretical Model, and the Theory of Planned Behavior (Noar et al., 2007; Krebs et al., 2010). Such theories suggest that tailoring to factors beyond knowledge acquisition, such as patients' prior personal and vicarious experiences ("successes" and "failures") with behavior change, is generally necessary to enhance self-efficacy (Ajzen, Joyce, Sheikh, & Cote, 2011; Bandura, 1997; Baranowski, Perry, & Parcel, 2002; Strecher et al., 1986; Rosenstock, Strecher, & Becker, 1988).

However, in the discipline of communication, health information seeking theory suggests the possibility that tailoring the process of knowledge acquisition may favorably influence self-efficacy. According to Niederdeppe et al. (2007), *health information seeking* describes the individual's effort to obtain specific information in response to a relevant event, a purposeful and goal-oriented activity, distinct from passive exposure to information in the environment. This definition suggests the notion of health information seeking as a form of personal agency, a socio-psychological construct describing the sense that one is able to control external events through one's own actions (Haggard & Chambon, 2012). There are some healthy volunteer experimental studies in the socio-psychological literature (Reed, Mikels, & Lockenhoff, 2012; Chua & Iyengar, 2006) and an observational study in the communication literature (Chen & Feely, 2013) that provide preliminary empirical support for the notion that personal agency may be associated with self-efficacy. Limited work also suggests that gain in knowledge may enhance self-efficacy. For example, in two quasi-experimental (non-randomized) studies of informational public health communication campaigns, individual knowledge increase was associated with increased behavioral self-efficacy (Rimal, 2000; Chew, Palmer, Slonska, & Subbiah, 2002). Additionally, in one of the studies, knowledge increase was associated with more optimal behavior, an effect partially mediated by self-efficacy (Rimal, 2000). However, no studies specifically have explored whether tailoring knowledge acquisition (whether viewed as relating to health information seeking or personal agency) enhances self-efficacy.

In tailoring knowledge acquisition, the patient is first asked to answer questions aimed at assessing their baseline knowledge regarding the focus topic(s). Subsequently, the patient is provided with tailored information in response to their answers, including reinforcement of correct answers, clarification of incorrect answers, and offers to view optional more detailed information if desired. Thus, tailoring knowledge acquisition *creates* and *fosters* the conditions of active health information seeking as delineated by Niederdeppe et al. (2007), and also increases the personal salience of the health information provided. These features of tailoring knowledge acquisition would be expected to improve users' information seeking experiences (**i.e.,** sense of agency) as compared with the provision of non-tailored information.

These observations support the notion that tailoring patient knowledge acquisition could lead to enhanced behavioral self-efficacy. However, as noted previously, no empirical studies have explored this issue.

Research Question and Hypotheses

In the present study, we addressed the research question of whether an intervention tailoring knowledge acquisition can enhance behavioral self-efficacy. We conducted analyses of data from an ongoing multicenter RCT of an experimental interactive multimedia computer program (IMCP) tailoring patient acquisition of knowledge regarding behaviorally-relevant CRC screening issues: evidence-based test options, potential harms, and common inconveniences. The primary outcome of the RCT is CRC screening; here we focus on the secondary outcome of CRC screening self-efficacy. Based on health information seeking theory, we predicted that patient exposure to the experimental intervention tailoring knowledge acquisition would lead to higher CRC screening knowledge and higher CRC screening self-efficacy than would exposure to a control non-tailored ("electronic leaflet") intervention.

Behavioral psychology and communication theory also suggest tailored interventions could help to mitigate socio-demographic disparities in health behaviors (Jerant, Sohler, Fiscella, Franks, & Franks, 2011). This is also an important question, given disparities in CRC screening and other behaviors and outcomes affecting ethnic minorities (Jerant et al., 2008; Klabunde et al., 2011; Centers for Disease Control and Prevention, 2011). Prior studies were not designed to examine whether tailoring effects on self-efficacy are comparable across ethnic and language groups. The design of our RCT, in which randomization was stratified by ethnicity (Hispanic versus non-Hispanic) and language (Spanish versus English), permitted us to address this question. If tailoring knowledge acquisition has the potential to enhance self-efficacy, as health information seeking theory suggests, two additional observations indicate the likelihood of similar effects across ethnic and language groups. The first is that CRC screening knowledge appears low across ethnic and language groups (Ford, Coups, & Hay, 2006). The second is that information seeking experiences appear to influence self-efficacy across socio-demographic groups (Chen & Feely, 2013). Thus, we predicted that the association of experimental intervention exposure with higher CRC screening self-efficacy in our sample would not differ substantively across ethnicity/language stratification groups.

We summarize this discussion as follows:

Hypothesis 1: As compared with exposure to a non-tailored control intervention, exposure to the experimental intervention tailoring knowledge acquisition will be associated with (a) higher CRC screening knowledge and (b) higher CRC screening self-efficacy.

Hypothesis 2: The association of exposure to the experimental intervention tailoring knowledge acquisition with higher CRC screening self-efficacy (as compared with control) will not differ substantively across ethnicity/language stratification groups.

Methods

Study activities were conducted from February 1, 2010 through October 31, 2011. The Institutional Review Boards at all participating sites approved the study. The study was registered on ClinicalTrials.gov.

