Efficacy of a Web-Based Intelligent Tutoring System for Communicating Genetic Risk of Breast Cancer: A Fuzzy-Trace Theory Approach

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Background. Many healthy women consider genetic testing for breast cancer risk, yet BRCA testing issues are complex. Objective. To determine whether an intelligent tutor, BRCA Gist, grounded in fuzzy-trace theory (FTT), increases gist comprehension and knowledge about genetic testing for breast cancer risk, improving decision making. Design. In 2 experiments, 410 healthy undergraduate women were randomly assigned to 1 of 3 groups: an online module using a Web-based tutoring system (BRCA Gist) that uses artificial intelligence technology, a second group read highly similar content from the National Cancer Institute (NCI) Web site, and a third that completed an unrelated tutorial. Intervention. BRCA Gist applied FTT and was designed to help participants develop gist comprehension of topics relevant to decisions about BRCA genetic testing, including how breast cancer spreads, inherited genetic mutations, and base rates. Measures. We measured content knowledge, gist comprehension of decision-relevant information, interest in testing, and genetic risk and testing judgments. Results. Control knowledge scores ranged from 54% to 56%, NCI improved significantly to 65% and 70%, and BRCA Gist improved significantly more to 75% and 77%, \( P < 0.0001 \). BRCA Gist scored higher on gist comprehension than NCI and control, \( P < 0.0001 \). Control genetic risk-assessment mean was 48% correct; BRCA Gist (61%) and NCI (56%) were significantly higher, \( P < 0.0001 \). BRCA Gist participants recommended less testing for women without risk factors (not good candidates; 24% and 19%) than controls (50%, both experiments) and NCI (32%), experiment 2, \( P < 0.0001 \). BRCA Gist testing interest was lower than in controls, \( P < 0.0001 \). Limitations. BRCA Gist has not been tested with older women from diverse groups. Conclusions. Intelligent tutors, such as BRCA Gist, are scalable, cost-effective ways of helping people understand complex issues, improving decision making. Key words: genetic testing; breast cancer risk; Intelligent Tutoring System; Fuzzy-Trace Theory. (Med Decis Making 2015;35:46–59)

Breast cancer affects about 1 in 8 American women, and in 2011, there were an estimated 39,520 breast cancer deaths in the United States. Thus, it is understandable that many women are concerned about breast cancer. Since the discovery of BRCA mutations and the advent of commercially available tests, many women have pondered whether to undergo testing for genetic breast cancer risk. This number has increased due to recent attention brought to the issue by the Supreme Court decision in Association for Molecular Pathology v. Myriad Genetics and by actor Angelina Jolie. Although genetic testing for breast cancer risk potentially saves lives, most women are not good testing candidates. Understanding genetic risk is challenging for most patients, and systematic biases in risk estimation have been demonstrated for both patients and providers (e.g., base-rate neglect). Moreover, BRCA tests and associated genetic counseling are expensive and, without a family history of breast cancer, often not covered by insurance. Furthermore, many patients are unsure what they would do if they were to receive positive, negative, or ambiguous results.
Those who have positive results must decide about measures such as more frequent mammography, tamoxifen treatments, prophylactic risk-reducing bilateral oophorectomy or salpino-oophorectomy, screening for ovarian cancer, chemoprevention for ovarian cancer, and prophylactic mastectomy.\textsuperscript{11–13} However, positive results do not dictate specific actions, and negative results do not guarantee a cancer-free lifetime. There are also emotional and social risks associated with testing and possible negative consequences with ambiguous results.\textsuperscript{14,15} Moreover, the results often have implications for other family members. In some cases, having another family member tested rather than oneself is recommended.\textsuperscript{16} Yet communication about genetic risk among family members is often poor.\textsuperscript{17} There are also issues concerning the privacy of medical records and the potential for genetic discrimination.\textsuperscript{18} Little time is available in the clinical encounter to discuss these complex issues, and many patients have little access to genetic counselors.

