Cancer Control
Volume 30: 1–14

DOI: 10.1177/10732748221130162
journals.sagepub.com/home/ccx
SAGE

# Information Architects: Using Community-Engaged and Qualitative Methods to Design a Technology-Based Nutrition and Cancer Risk Intervention for Rural Adults

**Melissa J. Vilaro, PhD, MPH[1], Kathryn McAlindon, PhD[2], Gillian Mertens, PhD[2], Taylor Ashley, BS[2], Mohan Zalake, BS[3], Eric J. Cooks, PhD[2], and Janice L. Krieger, PhD[2]**

## Abstract

**Background:** Nearly half of all cancer deaths are preventable through modification or avoidance of key risk factors. As such, there is a growing urgency to identify effective, low-resource, and scalable technologies that support clinical care and patient self-management of health behaviors.

**Purpose:** Informed by theories of cognitive load and user-centered design approaches, we develop a culturally tailored, multicomponent digital intervention to engage rural adults between 50-73 years old with their personalized nutrition risk factors for colorectal cancer (CRC) prevention.

**Method:** A total of 48 adults tested a Virtual Health Assistant (VHA) prototype during focus groups in individual think-aloud interviews to facilitate iterative adaptations to a web-based CRC prevention intervention. Qualitative data was analyzed to identify user needs and preferences related to information and with a focus on avoiding cognitive overload.

**Results:** The VHA serves as a conceptual pre-training for users helping them understand CRC prevention key concepts and engendering motivation to act on the promoted behavior. A website was identified as a strategy to fill information gaps and present actionable information, after the VHA interaction. Cognitive load reducing strategies were used including segmenting where information is presented in learner-controlled segments rather than continuously.

**Conclusions:** Findings indicate potential benefits of designing CRC prevention information technologies with the rural older adults. Integrating patient-centered needs before launching health information web content will be important as the rapid growth of telemedicine aims to reach traditionally marginalized and underserved populations. Theoretically informed considerations for potential adverse outcomes (eg, information overload) are discussed.

## Keywords

telehealth, cognitive load, colorectal cancer prevention, website design, digital health interventions, rural health disparities, qualitative

Received December 17, 2021. Received revised July 25, 2022. Accepted for publication September 15, 2022.

[1]Department of Family, Youth and Community Sciences, University of Florida, Gainesville, FL, USA
[2]STEM Translational Communication Center, University of Florida, Gainesville, FL, USA
[3]Computer & Information Sciences & Engineering, University of Florida, Gainesville, FL, USA

**Corresponding Author:**
Melissa J. Vilaro, PhD, MPH, Institute of Food and Agricultural Sciences, Department of Family, Youth and Community Sciences, University of Florida, PO Box 110310, Gainesville, FL 32611-310, USA.
Email: mgraveley@ufl.edu

There is a growing urgency to identify effective, low-resource, and scalable technologies that support clinical care and patient self-management of health behaviors. It is estimated that in 2021 over 600 000 people will die of cancer in the United States.[1] However, data indicates that nearly half of all cancer deaths are preventable through modification or avoidance of key risk factors, many of which are related to diet and behavior.[2] For example, routine screening for colorectal cancer (CRC) can dramatically reduce population disease burden, yet in 2018 only 69% of eligible adults were adherent to CRC screening guidelines.[3,4] Further, upwards of 6% of worldwide cancer deaths have been attributed to alcohol consumption.[5] Red and processed meats have also been classified as having carcinogenic properties, with consumption positively associated with various cancers.[6-8] Given the impact of health behavior changes on cancer risk, research that focuses on enhancing the design of health information and communication technologies to facilitate adoption and use is urgently needed.

The current paper is part of a larger pilot study to develop and test an interactive, web-based, nutrition risk intervention delivered by a virtual health assistant titled; "Reporting Nutrition Risk Factors via Virtual Humans for Colorectal Cancer Prevention". The pilot study is based on construal level theory3434 and is designed to engage rural adults who are non-adherent with recommended CRC screening guidelines with their proximal nutrition risk factors for CRC (ie, alcohol, red meat, processed meat). The theory, and research exploring its role in behaviors, suggest that bringing a risk closer may impact behavior or attitude change.3535 Thus, daily dietary intake is posed to bring the distant risk of CRC psychologically closer to promote screening intentions.

## Using Health Technologies for Cancer Prevention

Developing strategic messages to promote health behaviors is particularly critical for populations underrepresented in clinical research. Rural patient populations have therefore been identified as a priority group for precision health communication research. Often facing structural barriers to care, rural patients experience significant cancer disparities, including higher incidence of cancer types with modifiable risk factors and preventive screening options, including CRC.[9,10] Rural patients are also less likely to be up to date with cancer screenings.[11,12] Advancements in digital health interventions can serve as a critical component in building capacity to address CRC disparities based on geography as this technology can be delivered remotely, and in a manner that is both convenient and cost-effective.

However, despite perceptions that the "digital divide," defined as disparities in access, skills, and benefits to and from web-based technology,[13,14] precludes rural patients from engaging with technology-based health interventions, there are growing efforts to build the technology-based eHealth infrastructure (eg, telemedicine access, electronic health records, patient portals, virtual health assistants) to support health in rural areas.[15-18] These emerging interventions can be most useful if developed with community-engaged input to address unique needs of rural populations. Virtual Health Assistants (VHAs) are animated, virtual characters that can be adapted to deliver tailored messages and may be useful to aid information processing and address cognitive load considerations when designing health information technologies for an aging rural population. VHAs have been found to be effective in addressing various health behaviors, including alcohol consumption, personal fitness, and nutrition,[19-21] and may be particularly successful in educating rural patients about cancer.[22] Previous research explored older adults' processing of cancer-related information on a website and found that information recall improved when older adults felt emotionally supported by a website (eg, defined as the extent the user perceives the website helps them deal with emotions and stress).[23] Findings such as this cue the importance of exploring website design with a focus on the information needs and processing of older rural adults.

Six steps for making a user-friendly health website outlined in a publication from the Office of Disease Prevention and Health Promotion and the U.S. Department of Health and Human Services suggest the following: (1) learn about your users and their goals, (2) write actionable content, (3) display content clearly on the page, (4) organize content and simplify navigation, (5) engage users with interactive content, and (6) evaluate and revise your site.[24] Additionally, because rural adults – particularly older rural adults who are at increased risk for new cancers – may experience difficulties processing new information, participatory approaches to managing information processing should be considered during the design of web-based health information technologies.

### *Cognitive Load Theory*

Cognitive load theory explores how individual cognitive processing occurs during a learning activity.[25] Processing can be impacted by three types of cognitive load: intrinsic cognitive load (cognitive requirements of the task at hand), extraneous cognitive load (unnecessary cognitive load caused by design or information), and germane cognitive load (the effort necessary to process the information being added to prior knowledge).[26] A core tenet of cognitive load theory is that the capacity to process and store new information is limited; also, the duplicated presentation of multimodal information (eg, showing a figure and then showing descriptive text) can tax cognitive capacity.[26] Design experts stress that cognitive load should be a central consideration in multimodal information design to promote effective learning and problem-solving.[27]

The cognitive processing of risk information delivered via health information technologies should also account for pre-existing user knowledge. VHAs can be adapted to a user's specific knowledge base towards the aim of supporting retention and uptake of cancer risk and screening information.[28,29] However, little is known about the mechanisms involved in learning from a VHA and how those mechanisms might be leveraged to better promote behavior change within a VHA-led intervention. For this, a more recent iteration of cognitive load

theory[30] known as the cognitive theory of multimedia learning,[31] can be used to explore VHA-guided learning and decision making. Per this theory, we define learning as an active process of filtering, selecting, organizing, and integrating information based upon prior knowledge.[23] To optimize learning, it is key to consider how design aspects affect a user's cognitive load to prevent cognitive overload (eg, when a learner's available processing capacity is exceeded).