Study Setting, Sample Recruitment, and Randomization

A convenience sample of patients aged 50-75 years and not up to date for CRC screening was recruited from 26 different primary care offices (14 of them federally qualified health centers) located in and around five recruitment centers: Sacramento, California; the Bronx, New York; Rochester, New York; San Antonio, Texas; and Denver, Colorado. Consistent with evidence-based recommendations (U.S. Preventive Services Task Force, 2008) and prevailing opinion regarding optimal testing intervals (American Cancer Society, 2013), patients were considered up to date for CRC screening (and study ineligible) if they had one or more of the following: fecal occult blood testing (FOBT) within one year; flexible sigmoidoscopy (FS) within five years; or colonoscopy within 10 years. Initial eligibility was determined by review of electronic or paper medical records at all sites except the single office in the Bronx, where advance record review was not feasible; at that office, recruitment personnel approached patients in the waiting area, prior to appointments, and determined study eligibility based on self-report.

Study personnel fluent in both English and Spanish interviewed eligible patients via telephone or (at the Bronx) in person, to solicit their participation. Patients reporting FOBT, FS, and/or colonoscopy testing within the previously specified intervals (conflicting with the prior record review) were excluded from participation. Patients who reported no such testing were asked if they could speak and read English or Spanish and adequate eyesight, hearing, and hand function to use a touch screen computer program. Patients answering “no” to either or both questions were excluded; those answering “yes” to both questions and agreeing to participate were asked to arrive one hour before an upcoming visit they had scheduled with their primary care provider for any reason (**i.e.,** not a special study appointment), to allow enough time before the visit to complete informed consent and the intervention.

Patients were provided with touch screen notebook computers for use before and after the office visit. Research assistants logged the patients into the study software program prior to the visit using a unique patient study identification number, and showed the patients how to navigate the program. After initial questions regarding the patient's ethnicity (Hispanic or non-Hispanic) and preferred language for software use (English or Spanish) were answered, the program randomly assigned patients to either the tailored experimental or non-tailored control intervention in their preferred language. At each study site, randomization was at the level of the individual patient, stratified by ethnicity and software language, and implemented in blocks of 10 to help ensure a balance in sample size across the two study groups (Schulz & Grimes, 2002), using a random number generation program. Patients and in-office research assistants were not notified of the randomly assigned study group. Patients received a $20 gift card or $20 in cash for participating.

Study Interventions

IMCP Programming and Implementation—The experimental and control IMCPs were created collaboratively by the study investigators and experienced programmers with input from the study project managers. Traditional software engineering principles guided development, including phases for requirements, design, prototyping, implementation, integration, component and system testing, and maintenance (Pressman, 2005). Both IMCPs operated within the Google Chrome browser (Google Incorporated, Mountain View, CA). Patients navigated through the programs using a touch screen interface. Optional audio narration duplicating on-screen text was available to all users, activated by touching icons next to the text. Patients' questionnaire responses were automatically stored in a background database.

English and Spanish text and audio narration within the program was written as simply as possible, with most passages at 6th to 8th grade reading level as assessed via the Flesch-Kincaid method (Kincaid, Fishburne, Rogers, & Chissom, 1975). Initially the investigators created English versions of the experimental and control program materials. These materials were reviewed by plain language specialists (Transcend Translations, Davis, CA) who provided suggestions to improve their readability for lay audiences. After incorporating these suggestions into the English materials, initial Spanish translations were developed by certified health translators, and then edited by a certified linguist and a literacy specialist, to ensure language matched the desired reading level and typical conversational word choices. The resulting translations were reviewed by several members of the Sacramento area Latino community, to ensure they would meet the needs of individuals without a medical background. After incorporating community reviewer feedback, initial versions of the Spanish IMCPs were programmed and pilot tested with a small convenience sample of patients at each study center. Patient feedback was incorporated in the finalized Spanish language IMCPs.

Experimental Tailored Intervention—Development of the algorithm for tailoring acquisition of CRC screening knowledge in the experimental IMCP was guided by a previously described approach (Kreuter, Farrell, Olevitch, & Brennan, 2000). The experimental IMCP content primarily addressed FOBT and colonoscopy, since other test options were not routinely offered in any of the participating study offices. Throughout the experimental IMCP, the focus was on providing "actionable" knowledge, meaning knowledge most likely to influence practical decision making regarding CRC screening. Specifically conveyed in the program were the general effectiveness of screening in preventing CRC and CRC death; how FOBT and colonoscopy are performed; and the typical costs and potential harms and inconveniences of each test. Effort was made to avoid including material that would be unlikely to aid in (or could possibly distract from) making screening decisions, such as information regarding the specific treatments available for CRC.

Knowledge acquisition tailoring was sequential in the experimental IMCP. This approach was employed so that responses to each of the subcategories of knowledge questions would still be fresh in patients' minds when they viewed information tailored to the responses. Following a series of questions assessing baseline participant characteristics (Figure 1, box E1), an initial module assessed and then provided tailored text information (with optional audio narration) to increase knowledge of CRC screening tests (Figure 1, boxes E2 and E2a, respectively). The tailored information reinforced correct responses and gently clarified incorrect responses; an example of one tailored message variant is provided in Appendix A. Within the brief feedback message, patients were invited to touch a "more information" button if they wished to view more detailed optional non-tailored information (Figure 1, box E2b). In this manner, users were able to "self-tailor" how much CRC screening knowledge information they received, in accordance with theory and research demonstrating inter-individual differences in the desire for control over information acquisition, and in the cognitive and emotional impact of varying amounts of information (Bandura, 1992; Burger, 1989; Chua & Iyengar, 2006; Deci & Ryan, 1987; Haggard & Chambon, 2012; Miller, 1995; Miller & Mangan, 1983; Peterson & Stunkard, 1989; Wallston, Strudler Wallston, Smith, & Dobbins, 1987). In addition to providing more detailed basic explanations of FOBT and colonoscopy, the optional information also directly covered the issues of testing intervals, follow-up following an abnormal test, and insurance coverage and out of pocket costs, in the process beginning to indirectly address some of the potential harms and inconveniences of screening. Except for brief introductory and closing text, all of the optional information was provided in the form of comparative tables, with separate columns for FOBT and colonoscopy. An example of a typical optional detailed information screen is provided in Appendix A.