The BRCA Gist Intelligent Tutoring System

One novel approach to helping women understand genetic testing for breast cancer risk is to use an intelligent tutoring system (ITS) to provide more effective tutoring of patients than traditional educational materials can provide. An ITS is a computer-based system using artificial intelligence techniques to mimic one-on-one human tutoring.\textsuperscript{19} Individual human tutoring is arguably the gold standard for facilitating deep conceptual understanding,\textsuperscript{20,21} and there is evidence that the best ITs produce gains comparable with human tutors.\textsuperscript{22} An ITS is not the same as decision aids such as Gail, Claus, or BRCAPRO.\textsuperscript{23} This Web-based ITS applies artificial intelligence to create a scalable and cost-effective way of engaging many people in dialogue simultaneously. Emerging discourse technologies\textsuperscript{24} allow us to apply 2 complementary ideas rooted in fuzzy-trace theory (FTT): first, helping people mentally represent the gist of information\textsuperscript{25} can improve knowledge, understanding, and decision making in medical contexts, and second, helping people explain the gist of complex medical information\textsuperscript{26} in their own words fosters deep learning and comprehension.\textsuperscript{27}

Our ITS is called BRCA Gist (BReast CAncer Genetics Intelligent Semantic Tutoring).\textsuperscript{19} BRCA Gist is designed to supplement the clinical encounter, rather than replace it, or to be used as a freestanding public health resource for healthy women. This ITS is delivered online and can be self-administered by patients before or after a clinical encounter. ITSs in medicine are rare,\textsuperscript{28} and although computer-tailored interventions have demonstrable benefits in areas such as mammography screening,\textsuperscript{29} there is evidence that the best ITSs produce gains comparable with human tutors.\textsuperscript{22} BRCA Gist appears to be the first ITS applied to lay people’s medical decision making.\textsuperscript{19}

BRCA Gist was built using Shareable Knowledge Objects (SKO; formerly AutoTutor Lite),\textsuperscript{19,30} a Web-based version of AutoTutor.\textsuperscript{24,27,31,32} A talking avatar presents information orally and in text, graphics, and video. We used three female avatars of various apparent ethnicities. BRCA Gist converses with people, responding to what they type. It processes users’ verbal input using latent semantic analysis (LSA), a computational technique that mathematically measures the semantic similarity of 2 texts.\textsuperscript{33–36} To provide appropriate feedback, BRCA Gist uses LSA to compare sentences entered by users to specially prepared expectations texts,\textsuperscript{19,30} which we developed using verbal data from human respondents.\textsuperscript{19} LSA permits BRCA Gist to assess this association and respond accordingly—crucially, even when participants explain the gist of key concepts using different words than those in the expectations texts.

BRCA Gist is composed of 4 modules on breast cancer and metastasis, risk factors, genetic mutation testing, and the consequences of testing. It provides didactic information interspersed with 7 tutorial dialogues on topics including those requiring an explanation such as, “How do genes affect breast cancer
risk?” and “What should someone do if she receives a positive result for genetic risk of breast cancer?” and those requiring argumentation such as, “What is the case for (and against) genetic testing for breast cancer risk?”

There is good evidence that actively generating arguments such as, “What is the base rate of breast cancer?”, and “What should someone do if she receives a genetic result for breast cancer?”, and “Should someone surviving breast cancer go on to receive genetic testing?”

The base rate of breast cancer is high. Figure 1 highlights 2 core concepts, stripping away details. Gist is not simply less information, in contrast to heuristic “strategies that ignore information to make decisions faster, more frugally . . . than more complex methods.”

Numeracy plays a critical role in understanding health-related information. Even high-numeracy patients and providers have difficulty with conditional probabilities (e.g., the probability of cancer given a genetic mutation). FTT differs from other numeracy theories in distinguishing verbatim versus gist accuracy. Informed decision making requires understanding qualitative gist relations, such as categorical and ordinal gist (e.g., categorizing risk as low v. high), evidence for which has been gathered in prior research.

BRCA Gist text and figures were designed to clearly convey these qualitative gist relations, for example, that “most patients survive” at every stage of breast cancer except the most advanced.

In making decisions, people often prefer to reason with the vaguest bottom-line gist that can be used to decide among options. Indeed, “the preference to operate on the crudest gist, the fuzzy-processing preference, increases with experience or expertise.” When people make decisions, it is often more helpful to rely on these fuzzy gist representations provided that they accurately capture decision-relevant features. Research indicates that gist representations are better retained, less vulnerable to extraneous interference, and easier to manipulate compared with verbatim representations, all of which reduce errors.