### Information Overload

Information overload can be caused by excessive or contradictory sources of information. At the individual level, information overload occurs when an excess of information (more than can be managed effectively) creates a degree of stress against which one's coping strategies are ineffective.[24] In their review of literature, Bawden &Robinson[32] posit that information overload occurs "when information received becomes a hindrance rather than a help, even though the information is potentially useful."(p. 183) Information overload may lead to adverse outcomes for information-seekers[33] such as anxiety,[34] information avoidance, discontinuing a search,[35-37] or "the inability to connect new information to prior knowledge."[38](p104)Nine strategies have been established based on experimental studies to manage cognitive load through information design (see Table 4 for an overview of strategies).[19]

### Purpose Statement and Research Questions

This study highlights the user-centered development of a digital cancer prevention resource. The purpose is to accommodate older rural adults' requests for additional cancer prevention information after they interact with a tailored web-based, VHA-delivered cancer risk intervention. Informed by theories of information overload and user-centered approaches for designing health information technology, we answer the following research questions: after testing a brief VHA-delivered, web-based intervention discussing nutrition risk factors for colorectal cancer; (1) what user-generated requests for more information emerge and (2) what content and design strategies can be incorporated into a supplemental website resource to accommodate user requests?

## Method

### Overview

The current VHA-delivered intervention allows users to report their dietary intake during an approximately 12-minute conversation, and receive evidence-based, tailored, recommendations for CRC prevention. The study protocol was approved by the university Institutional Review Board (IRB) and is a registered clinical trial (ClinicalTrials.gov, NCT04192071).

### Data Collection

A user-centered approach guided our process of including rural adults in the participatory development of the technology. Recruitment occurred via HealthStreet, a university affiliated community engagement and research resource, flyers, and via emailing potentially eligible participants identified via a university affiliated research registry. By collaborating with our users/stakeholders (older rural adults) we aimed to center their information needs. User-centered design approaches follow a typical pattern including identifying needs, specifying the context of use, specifying requirements, producing design solutions, evaluating designs, and determining if the system satisfies the user or if not, starting over again. For this study, after each round of data collection, the VHA was updated based on user feedback. Inkle script programming[39] was used to write and adapt for the virtual human prototype delivered on a virtual interviewer platform.[40]

A purposive sample of participants stratified by race and gender, completed the following in either a focus group or think-aloud interview: (1) individually tested an interactive VHA prototype via a web-based platform while researchers were present and available to troubleshoot as needed. Think-aloud participants were prompted to think out load with verbal thoughts and questions as they proceeded through the intervention), (2) completed a self-reported questionnaire on demographics, perceptions, and behaviors, (3) participated in a moderated discussion to provide feedback on the VHA prototype and preferences for graphic stimuli (eg, food images, infographic, visual representations of risk, existing cancer prevention resources). The VHA interaction was not the same for all participants, as after each round of data collection, the VHA was updated with user feedback.

Moderators were trained members of the research team. When possible, we sought to employ gender and racial concordance between participants and moderators. The first two focus groups were conducted in-person in January 2020, while the remaining data collection events occurred remotely via Zoom after a revision to the protocol to allow data collection to continue during Covid-19 related restrictions in place at the time. Questionnaire items included demographic information as well as validated measures to assess risk perceptions,[41] intentions to screen for CRC,[42] message relevancy,[43] and information avoidance among other items relevant to the larger pilot test of the intervention. Focus groups lasted approximately two hours and individual think-aloud interviews lasted about one hour. Sessions were video/audio recorded and transcribed verbatim. Participants received a $35 visa gift card or Amazon e-gift card.

### Data Analysis

Researchers iteratively reviewed transcripts and notes taken during data collection and conducted exploratory analysis to determine what changes were needed for each VHA prototype update. Regarding researcher characteristics, members of the research team hold several identities including Black, White, cancer survivor, and have experience working to promote

health equity in interdisciplinary teams that include the fields of health communication, computer science, education, and public health. Transcripts were managed with NVIVO software.[44] To facilitate data analysis we employed a general inducive approach to thematic analysis.[45,46] The research team created a codebook to formalize analysis of user-generated requests for more information which were coded as information gaps. We extract and describe participants experiences with the intervention in terms of Cognitive Load Theory. We defined information gaps as additional information or content requested by participants (beyond what was presented by the VHA). Information gaps could include specific suggestions for visual cues (eg, images, pop-up features, graphs), topics of interest (eg, recipes, behavior change techniques, cancer facts), or format of information (eg, PDFs, links, websites, videos).

Researchers coded transcripts individually and then discussed findings during weekly data analysis meetings from August 2020 to November 2020. Weekly meetings included discussion of a change log of how the script changed (additions and deletions) during each iteration. There were instances where new content added during a previous iteration, was deleted for the subsequent iteration based on user-feedback. Although those details are outside of the scope of this paper, we plan to report them with results of the quantitative pilot test. Questionnaire data were analyzed using SPSS to summarize participant characteristics with descriptive statistics and the SRQR reporting guidelines were used to ensure rigorous synthesis and reporting of qualitive findings

## Results

### Participants

Eligible participants were adults between 50-73 years old, proficient in English, and geographically rural areas of one southeastern U.S state. Non-Hispanic Black and White, males, and females participated and were (M = 61.7, SD = 7) years old (Table 1).

**Table 1.** Participant Demographics.

| Variable | n | % |
|---|---|---|
| Gender | | |
| Male | 24 | 50 |
| Female | 24 | 50 |
| Race | | |
| Black | 31 | 65 |
| White | 17 | 35 |
| Primary language | | |
| English | 47 | 100 |
| Marital status | | |
| Single | 12 | 25 |
| Married | 23 | 48 |
| Divorced/separated | 9 | 19 |
| Widowed | 3 | 6 |
| Missing | 1 | 2 |
| Education | | |
| Grade 1-8 | 1 | 2 |
| HS grad, technical college, some college | 24 | 50 |
| College graduate | 11 | 23 |
| Post-graduate training | 11 | 23 |
| Missing | 1 | 2 |
| Income | | |
| <$11,000 | 7 | 14 |
| $11,000-$30,000 | 9 | 19 |
| $30,000-$75,000 | 14 | 29 |
| $75000+ | 10 | 21 |
| Missing/prefer not to answer | 8 | 17 |
| Insurance [Status?] | | |
| Yes | 48 | 100 |
| No | 0 | 0 |
| Total | 48 | 100 |

### Information Gaps

The following categories represent user-generated topics of additional interest. While learning about how red meat, processed meat, and alcohol contribute to one's CRC risk from the VHA, participants asked for (1) recipes (2) statistics and details about scientific claims (3) more CRC screening information (4) meat alternatives and (5) behavior change strategies. Table 2 Presents descriptions of each category and participant comments from formative data collection. Participant comments and evidence-based strategies to limit cognitive overload were used to inform iterative changes to the script (VHA) as well as considerations for building a website as a supplement to the VHA interaction.