After completing the screening options module, participants answered a second block of knowledge questions dealing with the potential harms and common inconveniences of screening **(**Figure 1**, box E3)**, followed by a brief feedback message tailored to their answers **(**Figure 1**, box E3a)**, with the option to view more detailed non-tailored information regarding these issues primarily in comparative table format **(**Figure 1**, box E3b)**. After completing this second knowledge tailored module, patients answered questions assessing their CRC screening self-efficacy **(**Figure 1**, box E4).**

Control Non-Tailored "Electronic Leaflet" Intervention—After completing baseline characteristics and preferences questions **(**Figure 1**, box C1)**, patients randomly assigned to the control IMCP answered the same two blocks of knowledge questions as answered by those randomized to the tailored IMCP **(**Figure 1**, boxes C2 and C3)**. After answering *both* blocks of knowledge questions, control patients were presented with non-tailored CRC screening information developed by the National Cancer Institute, in their preferred language (Figure 1**, box C4**, English: http://www.cancer.gov/cancertopics/factsheet/detection/colorectal-screening; Spanish: http://www.cancer.gov/espanol/recursos/hojas-informativas/deteccion-diagnostico/examenes-colorrectal). Answers to all of the knowledge questions were included in this information, but unlike in the experimental intervention, the control intervention provided no feedback to participants regarding the accuracy of their responses to the preceding questions. Of the 11 screens of information provided in the control intervention, one screen was in comparative table format, while the rest were presented as narrative text. While covering some "actionable" information, the control intervention also covered less practical topics, such as how FOBT works at a chemical level. As in the experimental tailored IMCP, accompanying optional audio narration was available throughout the control IMCP; however, the control intervention offered no optional informational material. Examples of two portions of the control intervention are provided in Appendix A. After viewing their intervention, control patients answered the same self-efficacy questions answered by experimental group patients **(**Figure 1**, box C5)**.

Measures

Knowledge regarding recommended CRC screening test options was measured with three previously employed items (Appendix B) (Jerant et al., 2013). As noted previously, both experimental and control group patients answered these items before any information regarding test options was provided **(**Figure 1**, boxes E2 and C2)**. Thus, summing the individual item scores yielded a *baseline CRC screening knowledge score* (0-3 points, higher scores = greater pre-intervention knowledge). Six additional items, also previously employed, measured knowledge regarding potential harms and inconveniences of CRC screening (Appendix B) (Jerant et al., 2013). As noted previously, both control group and experimental group patients answered these items, but the experimental group patients did so after receiving mandatory brief tailored information plus optional more detailed non-tailored information regarding screening **(**Figure 1**, box E3)**, while controls did so immediately after answering the baseline knowledge questions **(**Figure 1**, box C3)**. Thus, summing the individual item scores yielded a score reflecting knowledge following some knowledge tailoring in the experimental group, referred to subsequently as post-knowledge acquisition tailoring CRC screening knowledge (0-6 points, higher scores = greater knowledge).

CRC screening self-efficacy was measured post-intervention (experimental tailored knowledge acquisition [Figure 1**, box E4**] or non-tailored control [Figure 1**, box C5**]) using a previously employed six item scale (Appendix B) (Jerant et al., 2013). Responses to individual items were averaged to yield a *total CRC screening self-efficacy score* (range 1-5, higher scores = higher self-efficacy; Cronbach's alpha in this sample = 0.71).

The remaining measures were included to examine how well the intervention groups were matched on characteristics that could influence CRC screening knowledge and self-efficacy. In addition to stratification by ethnicity (Hispanic or non-Hispanic) and software use language (Spanish or English), other socio-demographic characteristics measured included: age; gender; race (White, Black, or Other); income (<$10,000, $10,000 to <$15,000, $15,000 to <$25,000, $25,000 to <$50,000, or >$50,000); and education level (less than high school, some high school, high school graduate, some college, or college graduate). Health status was measured with the SF-12 Mental Component Summary and Physical Component Summary scores (range 0-100, higher scores = better health) (Ware, Kosinski, & Keller, 1996). Patients indicated whether they had ever undergone FOBT or colonoscopy ("yes" versus "no" or "don't know"). Patient satisfaction with randomly assigned intervention was assessed using a five item scale (score range 1-5, higher scores = greater satisfaction).