To illustrate, Reyna and Lloyd found that expert physicians discriminated patient risk categories better than less-expert physicians, yet they relied to a greater degree on simpler gist-based representations. More precise information processing—toward the verbatim end of the continuum of precision—was not associated with better risk judgments or better emergency room decisions. Indeed, experts’ precise numerical judgments sometimes violated basic rules of probability theory.

BRCA Gist content was adapted from the National Cancer Institute (NCI) Web site, and we compared the efficacy of BRCA Gist with both the NCI Web site and a control group. The NCI Web site is an excellent source of verbatim information about breast cancer and testing for genetic risk, but it was not designed as a gist-based intervention. Following FTT, our prediction was that BRCA Gist participants would...
perform better on measures of knowledge and gist comprehension of genetic testing and breast cancer risk than comparison groups. With their improved comprehension, we predicted that BRCA Gist participants would make better judgments and decisions about genetic testing. Finally, we predicted that these representational and class-inclusion interventions would not produce worry or anxiety.

METHODS

In 2 controlled laboratory experiments, participants were randomly assigned to 1 of 3 conditions: BRCA Gist, the NCI Web site, and a control tutorial on nutrition in a 1:1:1 ratio using computer randomization in randomized blocks of 3 established prior to the beginning of each experiment. The NCI condition was created by making PDFs of comparable portions of the NCI Web site. Participants browsed freely between NCI pages but could not follow hyperlinks to leave the site.

In experiment 1, all groups spent 1 h with their tutorials before completing the dependent measurers online. Experiment 2 replicates and extends experiment 1. We added content including breast cancer stages and how cancer spreads to both the BRCA Gist and NCI conditions to include all the major relevant areas covered on the NCI Web site. Time on task increased to 90 min for all groups. In both experiments in the BRCA Gist and control conditions, interacting with the avatar took approximately 60 and 90 min in the 2 studies, respectively. NCI Web participants were instructed to study the materials for these
allotted time periods. NCI participants read at their own pace, but the “continue” button did not appear until after the 60- or 90-min interval, equating time on task. Participants could not proceed until the time limit expired. Participants took between 60 and 90 min to complete the dependent measures. In the controlled laboratory setting, participants worked at their own pace but were prohibited from doing anything besides the experimental tasks.

Sample/Recruitment

Participants in both studies were undergraduate women recruited online at 2 universities in the Midwest and Eastern United States. As stated in the institutional review board–approved recruitment text, women could participate for course credit if they were 18 years or older and had not had breast cancer. An advantage of recruiting university women as participants is a relatively high rate of full compliance. In experiment 1, there were 202 participants who received credit for participating, with data from 2 missing because they could not complete any items due to technical problems reaching the data collection site, leaving 200 participants. Data were collected between 21 March 2012 and 6 May 2012. About 28% were ethnic minorities (10% African American, 10% Hispanic, 4% biracial, 13% Asian American in non–mutually exclusive categories) and 72% white non-Hispanic. The mean age was 19.70 years (s = 1.38). In experiment 2, 217 received credit, and 7 of these missed portions of the tutorial because of technical problems reaching the data collection site, leaving 200 participants. Data were collected between 14 September 2012 and 7 December 2012. About 27% were ethnic minorities (6% African American, 6% Hispanic, 4% biracial, 16% Asian American, in non–mutually exclusive categories) and 73% white non-Hispanic. The mean age was 19.03 years (s = 1.62). Participants were significantly younger in the fall than in spring (19.70 years, s = 1.38), F(1, 381) = 16.4, P < 0.0001 (most students are admitted in the fall). We did not find other demographic differences among conditions (see Table 1).

Instruments

A medical expert vetted tutorial content and research instruments. For knowledge instruments, unanswered items were scored as incorrect (declarative knowledge, knowledge of breast cancer, and gist comprehension described below). For Pedigree Assessment Tool (PAT) and anxiety, data were excluded for those who skipped 1 or more questions within a scale (which did not differ by group and did not affect results; see below).