*Recipes.* During the VHA interaction, The VHA presents the user with meal ideas that could be substitutions for dishes with red and processed meat. Participants indicated that they found suggestions useful but also requested specific recipes. Some users also asked about the possibility of receiving personalized meal plans to help them meet the VHA's recommendations to avoid red and processed meat. Participants prefaced requests for recipes with questions like, "so what can I eat"?

*Statistics and Research.* Participants also sought clarification of gradients of risk often in the form of research or statistics that could clarify their risk. Participants were also asked if their specific demographic characteristics would change their own risk or if specific populations were driving the trends for increased risk as described by the VHA. Often in response to the VHA discussing recommendations for alcohol, red meat, and processed meats, many participants asked for more data on "how much is okay to eat", perhaps to negotiate their existing dietary patterns with the recommendations to avoid or limit consumption of nutrition risk factors. Some participants also mentioned wanting to do their research to get more information after their VHA interaction.

**Table 2.** User-generated Categories of Additional Information Needs after VHA Interaction.

| Category | Example quotes | Strategies used to address information needs |
|---|---|---|
| Recipes | "Those are neat suggestions but where do I find how to make them [meat alternatives listed by VHA during the interactive module]." (TA 5) | The website provides users with a dedicated recipe section of alternatives to red meat, processed meat, and alcoholic beverages. Users can choose to access the webpage after interacting with the VHA or choose to skip this resource<br>(2) Segmenting gives optional access to recipes on a website after talking to the VHA<br>(3) Pretraining is used when the VHA names nutrition risk factors for colorectal cancer and alternative food items (eg, "chicken salad sandwich") |
| Statistics and research | "Then it would have said, you know, it could have spit back to me, you know, that this age, this is your likelihood or prevalence? You know, for your demographic" (FG11, P3) | Per-user request, the VHA script was updated to include one statistic describing colorectal cancer incidence among adults in the United States<br>(2) Segmenting limits statistical facts during the VHA interaction but provides more evidence-based statistics and research on the website's "quick links" section |
| | Give some stats, maybe based on three or four reports, not just one. I don't know how far you want to go, but I'm concerned about [if I'm at risk from prior smoking], and I will look it up." (FG14) | (4) Weeding: The trimmed down, need-to-know information found on the website's fast fasts section allows users to reorient themselves to key facts within the new website presentation space<br>(6) Aligning is used by placing the key term "fast facts" near the corresponding image of the colon on the website to reduce scanning |
| Colorectal cancer screening information | "I don't know how often you can do the home [test], so I guess I like more information about the home option." (FG5) | Requests included colorectal cancer risk statistics and quick references about screening<br>(2) Segmenting is used by iteratively adding information to the VHA describing home-stool and colonoscopy screening modalities, frequency, and age requirements but providing printed resources for evidence-based guidelines on the website |
| | "What I think is missing is showing where colon cancer can start. I don't know where that place is. Is it the large intestine? the colon? Is it the small intestine? Might be useful to show Where they go with a colonoscopy. Then again, I'm second-guessing myself here because maybe that's off-putting to some people" (FG7) | (3) Pretraining on key screening guidelines and terminology for CRC.<br>(5) Signaling is used with the website homepage label "Colorectal Cancer Fast Facts", signaling key info. Simple icons also provide visually aided reinforcement<br>(8) Synchronizing is employed with a brief VHA-narrated, animated video clip demonstrating the correct stool collection process as needed to complete the FIT home stool test. This video was user-developed and previously pilot-tested |
| Meat alternatives | "Maybe that's the new module or some new section, what a good diet would include? Are there any vegetables that you eat more of, and you can have more steak? …You're just telling me not to eat meat. What did he say something about replacing it with? I guess chicken or beans, legumes and beans and so forth, but that's only a piece of what we all eat." (FG8) | (1) Offloading: the use of a VHA, in general, provides an opportunity for diversification of modalities including the use of auditory channels for information delivery |
| | "I would have liked to have had more information expanded on...more advice on processed meats." (TA5) | (2) Segmenting is used when the VHA discusses examples of non-meat food alternatives (eg, beans/legumes). The website will provide a list of alternatives and additional resources determined in user testing |
| Behavior change strategies | "Give me some of the actual other things that I can do, as well. So, you know, it's almost like, here's all the stuff you did, that's bad, that's contributing to it, but tell me the things that I could do" (FG11, P3) | (3) Pretraining provides users with a few brief strategies they can try to reduce consumption of the nutrition risk factors described by the VHA.<br>(2) Segmenting "Fast Fact" Link directing users to "small changes" using the same text used in the VHA script |

*Colorectal Cancer Screening Information.* Participants requested additional information on CRC screening most frequently during prototypes one and two of the VHA-delivered nutrition module. This was due in part to an early focus on developing the dietary intake reporting features and accuracy of tailored feedback. Due to the extensive focus on nutrition reporting early on, scripted content in the initial prototypes omitted important details about CRC screening. By prototype three (of four) CRC screening content was added into the script. Across versions, participants comments changed from general feedback that there was a lack of information on colorectal cancer to asking more specific questions about where in the body colon cancer starts and how to screen with different modalities (home stool test vs colonoscopy) as well as questions about the accuracy of home stool tests compared to colonoscopy.

*Meat Alternatives.* Participants wanted more holistic information about food in addition to just the three nutrition risk factors presented by the VHA. Perhaps because the VHA only discussed three food/beverage items to avoid for CRC prevention, participants were curious about other foods, like vegetables, fiber, sugars, and simple carbohydrates, protein, and how these other foods were related to colorectal cancer risk. Table 2. describes in detail the type of user requests.

*Behavior Changes Strategies.* The VHA script provides users with the recommendation to avoid or limit the three nutritional risk factors discussed. While this was a theoretically informed design, users requested information that would help them engage in action-oriented change. Questions of how to engage in behavior changes were typically asked after the VHA discussed the brief strategies and suggested a list of red/processed meat alternatives.

## Delivering Supplemental Information

While the results above addressed *what* participants wanted to know more about in addition to the intervention content, the following results emerged from participant discussions on *how* they would like to receive additional information. First, based on suggestions a website was chosen to communicate supplemental information. Specific considerations and strategies were used in the development of a website prototype to optimize potential learning and behavior change (Table 4). The following considerations emerged as key factors for the visual and informational prototype design: (1) using a website format to provide additional information; (2) incorporating graphics/visual aids for key concepts; (3) labeling website sections with language that aligns with VHA-delivered content; (4) supplementing the intervention with credible and print resources; and (5) offering interactivity/a feedback loop (Table 3).

*Designing the Website Prototype.* The first design consideration involved choosing a medium through which to present the supplemental information requested by participants. Initially, the study team presented an infographic during focus groups and interviews (see Appendix) as an example of a static resource that could be provided to participants either in print or digitally. As data was reviewed, it became clear that a single infographic may not be able to accommodate the breadth of additional information that was being requested. Second, because participants agreed that the brief VHA interaction itself was "just right" in terms of length and information density, any additional information would need to be provided outside of the VHA content. Third, many participants suggested a website while viewing the infographic, citing their view that because different people might want to know about different information, an infographic would be too busy and dense if it were to accommodate the diversity of user needs. Participants also expressed desires for "links" (ie, hyperlinked resources) that elaborated on the main points in the intervention, so they could select only those that aided their learning at that moment. Thus, due to usability, customizability, and organizational capabilities, a website was considered an appropriate supplement to the VHA.

To help the study team operationalize and conceptualize the information design strategies being applied, iterative prototypes starting as a concept map and evolving to web wireframes, resulted in a prototype of the landing page for the website (Figure 1-3). The prototype design process involved using an interdisciplinary and user-centered lens to balance fidelity to the data, the use of existing resources, infrastructure (ie, a university website template) and visual design.