Data Analysis

Data were analyzed using Stata version 12.1 (Stata Corporation, College Station, TX). Descriptive comparisons used chi squared tests (categorical variables) and t-tests (continuous variables). To test study Hypothesis 1a, we employed linear regression analysis to examine the effects of the key predictor (experimental versus control intervention) on post-knowledge acquisition tailoring CRC screening knowledge (the dependent variable), adjusting for study strata (recruitment center, ethnicity, and language). To test study Hypothesis 1b, we employed three sequentially and cumulatively adjusted linear regression models to examine the effects of the key predictor (experimental versus control intervention) on CRC screening self-efficacy score (the dependent variable). The base model (Model 1) examined the association of exposure to the experimental intervention with CRC screening self-efficacy, adjusting for the study strata (recruitment center, ethnicity, and language); Model 2 added adjustment for baseline CRC screening knowledge; and Model 3 added further adjustment for post-knowledge tailoring CRC screening knowledge. The self-efficacy parameter estimates without and with adjustment for knowledge were compared using the method of Clogg, Petkova, and Haritou (1995). To test study Hypothesis 2, which proposed no significant differences in the effect of tailoring knowledge acquisition on self-efficacy across ethnicity/language strata, we employed a fourth model (Model 4), adding baseline CRC screening knowledge*ethnicity/language and experimental intervention*ethnicity language interaction terms to Model 3. Apart from the variables specifically noted above, all models were unadjusted, since the intervention groups were well-matched on baseline characteristics (Table 1).

Results

Figure 1 shows the flow of subjects through the RCT. Table 1 provides a summary of patient characteristics by study group. Of the 1164 patients enrolled in the RCT, 1159 had complete self-efficacy data and composed the current study sample; 49.3% were non-Hispanic, 27.2% were Hispanic/English, and 23.4% were Hispanic/Spanish. There were no significant study group differences on baseline characteristics, including baseline CRC screening knowledge, or in satisfaction with study software.

Hypothesis 1a

The unadjusted mean post-knowledge acquisition tailoring CRC screening knowledge scores (with standard deviations in parentheses) in the experimental group and control group were 4.23 (2.13) and 3.69 (2.14), respectively, a significant difference, $t(1162) = 4.30$, $p < .001$. In a linear regression analysis adjusted for study strata (recruitment center, ethnicity, and language), the mean post-knowledge acquisition tailoring knowledge score was 0.85 points higher in the experimental group than in the control group, $R^2 = .20$, $F(7, 1151) = 41.95$, $p < .001$, 95% CI [0.61, 1.10].

Hypothesis 1b

The unadjusted mean CRC screening self-efficacy scores (with standard deviations in parentheses) in the experimental and control group were 4.09 (0.71) and 3.84 (0.67), respectively, a significant difference, $t(1157) = 6.16$, $p < .0001$. Table 2 shows the findings of the three sequentially adjusted linear regression models, examining the effects of the knowledge-tailored intervention on self-efficacy as compared with the effects of the control intervention. In the base model (Model 1), adjusted only for study recruitment center, ethnicity, and language, exposure to the experimental intervention was significantly positively associated with CRC screening self-efficacy. The significant positive association of exposure to the experimental intervention with self-efficacy was unchanged after adjusting for baseline screening knowledge (Model 2) and was reduced with further adjustment for post-tailored knowledge acquisition screening knowledge (Model 3). Both pre- and post-knowledge acquisition tailoring knowledge scores also were significantly positively associated with self-efficacy (Model 3). As compared with Model 2 (adjusted for baseline knowledge and study strata), in Model 3 (adjusted for baseline knowledge, post-knowledge acquisition tailoring knowledge, and study strata) the effect size of the experimental intervention on self-efficacy was reduced by 0.03, $z = 2.90$, $p = .004$, 95% CI [0.01, 0.05].

Hypothesis 2

In an additional linear regression adding ethnicity/language subgroups as well as pre-intervention CRC screening knowledge*ethnicity/language and experimental intervention*ethnicity/language interaction terms to Model 3, the significant main effects of experimental intervention exposure and pre- and post-knowledge acquisition tailoring knowledge persisted, while none of the ethnicity/language subgroup or interaction terms were significant ($P > .27$ for all interactions; data not shown, available upon request).

Discussion

Confirming study Hypotheses 1a and 1b, respectively, we found exposure to tailoring of knowledge acquisition via the experimental IMCP was associated with significantly higher CRC screening knowledge and self-efficacy. Further, confirming Study Hypothesis 2, the positive association of the experimental intervention with self-efficacy was similar among Hispanic and non-Hispanic persons, and, within the Hispanic group, among both Spanish and English language software users.

The findings regarding Hypotheses 1a and 1b are consistent with health information seeking theory (Niederdeppe et al., 2007) and limited supporting observational (Chen & Feely, 2013) and quasi-experimental (Rimal, 2000; Chew et al., 2002) research, and also with socio-psychological theory and research concerning the interrelationship of personal agency and behavioral self-efficacy (Reed et al., 2012l; Chua & Iyengar, 2006). Also of note (although not hypothesized *a priori*), higher baseline (pre-intervention) CRC screening knowledge and post-intervention knowledge were associated with higher CRC screening self-efficacy, independent of experimental intervention effects on knowledge acquisition and self-efficacy (Table 2, Models 2 and 3). Taken together, these findings suggest the following: 1) both pre-existing knowledge of a health topic and tailoring knowledge acquisition may be associated with self-efficacy; and 2) the tailored intervention effect on self-efficacy was not fully captured by the measured effect of the intervention on knowledge acquisition.

Prior research has demonstrated that self-efficacy and, in turn, related health behaviors may be enhanced via a number of health behavior theory-driven approaches, such as providing messages tailored to personal or vicariously experienced “successes” and “failures” with behavior change (Lee, Arthur, & Avis, 2008; Parent & Fortin, 2000; Strecher et al., 1986). However, no prior published studies have addressed whether knowledge tailoring alone is sufficient to influence self-efficacy for health behaviors (in this case, CRC screening). Thus, the current findings add to the literature on tailored interventions.