Prediction 1: BRCA Gist Will Increase Knowledge and Gist Comprehension

Declarative knowledge of breast cancer, genetic testing, and genetic risk (see online appendix). Declarative knowledge is factual knowledge that can be stated verbally. FTT suggests that a good gist understanding is the basis for organizing and remembering factual knowledge. We developed 52 four-alternative multiple-choice items on breast cancer, genetic risk, and genetic testing. The test was created in 2 phases to test the hypothesis that BRCA Gist would help participants learn more factual content than the other conditions. Items were drawn primarily from NCI Web site content and were created corresponding to 4 BRCA Gist modules. An item on breast cancer and how it spreads is “breast cancer usually forms in which part of the breast (ducts and lobules).” An item on risk factors and risk estimation is, “Which of the following is a risk factor for breast cancer? (having larger areas

Table 1  Participant Demographic Characteristics by Experiment and Condition

<table>
<thead>
<tr>
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<th>Experiment 1</th>
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<th>Experiment 2</th>
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<tbody>
<tr>
<td></td>
<td>BRCA Gist</td>
<td>NCI Web</td>
<td>Control</td>
<td>BRCA Gist</td>
</tr>
<tr>
<td>Female (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Some college education (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>White non-Hispanic (%)</td>
<td>72</td>
<td>79</td>
<td>69</td>
<td>73</td>
</tr>
<tr>
<td>One or more Pedigree Assessment Tool risk factors (%)</td>
<td>58</td>
<td>52</td>
<td>41</td>
<td>48</td>
</tr>
<tr>
<td>Age (y), x (s)</td>
<td>19.6 (1.2)</td>
<td>19.6 (1.1)</td>
<td>19.9 (1.7)</td>
<td>19.1 (1.1)</td>
</tr>
</tbody>
</table>

Note: F or χ² P > 0.05 (no differences among experimental groups were significant).
of dense breast tissue on a mammogram; having your first menstrual period before age 12; and going through menopause after age 55). An item on mutations, genetic testing, and genetic risk reads, “A BRCA1 or BRCA2 mutation does not increase a woman’s risk developing breast and ovarian cancer (false).” An item on consequences of genetic testing is, “What is the goal of surveillance? (to find cancer early when it is most treatable).” In experiment 1, Cronbach’s $\alpha$ for the initial 32-item instrument was 0.79. In experiment 2, Cronbach’s $\alpha$ for the entire 52-item instrument was 0.88.

Green and others: Knowledge of breast cancer, heredity, and genetic testing.63,64 This is a 20-item multiple-choice questionnaire assessing declarative knowledge about breast cancer, heredity, and genetic testing. This instrument was not designed to specifically measure content of the NCI Web site, and Green and colleagues do not report reliability (we obtained a Cronbach’s $\alpha$ of 0.49); however, it permits comparisons with previous studies.

Gist comprehension of genetic breast cancer risk (see online appendix). We developed a 30-item Likert-type scale ranging from 1 to 7 assessing gist comprehension of key information on breast cancer and genetic testing. Gist comprehension items such as “BRCA (breast cancer) genetic mutations account for only a small percentage of all breast cancers,” express the essential bottom-line decision-relevant meaning of that knowledge. People can strongly endorse such statements without remembering the precise numerical risks and, surprisingly, can recall precise numbers without comprehending their bottom line meaning, a phenomenon known as verbatim-gist independence.65 Unlike declarative knowledge items, the item stem is stated at a general level such that answering does not require verbatim information, and the response format permits degrees of agreement. Unlike attitude measures, gist items have independently verifiable answers. Cronbach’s $\alpha$ for Gist comprehension was 0.85.

Prediction 2: BRCA Gist Will Improve Judgments and Decisions about Genetic Testing

Risk assessment scenarios for genetic risk of breast cancer (see online appendix). Participants received 12 scenarios describing women with no genetic risk factors or medium or high genetic breast cancer risk based on PAT scores of 0, 3 to 5, and 8 to 10, respectively.66 Participants categorized the degree of genetic breast cancer risk for each woman as low, medium, or high. Participants later decided whether each woman should undergo testing. For risk assessment, Cronbach’s $\alpha$ was 0.40 in experiment 1 and 0.37 in experiment 2, unsurprising given that the scenarios were designed to differ from one another.