*Communicating Key Concepts with Visual Aids.* In terms of visual components of a supplemental resource, feedback suggested participants preferred a minimal and intentional approach. While participants commented on the benefit of graphics for "[grabbing] my eye" or aiding developing mental representations (eg, for those unfamiliar with CRC or screening, "an image of what [CRC] is would help"), they also expressed concern about graphics making things "too busy" or being superfluous and ultimately distracting. To avoid overload from extraneous visual elements, weeding and signaling were key cognitive load reducing strategy used in website design (see Table 4 for definitions). Thus, the website homepage is labeled "Colorectal Cancer Fast Facts', to signal brief and visually aided reinforcement of key information delivered by the VHA (see Figure 1, or "Quick Links" in Figure 3 for another example). Signaling reinforces what they just learned cued by phrasing taken directly from the intervention. The trimmed-down, need-to-know information presented in the Fast Facts section of the website is an example of weeding and aims to provide participants the opportunity to reorient themselves to content priorities within the new website presentation space.

*Aligning Virtual Health Assistants and Website Content.* As the viewer scrolls further down, the next section, labeled "More from ALEX", illustrates the use of the third design consideration: reinforcing "pretraining," defined as key information participants learn such as terms and definitions, by labeling

**Table 3.** Website Design Considerations and location of Features in Initial Prototype.

| Website design considerations | Participant suggestions from data | Website section (Figures 1-3) |
|---|---|---|
| (1) Using a website for additional information | "Maybe if [the VHA] could tell you where to get either links or websites or brochures, where you can get more in-depth information. Because [the intervention] kind of goes kind of quick." TA6<br>"Maybe an option at the end. Because I'm not sure where it would have fit in the context of this virtual presentation. Possibly at the end if there were an option to look at [additional information], I would go through that kind of an option personally. I think that kind of thing is informative, something that [viewers] could download or a link to your references." FG8 | All sections |
| (2) Incorporating graphics/visual aids for key concepts | "You asked about [this infographic], I like this, it kind of grabbed my eye with some of the illustrations. The illustration sections are very easy to read, quick to read." FG8<br>"Also, the supplementary info, besides being written for patients, should be more graphic." TA5<br>"I went into this interaction with the assistant, knowing about colorectal cancer but there was no image of it...and if this assistant is meant to deal with people who are not being screened, who don't know much about it, then I think an image of what colorectal cancer is would help." TA5 | CRC fast facts<br>Quick links |
| (3) Labeling website sections in plain language that align with intervention content | "I think having several sections, one would include actual files, like the [infographic you showed, and] I like the idea of the list of other websites with the web addresses there. What is, I think, important also is to have each one properly labeled." FG8<br>"The one doubt I had was when [the VHA] said he'll be giving more complementary materials. I hope it's not the general vague complementary materials that you get. I have seen so many materials handed out, by either physicians or that you get online, that are just so general and that seem to be directed more at satisfying institutional and legal requirements rather than coming down and telling the patient in more common [language]." TA5 | More from ALEX |
| (4) Adding credible, print resources | "If it was really going to change my opinion, I got to [know,] what are the real stats involved with it?" FG8<br>"You always want to read what [you've heard] people say, you know, that's where you back it up. If it's in writing, if it's in print, I'm more likely [to believe it]. Sometimes [what people say] is believable but, yeah, you want to read it also." FG10<br>"In this day and age of conspiracy theories, a lot of people say a lot of different things. It's about backing it up with some sort of data." TA2 | More from ALEX pages (information pages for the five info gaps) |
| (5) Offering interactivity/feedback loops | "Like I said, the comment box. Someone may need to leave a comment or ask a question that wasn't [covered] that they needed information on regarding nutrition or colorectal cancer, you know." TA1<br>"It would be nice somewhere in there, to have a box, where you can ask an additional question. All the questions [in the intervention] have already been designed with answers and then you may have another question that it cannot answer." TA3 | Ask ALEX |

additional resources in direct alignment with what was just learned. Participants saying, "I hope it's not the general vague complementary materials that you get," reinforced the need for this consideration. Some participants discussed the difficulty of using supplementary materials without explicit connections to what they just learned. Thus, the webpage section in Figure 2

**Table 4.** Load reducing methods as defined by Mayer and Moreno[19] and applied during content development.

| Load reducing method | Definition | VHA affordances | Translation to website* |
|---|---|---|---|
| 1. Off-loading | Moving some essential processing from visual channel to auditory channel. Better transfer when words are presented as narration rather than as on-screen text | The use of a VHA provides the opportunity to diversify modalities and use visual and auditory channels to deliver information | Video clips with audio and visuals, with bulleted text |
| 2. Segmenting | Allow time between successive bite-sized segments. Better transfer when info is presented in learner-controlled segments rather than as a continuous unit | Users have the option to access the website after talking to the VHA, allowing for learner-controlled segmenting | Segmenting of information on the website into topic-specific sections |
| 3. Pretraining | Provide pretraining in names and characteristics of components | The VHA introduces users to key concepts related to colorectal cancer nutrition risk factors and prevention | The website expands on the same key terms from VHA. |
| 4. Weeding | Eliminate interesting but extraneous material to reduce processing load | VHA only presents "need to know" content to eliminate extraneous info as determined by user feedback | Pilot data may be used to test algorithms that filter content based on user input |
| 5. Signaling | Provide cues for how to process, select, and organize the material. Signaling is most useful when extra information is in a presentation, as it helps learners focus on the most important content | Plans to use signaling in VHA include adding pop-up images and text to emphasize keywords and facts. Participant suggestions include pop-up text when the VHA discusses nutrition risk factors, a pop-up image of a colon, pop-up number when the statistics are presented | Visible headers signal the reading path to readers. Keywords are bolded and defined in sidebar boxes |
| 6. Aligning | Place printed words near corresponding parts of graphics to reduce the need for visual scanning | N/A | Placed key terms next to corresponding graphics to prevent excessive scanning |
| 7. Eliminating redundancy | Avoid presenting identical streams of printed and spoken words. Better transfer when words are presented as narration rather than narration and on-screen text | Did not have subtitles in the VHA prototype however, based on previous work in this area and in accordance with ADA guidelines, we plan to build and test a final version with subtitles to enhance accessibility | Website text will be run through text Lexile calculator with a target Lexile range of 740-875 |
| 8. Synchronizing | Present narration with animation simultaneously to minimize the need to hold representation in mind | The current VHA does not include added animations. Plans to include animations in updated prototypes will follow best practices related to synchronizing | The website will house a VHA narrated, animation of the correct stool collection method |
| 9. Individualizing | Typically used when synchronization is not possible to ensure users can hold mental representations | This would entail matching high-quality media design with the users' spatial learning ability if synchronizing could not be implemented | N/A |

displays the five categories of desired additional information, accompanied by direct quotes from the VHA's discussion of that topic. An image of the VHA accompanies the quote, designed as a multimodal cue to reactivate previously learned information. This approach again employed signaling and brought in the strategy of segmenting which involves breaking the information into "bite-size" and distinct segments. These "learner-controlled segments" help information transfer.[27]

*Credible Information.* The fourth consideration involved the source of the information. Participants wanted to see credible information, so we link users to curated content via the links in the "More from ALEX" section (Figure 2). While segmenting was the primary strategy applied to this consideration, pretraining influenced the decision to include outside resources and materials like journal articles or evidence-based guides. Meaningful learning of complex topics or systems can be assisted by pretraining on basic definitions and behaviors of the system's components (eg, what is colon cancer and how is it affected by nutrition). So, while scientific journal articles may not be a participant's typical reading choice, pretraining from the VHA may support learners in parsing specific, peer-reviewed sources, that represent a curated selection to directly address the most requested information.