Given prior research showing self-efficacy is a precursor of CRC screening behavior (Basch et al., 2006; Dietrich et al., 2007; Fiscella et al., 2011; Manne et al., 2009; Marcus et al., 2005; Walsh et al., 2010), the findings suggest the possibility that an IMCP tailoring knowledge acquisition could increase CRC screening uptake, including among English- and Spanish-speaking Hispanics. The parameter estimate in our Model 2, which provides the effect of the experimental intervention **on self-efficacy** after adjusting for baseline CRC screening knowledge and study strata, was 0.25 (Table 2), while the standard deviation **for self-efficacy** was 0.64. Dividing the parameter estimate **for self-efficacy** by the standard deviation **for self-efficacy** yields the **Cohen’s d** effect size, or number of standard deviations by which the tailored intervention group differed from the control group in terms of self-efficacy enhancement **(**Cohen, 1988**)**. The **Cohen’s d** in our study (0.25/0.64 = 0.39) falls between 0.3 and 0.5, the values often invoked as suggesting small and medium effects, respectively (Cohen, 1988), and is as large as or larger than the **Cohen’s d effect sizes** in most prior RCTs that examined tailored intervention effects on self-efficacy, such as those meta-analyzed by Noar et al. (2007). This is noteworthy given that the prior RCTs examined interventions incorporating tailoring to multiple socio-psychological factors (sometimes including, but never limited to, knowledge), and many of the interventions led to clinically important behavioral effects (Noar et al., 2007). Thus, while our findings clearly are exploratory, they support the potential utility of additional RCTs designed expressly to examine the effects of tailoring knowledge acquisition on self-efficacy and, ultimately, linked distal health behaviors such as CRC screening.

Adjustment for CRC screening knowledge reduced the parameter estimate for the experimental effect on self-efficacy by approximately 10% (Table 2, Model 3). What might explain the residual association? As noted previously, the experimental tailored IMCP included knowledge "self-tailoring," offering patients a degree of choice over which and how much CRC screening information to view. It seems reasonable to hypothesize that self-tailoring features may have further enhanced participants' health information seeking (**i.e.,** knowledge acquisition) *experiences*, beyond the effects measured by the change in knowledge scores, thereby further enhancing self-efficacy for the focus health behavior (in this case, CRC screening) (Chen & Feely, 2013). Future RCTs are needed to test this hypothesis, since health information seeking perceptions were not measured in our study. However, the hypothesis is consistent with theory and research regarding the interrelationship of self-efficacy with personal agency, the experience of controlling external events through personal actions such as information seeking (Bandura, 1997; Reed et al., 2012). Particularly if the tailored IMCP is found to increase CRC screening across ethnicity/language groups in future analyses, it would suggest the need to reconsider the role of knowledge acquisition in influencing patient self-efficacy and health behaviors.

If future RCTs find that tailoring knowledge acquisition improves CRC screening, and possibly other health behaviors, it could simplify the design of tailored IMCPs. Tailored materials similar to the type employed in the current study could consist simply of brief text messages (with or without narration), with embedded links to optional more detailed material. By contrast, other tailored approaches to enhancing self-efficacy typically require developing computer programs capable of generating many message variants tailored to gradations in patient standing on self-efficacy and interrelated constructs (e.g., perceived barriers) (Schumann et al., 2008). Such programs also often involve producing persuasive multimedia elements (e.g., patient testimonial videos, to provide positive vicarious health behavior change experiences) (Jerant et al., 2007). The creation and implementation costs of such interventions are considerable (Lairson, Chang, Bettencourt, Vernon, & Greisinger, 2006; Lairson et al., 2008). Lower creation and implementation costs associated with tailoring knowledge acquisition alone could stimulate the development of tailored IMCPs aimed at influencing health behaviors.

The current study had some limitations. There was no baseline (pre-intervention) measure of self-efficacy. However, the higher mean post-intervention self-efficacy score in the experimental group is likely to represent a true effect of the intervention. A chance group imbalance in CRC screening self-efficacy would seem less likely, given the magnitude of the difference in self-efficacy between groups, and given that randomization resulted in study groups that were well-matched on other pre-intervention characteristics (Table 1). The generalizability of our findings is uncertain, a limitation applicable to virtually all RCTs. The findings have unclear applicability to self-efficacy related to other health behaviors. Additionally, while the RCT population was large and diverse, with strong representation of English- and Spanish-speaking Hispanic persons as well as Black persons, it is unclear whether the findings are applicable to other racial/ethnic (e.g., Asian American) and language groups. As noted in the Methods (pp. 11-12), the experimental intervention differed from the control intervention in aspects other than tailoring knowledge acquisition, such as the employment of comparative tables (rather than narrative text) to present most information. Our study was not designed specifically to tease out the pure effects of tailoring knowledge acquisition. Rather, we examined the effects of a pragmatic tool that incorporated knowledge acquisition tailoring as well as other features expected to facilitate behavioral effects. Future RCTs of IMCPs aimed at disentangling the effects of tailoring knowledge acquisition on self-efficacy from effects emanating from other features (e.g., presentation format) would be useful in helping to better inform the design of these tools.

Conclusion

An experimental IMCP tailoring patient acquisition of knowledge regarding CRC screening was associated with significantly higher CRC screening self-efficacy than a non-tailored control IMCP. The experimental tailored IMCP effect was observed in both Hispanic and non-Hispanic patients and in those using the English- or Spanish-language versions. Given that self-efficacy is a key mediator of CRC screening behavior, these findings suggest that interventions tailoring knowledge acquisition alone may have promise as tools for increasing CRC screening across ethnic and language groups. Analyses examining effects of tailoring knowledge acquisition on CRC screening behavior will be required to further explore this promise.