Interest in genetic testing. Personal interest in genetic testing was assessed with a version of the item from Hall and others67: “How interested would you be in having a blood test for BRCA1 and BRCA2 mutations if you knew that the genetic test was 100% accurate?” Participants rated interest on a 5-point scale. Because it is reasonable to assume that only a small portion of the sample was at high genetic risk,66 we predicted that BRCA Gist participants would appropriately express less interest in having a genetic test than controls.

Prediction 3: BRCA Gist Will Not Increase Anxiety or Worry about Breast Cancer

Worry about breast cancer risk and anxiety. Creating tutorials that are not anxiety provoking was a high priority. Worry about breast cancer risk was assessed with Anderson and colleagues’ 5-item instrument.68 The authors did not report reliability, but in both of our experiments, we found a Cronbach alpha of 0.69. Anxiety was measured using the Spielberger State-Trait Anxiety Inventory State Anxiety subscale, an instrument that typically achieves Cronbach’s $\alpha >0.90$.69 We predicted BRCA Gist would not increase general anxiety. Indeed, if there were to be an effect, we predicted that BRCA Gist participants might experience less cancer-specific worry.

PAT. We asked 5 questions from the PAT66 about family members with breast or ovarian cancer and Ashkenazi Jewish heritage. Respondents were coded as reporting or not reporting risk factors, enabling assessments of whether the interventions are equivalent with both groups.

We administered tasks in the following fixed order: Web site evaluation, worry about breast cancer, risk assessment and testing decisions, Green and others instrument, declarative knowledge, level of interest in having a genetic test, filler and non-outcome tasks, PAT, anxiety, and demographic questions. Within instruments, item order and alternative order within items were presented randomly.
Data Analysis

Data were analyzed using JMP Pro 10.0.2 with 3 (condition) \( \times \) 2 (research site) analyses of variance (ANOVAs), with differences among conditions assessed with Tukey HSD. We assessed whether data provided evidence of superiority of BRCA Gist over the NCI and control conditions (with differences between sites being of no theoretical interest but assessed because the Eastern university is more academically selective). There were no demographic differences between participants who were excluded for skipping 1 or more items (9 total items across groups in experiment 1, and 11 total items across groups in experiment 2). ANOVA is robust to violations of distributional assumptions, and Levene tests and Welch ANOVA indicate the 2 such violations (of 33) did not affect results (see online materials).

RESULTS

Prediction 1: BRCA Gist Will Increase Knowledge and Gist Comprehension

Knowledge of Breast Cancer, Genetic Testing, and Genetic Risk

In both experiments on total declarative knowledge, BRCA Gist participants scored significantly higher than NCI participants, and both scored significantly higher than control group participants (see Table 2). In experiment 1, for condition, \( F(2, 194) = 30.56, P < 0.0001, \eta^2 = 0.2332 \). The BRCA Gist mean percentage correct was 0.74, the NCI mean was 0.67, and the control group mean was 0.56. There was also a significant main effect for site, with BRCA Gist scoring significantly higher at both sites, \( F(1, 194) = 5.92, P = 0.016 \), with Eastern university participants scoring significantly higher than Midwestern university participants [0.69 and 0.64, respectively]. Importantly, the site by condition interaction was not significant, \( F(2, 194) = 1.12, P = 0.33 \). For knowledge and other variables, there were significant main effect differences between sites, with the Eastern university scoring higher. However, BRCA Gist was consistently effective at both sites; there was only 1 significant interaction. Given limited interest in distinguishing among undergraduate samples, we report other site differences only in an online appendix. They are not of theoretical interest.) These results were replicated in experiment 2 (see Table 2); for condition, \( F(2, 204) = 38.33, P < 0.0001, \eta^2 = 0.2536 \). The BRCA Gist mean percentage correct was 0.75, the NCI mean was 0.67, and the control group mean was 0.55.