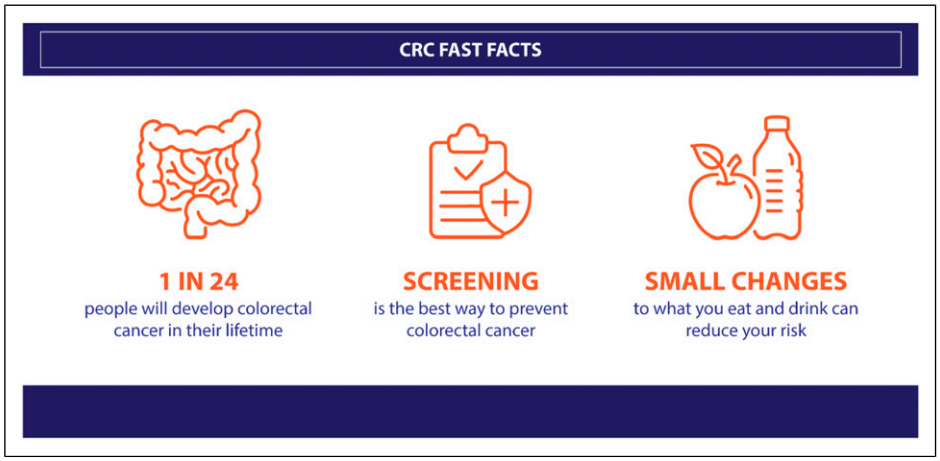



**Figure 1.** Website prototype section one.

*Offering Interactivity.* Finally, participants requested more personalized experiences. This often was expressed by asking about ways of sharing comments or questions with the VHA. Thus, the "Ask ALEX" Website section was incorporated at the bottom of the prototype to allow the participants a feedback loop with the research team (Figure 3). While a feedback mechanism of this kind may present barriers that still need to be addressed as the prototype progresses (eg, making it clear that the team cannot provide medical advice, being explicit about the level of privacy, deciding if connecting participants to local resources is within the scope of the project), user requests made it clear that individualizing the information processing experience was of interest.

## Discussion

Despite the growing use of information technologies to support the health goals of diverse audiences, the development of theoretically informed, cancer prevention and control interventions with older rural adults have not been adequately explored. The present study identifies participants' preferences for the content and design of a VHA-delivered CRC prevention intervention. The main findings suggest that having access to a website after discussing cancer risks with a VHA that gives real-time, person-specific feedback is desirable and may support action planning needs. Participants specified five categories of information gaps after the VHA interaction. Researchers used this feedback to inform the content and design of a website that also considered the potential impact of the participant's cognitive load. Providing participants direct access to decision support materials after learning about cancer risks is supported by previous research. Zikmund-Fisher et al[47] describe how women being asked to consider breast cancer treatment options who received cancer therapy options sequentially (rather than all at once) had improved comprehension of risks.

### *Theory-Informed vs User-Informed*

Cancer information-seekers may be primed to experience cancer information overload if confronted with content without the appropriate schema to process it. Existing research indicates as mental schemas evolve and learn, they impact cognitive processing and workload of the user.[48] For example, providing new recipes may be helpful to promote reducing processed meat consumption, however, if recipes are presented alongside need-to-know information about CRC risk and screening options, the recipes have the potential to contribute to cognitive overload. Thus, design considerations to manage cognitive load may be particularly important.

Four of the several evidence-based strategies used to prevent cognitive overload are expanded on including pretraining, segmenting, signaling, and weeding. First, the brief VHA interaction serves as a conceptual pretraining for users, who can form a mental map of CRC concepts before getting access to a website with additional content. Second, the website segments or breaks up information into bite-sized pieces, which avoids problems from presenting too many risks at once.[49] Segmenting may be particularly important for the task of information recall (eg, recalling information to plan diet changes and obtain cancer screening) which otherwise could be impeded by the existing cognitive load of learning about personal cancer risk in the same interaction.[50] Third, signaling is most useful when extra information is included in a learning aid, as it helps learners focus on the most important pieces of information. In the current study, signaling was used by placing exact phrases from the VHA interaction into website headings.[51] Finally, weeding prioritizes need-to-know information and was used to eliminate extraneous material from the brief VHA interaction throughout the iterative process.

Despite the use of theoretically informed information architecture, the importance of user-centered implementation strategies beyond the development phase is crucial. In the current study, the VHA presents proximal nutrition risk factors to activate the more psychologically distant risk of potential future cancer based on construal level theory.[52] Conversely, the user-centered approach allowed researchers to supplement the VHAs risk information with additional