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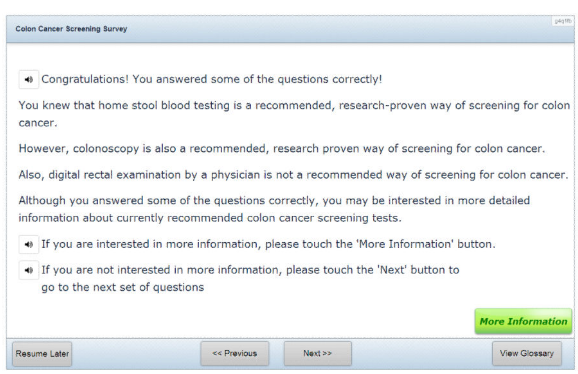
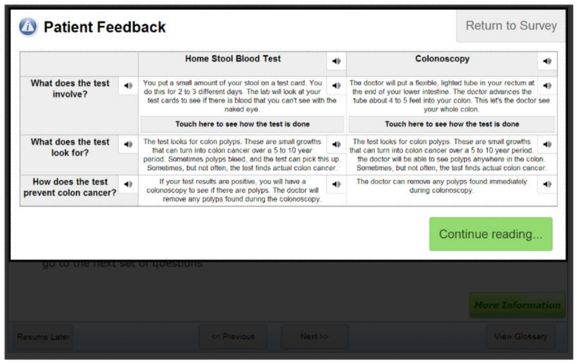
Appendix A Examples of Experimental and Control Intervention Content

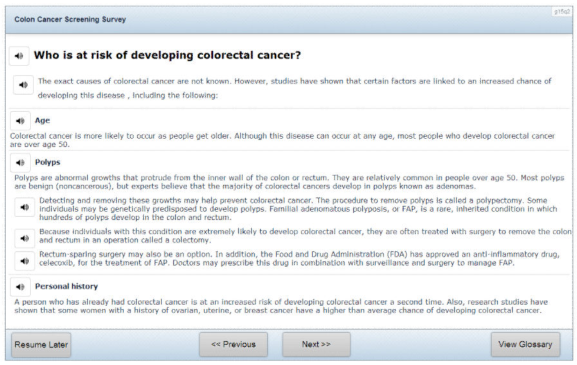
Example of one tailored variant of the experimental IMCP screen providing brief feedback regarding answers to items regarding knowledge of recommended CRC screening test options. Note the option to access more detailed information.

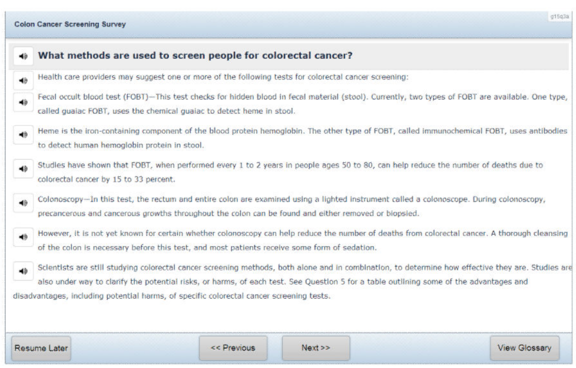


Example of a portion of (screen from) the experimental IMCP optional detailed CRC screening information module, accessed via the “More Information” button in the preceding screen



Examples of CRC screening information provided in the non-tailored control IMCP





Appendix B Key Study Measures

CRC screening knowledge measures

Knowledge regarding recommended CRC screening test options (3 items)

Currently recommended options for colon cancer screening are:

1. Home stool blood testing (true)

2. Digital rectal examination by a physician (false)
3. Colonoscopy (true)

Response options for all items: true (1 point), false (0 points), don't know (0 points). Item 2 was reverse coded prior to scoring.

Knowledge regarding potential risks and inconveniences of CRC screening (6 items)

Risks of being screened for colon cancer are:

1. Additional unnecessary tests to look in to findings that at first seem concerning but turn out to be normal (true)
2. For colonoscopy, putting a hole in the colon (also known as perforation) leading to surgery, serious illness and/or death (true)
3. False reassurance due to abnormalities being missed (true)

Common inconveniences of colon cancer screening are:

4. For colonoscopy, severe abdominal pain during the test (false)
5. For colonoscopy, the need to have someone drive you home from the test appointment (true)
6. For home stool blood testing, unpleasantness of collecting and handling stool samples (true)

Response options for all items: true (1 point), false (0 points), don't know (0 points). Item 4 was reverse coded prior to scoring.

CRC screening self-efficacy measure (6 items)

1. I am confident that I can undergo colon cancer screening
2. Arranging my schedule to go through colon cancer screening is an easy thing to do.
3. Finding time to go through colon cancer screening would be difficult for me to do.
4. Going through colon cancer screening would be easy for me to do.
5. I am confident that I can do home stool blood testing.
6. I am confident that I can go for colonoscopy.

Response options for all items: strongly agree (5 points), agree (4 points), neither agree nor disagree (3 points), disagree (2 points), strongly disagree (1 point). Item 3 was reverse coded prior to scoring.

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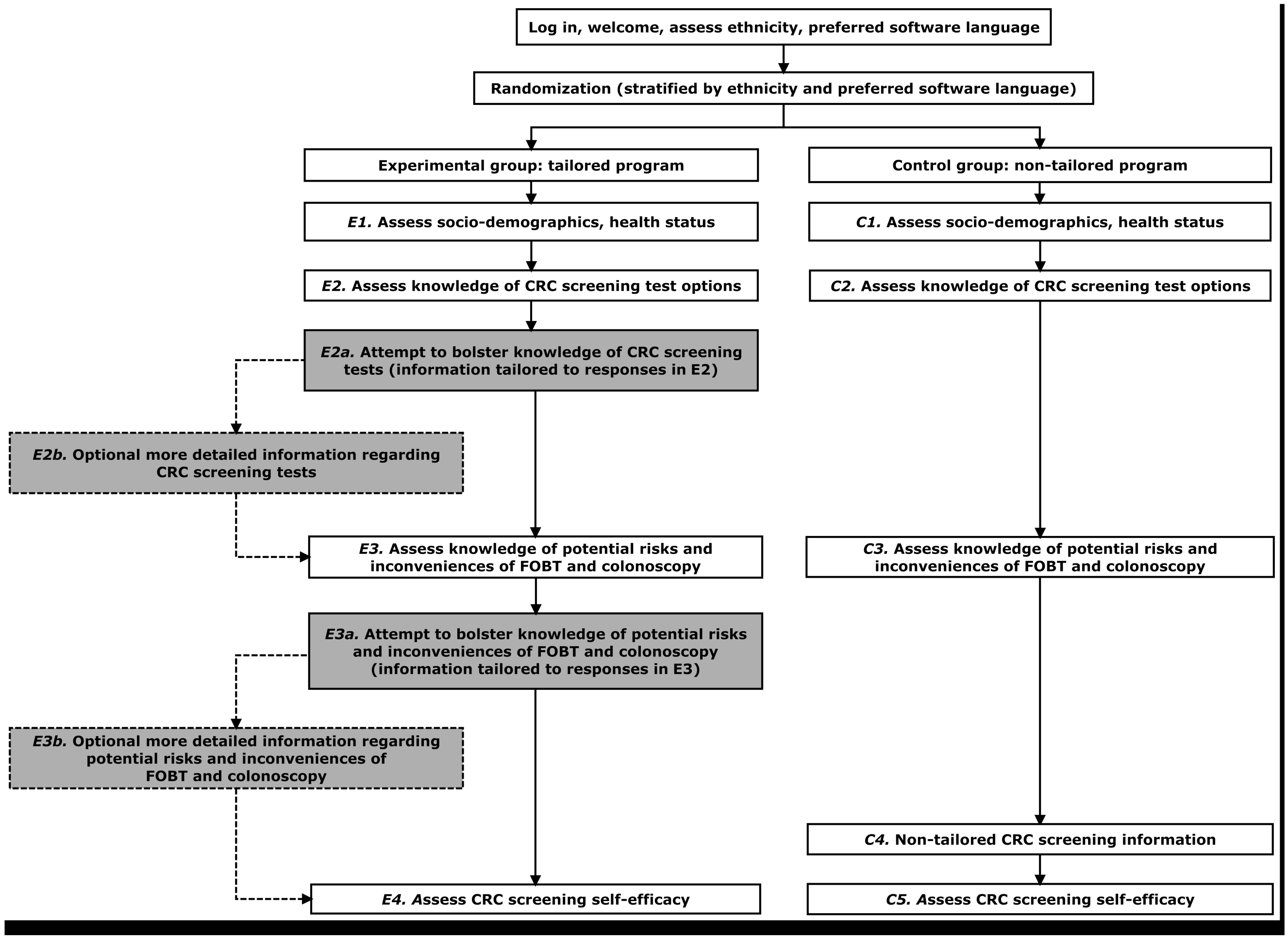

Figure 1.

Sequence and Content of Experimental and Control Interventions

Shaded boxes indicate aspects of the experimental intervention tailoring knowledge acquisition. CRC = colorectal cancer; FOBT = fecal occult blood testing