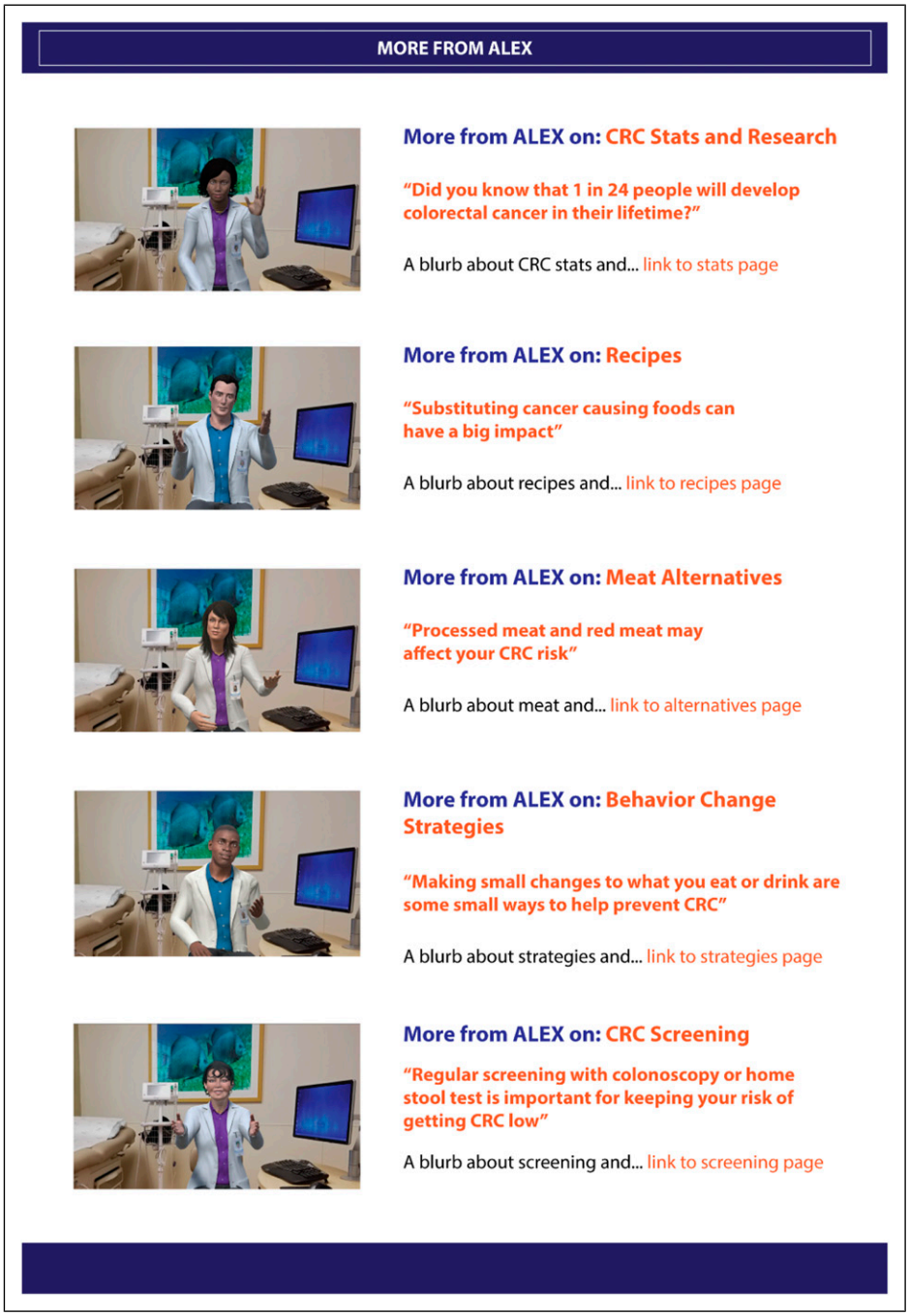



**Figure 2.** Website prototype section two.

website content as requested by participants. Moreover, understanding how cancer information overload is experienced by audiences with varied social determinants of health is important. In fact, education, income, and employment status are predictors of cancer information overload; with those making less than $50,000 annually, no college degree, and no employment more likely to experience overload.[36] Preferences of traditionally marginalized populations regarding health are just beginning to enter the literature.

## *Virtual Health Assistants as Information Curators*

As a practical application, VHAs are well suited to act as credible gatekeepers and bridges to curated cancer information in various ways. First, A common predictor of engaging with CRC screening is a recommendation from a doctor or a close family/friend.[53] If VHAs are seen as credible, familiar sources, they may be effective at facilitating the uptake of promoted cancer prevention behaviors. Second, VHAs may also be an

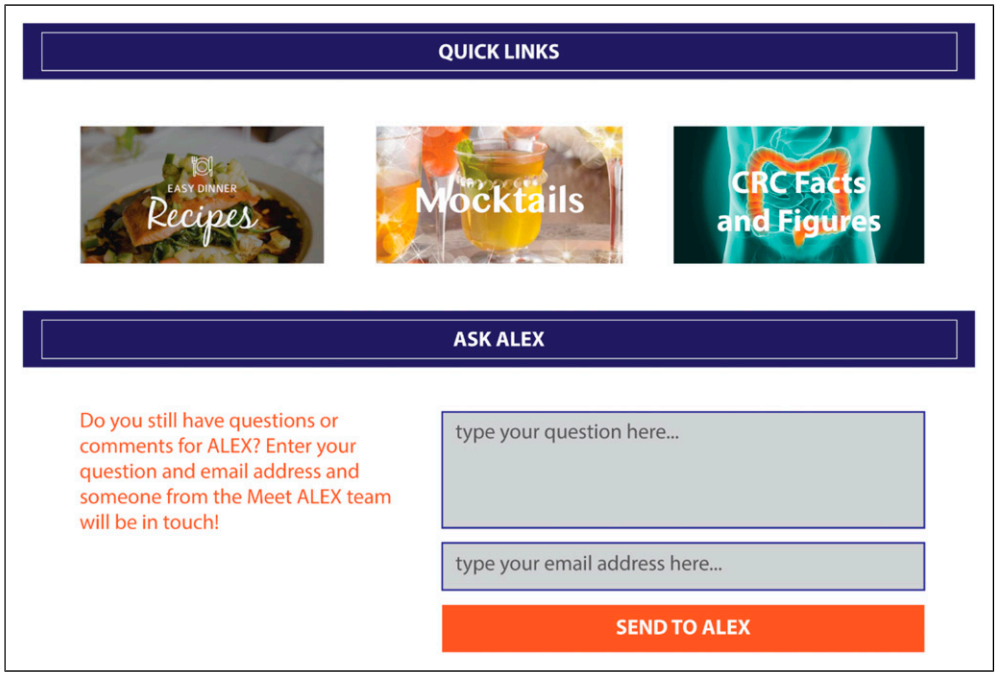



**Figure 3.** Website prototype section three.

effective gatekeeper for cancer information seekers an important affordance, given the high prevalence of harmful cancer information and misinformation on social media.[54] VHAs role in filtering information may also avoid message fatigue (eg, feeling exhausted when exposed to too many undesired similar messages) and the related negative outcomes like reactance, opposition, or disengagement.[36] Thus, Directing information seekers to a curated site may help users who want additional resources avoid harmful cancer information and message fatigue.

### *Study Limitations*

The current study findings should be considered in the context of intervention design and development, rather than generalized to assume causal links with intentions or behavior. The impact of website features, content, and implementation must still be tested for feasibility and efficacy. Finally, participants are given an option to access additional content *after* the VHA interaction, however, the current design does not assess engaging with a website prior to or simultaneously with a VHA, as such content will continue to be adapted as we learn more about how adults interact developed cancer prevention materials.

### *Future Directions*

The developed intervention will be pilot tested using a national Qualtrics survey panel of adults living in rural areas of the United States. Future directions may also include developing models to curate the user experience of navigating websites. For example, user data provided during interactions with a VHA (eg, content preferences, eating, drinking, or smoking habits) could be used by a system to enable or disable certain sections of the subsequent website (eg, a recap of general screening guidelines, options to order home stool kits, resources for how to talk a doctor about screening). While the current study does not explicitly test for mechanisms of motivation or change, we lay the groundwork for exploring theoretically informed navigation between related cancer prevention resources among a traditionally understudied population. Future studies of mechanistic pathways associated with using VHAs as cancer prevention information curators are needed. Finally, measuring website user information overload with validated scales will be useful for the next steps and user-testing.[55]