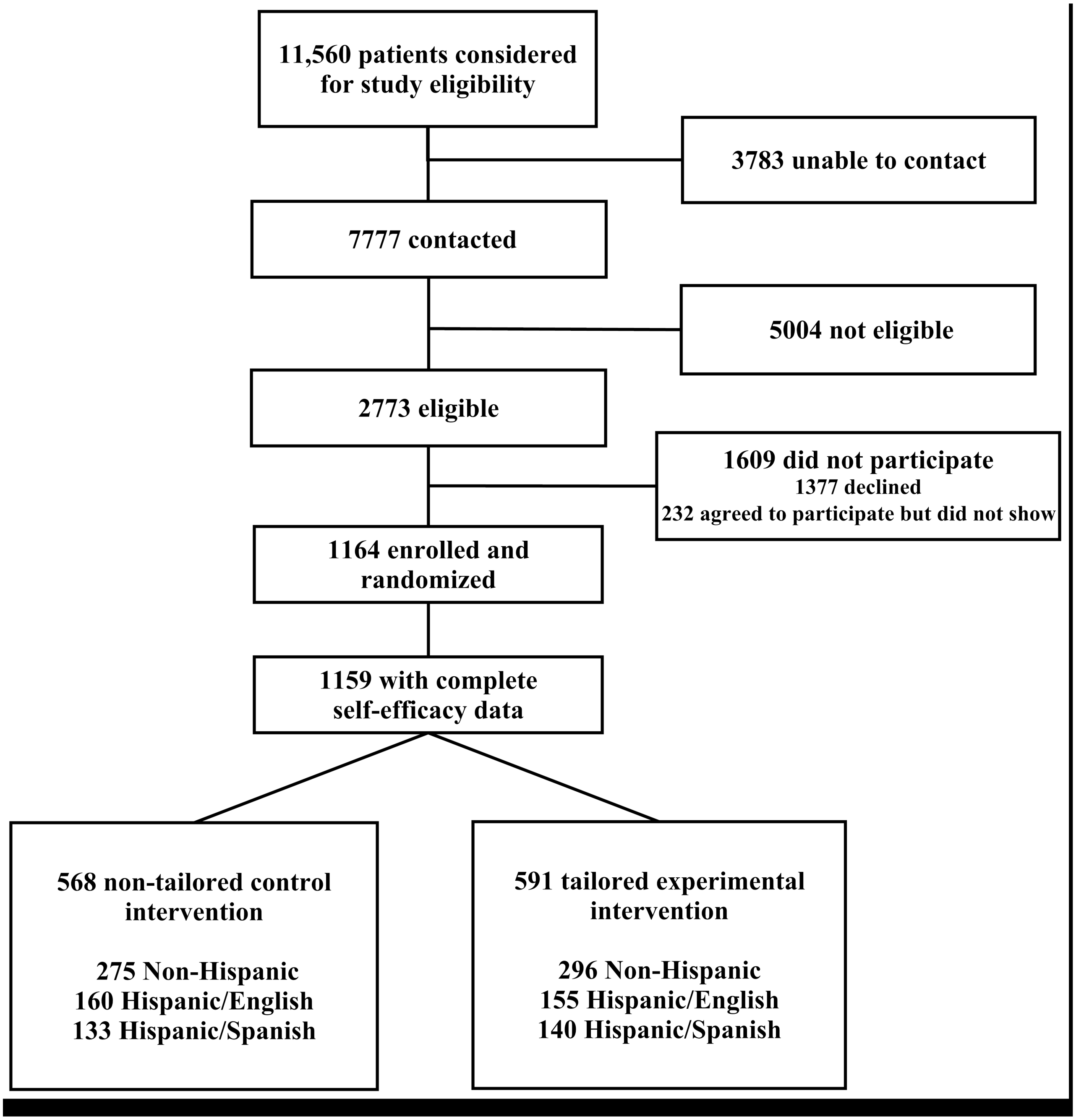

Figure 2.
Flow of Patients Through the Study

Table 1

Characteristics of participants by study group

	Study intervention group		
	Control (n = 568)	**Experimental (n = 591)**	***p*** [a]
Patient enrollment by site, %			.99
Denver and Southwestern Colorado	15.6	16.0	
Bronx, New York	24.0	24.1	
Rochester, New York	20.9	21.0	
Sacramento, California	21.6	22.2	
San Antonio, Texas	17.9	16.7	
Socio-demographics			
Age, mean (SD)	57.1 (6.2)	57.0 (6.1)	.90
Female, %	65.8	65.0	.77
Spanish language version of software, %	23.5	23.4	.96
Ethnicity/race category, %			.87
Hispanic (any race)	51.5	49.7	
Non-Hispanic			
White	20.7	21.0	
Black	23.0	24.9	
Other race	4.7	4.4	
Education level, %			.36
Less than high school	15.8	19.0	
Some high school	21.5	18.1	
High school graduate	25.1	23.8	
Some college	18.5	20.9	
College graduate	19.0	18.3	
Income level, %			.69
<$10,000	33.2	35.0	
$10,000 to <$15,000	18.9	17.8	
$15,000 to <$25,000	17.8	14.7	
$25,000 to <$50,000	14.5	15.3	
>$50,000	15.6	17.2	
Health status, mean (SD)			
SF-12 Physical Component Summary	42.9 (11.1)	42.1 (11.7)	.31
SF-12 Mental Component Summary	45.4 (11.4)	45.5 (11.3)	.88
Prior CRC screening, %			
FOBT	26.5	26.9	.88
Colonoscopy	13.2	15.9	.20
Satisfaction with study software (range 1-5), mean(SD)	4.2 (0.5)	4.3 (0.5)	.12
Baseline CRC screening knowledge	1.6 (0.8)	1.7 (0.8)	.42

Notes: CRC = colorectal cancer; FOBT = fecal occult blood test; SD = standard deviation.

[a]Chi-squared test for categorical variables, t-test for continuous variables

Table 2

Association of CRC screening self-efficacy with experimental intervention exposure (versus control exposure), without and with sequential adjustment for baseline and post-knowledge tailoring CRC screening knowledge

	CRC screening self-efficacy					
	Model 1		Model 2		Model 3	
Variable[a]	B	95% CI	B	95% CI	B	95% CI
Experimental intervention (versus control)	0.25*	[0.17, 0.33]	0.25*	[0.17, 0.33]	0.22*	[0.14, 0.30]
Baseline CRC screening knowledge			0.13*	[0.08, 0.18]	0.11*	[0.05, 0.16]
Post-tailoring CRC screening knowledge					0.03*	[0.01, 0.05]
R^2	0.04		0.07		0.09	
F	7.39*		10.59*		11.90*	
ΔR^2			0.03		0.02	
ΔF			3.20		1.31	

Note: CI = confidence interval; CRC = colorectal cancer

[a] All models also were adjusted for study strata (recruitment center, language, and ethnicity)

* $p < .001$