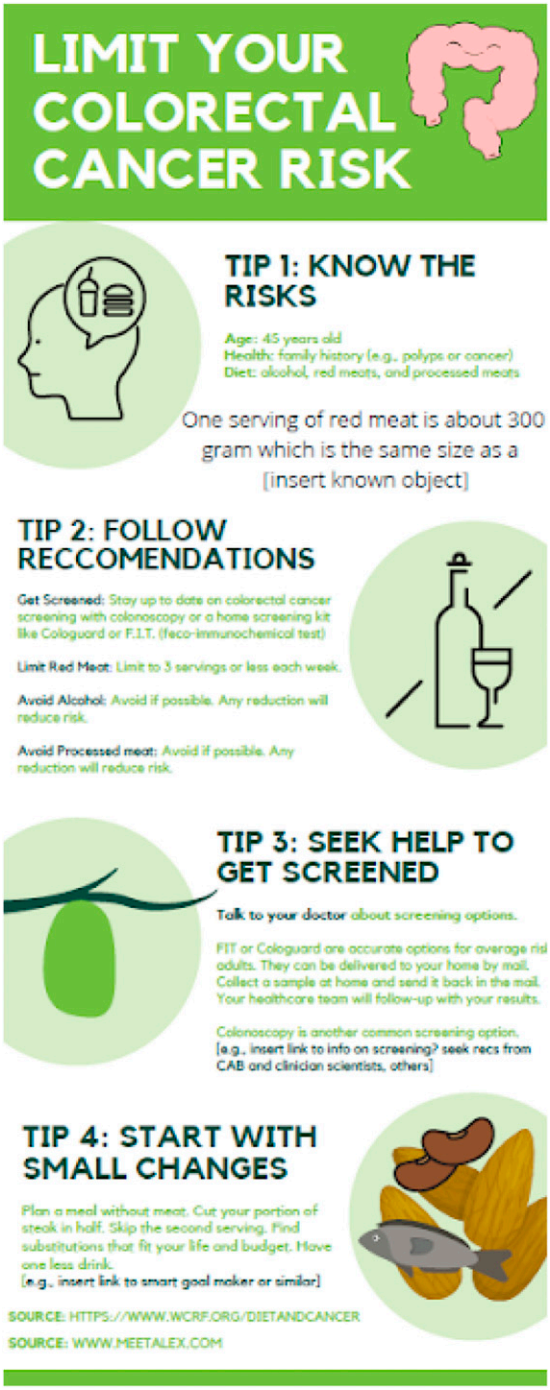
## Conclusion

The role of curating web-based navigation between evidence-based cancer prevention and control resources warrants more research, especially among older rural adults. The continual incorporation of user feedback allowed the option to add a supplemental website, consistent with strategies "to apply rapid bidirectional approaches to fail fast and learn quickly" that facilitate timely and equitable development of resources.[53] Although information needs of older rural adults can be strategically accommodated in health information

technologies- meeting these needs may be enhanced if design considerations are informed by cognitive load theories and user-centered design principles.

## Appendix

### Infographic Prototype Presented in Focus Groups and Interviews





## Acknowledgments

The authors would like to thank the stakeholders and community advisory board members who provided feedback.

## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by National Cancer Institute, National Institutes of Health, Award #3R01CA207689-03S2. Dr. Cooks was supported by a grant from the National Cancer Institute (T32CA257923). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

## Ethical Approval

All procedures were approved by the University of Florida institutional review board (IRB#201902537) and Scientific Review and Monitoring Committee (SRMC) OCR27722. Informed consent was obtained from all participants.



## ORCID iD

Melissa J. Vilaro https://orcid.org/0000-0003-3975-0274


## References


1. National Cancer Institute. Cancer stat facts: Common cancer sites. 2021. https://seer.cancer.gov/statfacts/html/common.html. Accessed November 16, 2021.
2. Islami F, Goding Sauer A, Miller KD, et al. Proportion and number of cancer cases and deaths attributable to potentially modifiable risk factors in the United States. *CA A Cancer J Clin*. 2018;68(1):31-54. doi:10.3322/CAAC.21440.
3. U.S. Preventive Services Task Force. Final update summary: Colorectal cancer: Screening. 2015. Published online. https://www.uspreventiveservicestaskforce.org/Page/Document/UpdateSummaryFinal/colorectal-cancer-screening. Accessed November 11, 2019.
4. Joseph DA, King JB, Dowling NF, Thomas CC, Richardson LC. Vital signs : Colorectal cancer screening test use — United States, 2018. *MMWR Morb Mortal Wkly Rep*. 2020;69(10):253-259. doi:10.15585/mmwr.mm6910a1.
5. Praud D, Rota M, Rehm J, et al. Cancer incidence and mortality attributable to alcohol consumption. *Int J Cancer*. 2016;138(6):1380-1387. doi:10.1002/IJC.29890.
6. Cross AJ, Leitzmann MF, Gail MH, Hollenbeck AR, Schatzkin A, Sinha R. A prospective study of red and processed meat intake in relation to cancer risk. *PLoS Med*. 2007;4(12):e325. doi:10.1371/JOURNAL.PMED.0040325.
7. Bouvard V, Loomis D, Guyton KZ, et al. Carcinogenicity of consumption of red and processed meat. *Lancet Oncol*. 2015;16(16):1599-1600. doi:10.1016/S1470-2045(15)00444-1.

8. Larsson SC, Rafter J, Holmberg L, Bergkvist L, Wolk A. Red meat consumption and risk of cancers of the proximal colon, distal colon and rectum: The Swedish mammography cohort. *Int J Cancer*. 2005;113(5):829-834. doi:10.1002/IJC.20658.
9. Zahnd WE, James AS, Jenkins WD, et al. Rural–urban differences in cancer incidence and trends in the United States. *Cancer Epidemiol Biomark Prev*. 2018;27(11):1265-1274. doi:10.1158/1055-9965.EPI-17-0430.
10. Zahnd WE, Murphy C, Knoll M, et al. The intersection of rural residence and minority race/ethnicity in cancer disparities in the United States. *Int J Environ Res Publ Health*. 2021;18(4):1384. doi:10.3390/IJERPH18041384.
11. Moreno CC, Duszak R, Yee J, Horny M. Geographic dispersion and rural versus urban utilization of CT colonography in the United States. *J Am Coll Radiol*. 2020;17(4):475-483. doi:10.1016/J.JACR.2019.10.002.
12. Shete S, Deng Y, Shannon J, et al. Differences in breast and colorectal cancer screening adherence among women residing in urban and rural communities in the United States. *JAMA Netw Open*. 2021;4(10):e2128000. doi:10.1001/JAMANETWORKOPEN.2021.28000.
13. van Dijk JA. *The Deepening Divide: Inequality in the Information Society*. Sage publications; 2005. https://books.google.com/books?hl=en&lr=&id=AwGJCgAAQBAJ&oi=fnd&pg=PP1&dq=info:2_d4BU80JF8J:scholar.google.com&ots=vKygKndm65&sig=ZWyVPVtISucgh8LlmyV-3bmukOs#v=onepage&q&f=false. Accessed July 17, 2022.
14. van Deursen AJAM, Helsper EJ. The third-level digital divide: Who benefits most from being online? Published Online December. 2015;12:29-52. doi:10.1108/S2050-206020150000010002.
15. SunRan EBISTK, LiDan MS. Use of a patient portal for engaging patients with type 2 diabetes: Patterns and prediction. 2019;21(10):581-588. doi:10.1089/DIA.2019.0074. https://home.liebertpub.com/dia
16. Vilaro MJ, Wilson-Howard DS, Griffin LN, et al. *Tailoring Virtual Human-Delivered Interventions: A Digital Intervention Promoting Colorectal Cancer Screening for Black Women*. Psycho-Oncology; 2020. Published online. doi:10.1002/pon.5538.
17. Zachrison KS, Boggs KM, Hayden EM, Espinola JA, Camargo CA. Understanding barriers to telemedicine implementation in rural emergency departments. *Ann Emerg Med*. 2020;75(3):392-399. doi:10.1016/J.ANNEMERGMED.2019.06.026.
18. Chu C, Cram P, Pang A, Stamenova V, Tadrous M, Bhatia RS. Rural telemedicine use before and during the COVID-19 pandemic: Repeated cross-sectional study. *J Med Internet Res*. 2021;23(4):e26960. doi:10.2196/26960.
19. Olafsson S, O'leary TK, Bickmore TW. *Motivating Health Behavior Change with Humorous Virtual Agents*; 2020. Published online. doi:10.1145/3383652.3423915.
20. Lisetti C, Amini R, Yasavur U, Rishe N. I can help you change! An empathic virtual agent delivers behavior change health interventions. *ACM Trans Manag Inf Syst*. 2013;4(4). doi:10.1145/2544103.
21. Lucas GM, Krämer N, Peters C, Taesch LS, Mell J, Gratch J. Effects of perceived agency and message tone in responding to a virtual personal trainer. Proceedings of the 18th International Conference on Intelligent Virtual Agents, IVA; November 5, 2018:247-254. Published online. doi:10.1145/3267851.3267855.
22. Mendu S, Boukhechba M, Gordon JR, et al. Design of a culturally-informed virtual human for educating hispanic women about cervical cancer. *Int Conf Pervasive Comput Technol Healthc*. 2018;2018:360-366. doi:10.1145/3240925.3240968.
23. Bol N, Weert JCMV, Haes HCJM de, et al. Using cognitive and affective illustrations to enhance older adults' website satisfaction and recall of online cancer-related information. 2014;29(7):678-688. doi:10.1080/10410236.2013.771560.
24. Hou SI. Health literacy online: A guide to writing and designing easy-to-use health web sites. 2012;13(5):577-580. doi:10.1177/1524839912446480.
25. Chandler P, Sweller J. Cognitive load theory and the format of instruction. *Cognit InStruct*. 1991;8(4):293-332. doi:10.1207/s1532690xci0804_2.
26. Merriënboer JJGV, Sweller J. Cognitive load theory in health professional education: design principles and strategies. *Med Educ*. 2010;44(1):85-93. doi:10.1111/J.1365-2923.2009.03498.X.
27. Mayer RE, Moreno R. Nine ways to reduce cognitive load in multimedia learning. 2003;38(1):43-52. doi:10.1207/S15326985EP3801_6.
28. Krieger JL, Neil JM, Duke KA, et al. A pilot study examining the efficacy of delivering colorectal cancer screening messages via virtual health assistants. *Am J Prev Med*. 2021;61(2):251-255. doi:10.1016/J.AMEPRE.2021.01.014.
29. Kotranza A, Lok B. Virtual human + tangible interface = mixed reality human an initial exploration with a virtual breast exam patient. 2008 IEEE Virtual Reality Conference. 2008:99-106. Published online. doi:10.1109/VR.2008.4480757.
30. Sweller J. Cognitive load during problem solving: Effects on learning. *Cognit Sci*. 1988;12(2):257-285. doi:10.1207/S15516709COG1202_4.
31. Sweller J, van Merriënboer JJG, Paas F. Cognitive architecture and instructional design: 20 years later. *Educ Psychol Rev*. 2019;31(22):261-292. doi:10.1007/S10648-019-09465-5.
32. Bawden D, Robinson L. The dark side of information: overload, anxiety and other paradoxes and pathologies. 2008;35(2):180-191. doi:10.1177/0165551508095781.
33. Swar B, Hameed T, Reychav I. Information overload, psychological ill-being, and behavioral intention to continue online healthcare information search. *Comput Hum Behav*. 2017;70:416-425. doi:10.1016/J.CHB.2016.12.068.
34. Wurman RS, Loring L, David S, Karen W. *Information Anxiety 2*. 2nd ed. Hayden/Que; 2000.
35. Soroya SH, Farooq A, Mahmood K, Isoaho J, Zara Se. From information seeking to information avoidance: Understanding the health information behavior during a global health crisis. *Inf Process Manag*. 2021;58(2):102440. doi:10.1016/J.IPM.2020.102440.

36. Kim S, So J. How message fatigue toward health messages leads to ineffective persuasive outcomes: Examining the mediating roles of reactance and inattention. 2017;23(1):109-116. doi:10.1080/10810730.2017.1414900.
37. Case DO, Andrews JE, Johnson JD, Allard SL. Avoiding versus seeking: the relationship of information seeking to avoidance, blunting, coping, dissonance, and related concepts. *J Med Libr Assoc*. 2005;93(3):353. /pmc/articles/PMC1175801/. Accessed November 17, 2021.
38. Chen CY, Pedersen S, Murphy KL. Learners' perceived information overload in online learning via computer-mediated communication. *ALT-J: Res Learn Technol*. 2011;19(2):101-116. doi:10.1080/21567069.2011.586678.
39. Inkle. *Ink: Inkle's Open Source Scripting Language for Writing Interactive Narrative*. https://github.com/inkle/ink
40. Zalake M, de Siqueira AG, Vaddiparti K, Antonenko P, Hamza-Lup F, Lok B. Towards rapid development of conversational virtual humans using Web3D technologies. Proceedings - Web3D 2020: 25th ACM Conference on 3D Web Technology. Association for Computing Machinery, Inc; 2020. doi:10.1145/3424616.3424727.
41. Dillard AJ, Ubel PA, Ferrer RA. Risk perception measures' associations with behavior intentions, affect, and cognition following colon cancer screening messages. *Health Psychol*. 2012;31(1):106-113. doi:10.1037/a0024787.
42. Boonyasiriwat W, Hung M, Hon SD, et al. Intention to undergo colonoscopy screening among relatives of colorectal cancer cases: A theory-based model. *Ann Behav Med*. 2014;47(3):280-291. doi:10.1007/s12160-013-9562-y.
43. Jensen JD, King AJ, Davis L. Why are tailored messages more effective? A multiple mediation analysis of a breast cancer screening intervention. *J Commun*. 2012;62(5):851-868. doi:10.1111/j.1460-2466.2012.01668.x.
44. QSR International Pty Ltd. NVivo. Published online. 2020.
45. Thomas DR. A general inductive approach for analyzing qualitative evaluation data. 2016;27(2):237-246. doi:10.1177/1098214005283748.
46. Braun V, Clarke V. One size fits all? What counts as quality practice in (reflexive) thematic analysis? 2020;18(3):328-352. doi:10.1080/14780887.2020.1769238.
47. Zikmund-Fisher BJ, Angott AM, Ubel PA. The benefits of discussing adjuvant therapies one at a time instead of all at once. *Breast Cancer Res Treat*. 2011;129(1):79-87. doi:10.1007/S10549-010-1193-4.
48. Gu H, Yao Q, Chen H, et al. The effect of mental schema evolution on mental workload measurement: An EEG study with simulated quadrotor UAV operation. *J Neural Eng*. 2022;19(2). doi:10.1088/1741-2552/AC6828.
49. Zikmund-Fisher BJ, Fagerlin A, Ubel PA. A demonstration of "less can be more" in risk graphics. *Med Decis Making*. 2010;30(6):661. doi:10.1177/0272989X10364244.
50. Carayon P, Hoonakker P. Human factors and usability for health information technology: Old and new challenges. *Yearb Med Inform*. 2019;28(1):71-77. doi:10.1055/S-0039-1677907.
51. Albers MJ. *Infographics and Communicating Complex Information*; 2015. Published online. doi:10.1007/978-3-319-20898-5_26.
52. Zwickle A, Wilson RS. "*Construing risk: implications for risk communication," in* Effective Risk Communi*cation*, eds J. L. Arvai RiversRoutledge (New York, NY:), 2014;190-203.
53. Christy SM, Perkins SM, Tong Y, et al. Promoting colorectal cancer screening discussion: A randomized controlled trial. *Am J Prev Med*. 2013;44(4):325-329. doi:10.1016/J.AMEPRE.2012.11.032.
54. Johnson SB, Parsons M, Dorff T, et al. Cancer misinformation and harmful information on facebook and other social media: A brief report. *JNCI: J Natl Cancer Inst*. 2021(0):141. doi:10.1093/JNCI/DJAB141.
55. Jensen JD, King AJ, Carcioppolo N, Krakow M, Samadder NJ, Morgan S. Comparing tailored and narrative worksite interventions at increasing colonoscopy adherence in adults 50–75: A randomized controlled trial. *Soc Sci Med*. 2014;104:31-40. doi:10.1016/J.SOCSCIMED.2013.12.003.