We analyzed declarative knowledge for each BRCA Gist module (see Table 2). BRCA Gist participants scored significantly higher than NCI participants, and both scored significantly higher than control participants on modules on breast cancer and how it spreads (experiment 1, \( F(2, 194) = 41.42, P < 0.0001 \); and experiment 2, \( F(2, 204) = 29.43, P < 0.0001 \)) and mutations, genetic testing, and genetic risk (experiment 1, \( F(2, 194) = 25.74, P < 0.0001 \); and experiment 2, \( F(2, 204) = 30.76, P < 0.0001 \)). For the module risk factors and risk estimation, both BRCA Gist and NCI participants scored significantly higher than control participants, and the differences between NCI and BRCA Gist were not significant: experiment 1, \( F(2, 194) = 8.30, P < 0.0003 \), and experiment 2, \( F(2, 204) = 15.04, P < 0.0001 \). For the module consequences of genetic testing, BRCA Gist participants scored significantly higher than both the NCI and control groups, and the differences between NCI and control were not significant: experiment 1, \( F(2, 194) = 10.83, P < 0.0001 \), and experiment 2, \( F(2, 204) = 12.91, P < 0.0001 \).

For the Green and others\(^63\) knowledge test, in experiment 1, BRCA Gist scored significantly higher than NCI, and both scored significantly higher than the control group (see Table 3); for condition, \( F(2, 194) = 29.34, P < 0.0001, \eta^2 = 0.2191 \). The BRCA Gist mean percentage correct was 0.77, the NCI mean was 0.70, and the control group mean was 0.62. In experiment 2, both BRCA Gist and NCI performed significantly better than the control group (see Table 3), with \( F(2, 204) = 17.37, P < 0.0001, \eta^2 = 0.1428 \). The BRCA Gist mean percentage correct was 0.73, the NCI mean was 0.74, and the control group mean was 0.66.

Gist Comprehension

Gist comprehension was assessed only in experiment 2. As predicted, BRCA Gist scored significantly higher than NCI, and both scored significantly higher than the control group (see Table 3). For condition, \( F(2, 204) = 40.36, P < 0.0001, \eta^2 = 0.2694 \). On a scale ranging from 1 to 7 (higher indicating greater comprehension), the BRCA Gist mean was 5.34, the NCI mean was 4.98, and the control group mean was 4.51. There was a strong positive correlation between declarative knowledge and gist comprehension, \( r(208) = 0.77 \).
Table 2  Percentage Correct Declarative Knowledge for Each Module by Condition and Experiment

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
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<th>Experiment 2</th>
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</thead>
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<tr>
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<td>BRCA Gist</td>
<td>NCI</td>
<td>Control</td>
<td>Grand Mean</td>
<td>BRCA Gist</td>
<td>NCI</td>
<td>Control</td>
<td>Grand Mean</td>
</tr>
<tr>
<td>I. Breast cancer and</td>
<td>78%&lt;sup&gt;a&lt;/sup&gt; (24)</td>
<td>67% (23)</td>
<td>43% (26)</td>
<td>62%</td>
<td>79%&lt;sup&gt;a&lt;/sup&gt; (21)</td>
<td>68% (17)</td>
<td>56% (18)</td>
<td>68%</td>
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<td>[-0.730]</td>
<td>[0.106]</td>
<td>[-0.219]</td>
<td>[-1.319]</td>
<td>[-0.680]</td>
<td>[-0.475]</td>
<td>(21)</td>
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<td></td>
<td>&lt;0.745&gt;</td>
<td>&lt;0.237&gt;</td>
<td>&lt;0.048&gt;</td>
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<td>&lt;1.319&gt;</td>
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<td>&lt;0.059&gt;</td>
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<td>II. Risk factors and</td>
<td>69%&lt;sup&gt;b&lt;/sup&gt; (20)</td>
<td>67% (21)</td>
<td>56% (21)</td>
<td>64%</td>
<td>69%&lt;sup&gt;b&lt;/sup&gt; (19)</td>
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<td>53% (20)</td>
<td>63%</td>
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<td>[-0.409]</td>
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<td>[-0.404]</td>
<td>[-0.039]</td>
<td>(20)</td>
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<td>69% (13)</td>
<td>59% (16)</td>
<td>69%</td>
<td>77%&lt;sup&gt;a&lt;/sup&gt; (20)</td>
<td>70% (16)</td>
<td>55% (18)</td>
<td>68%</td>
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<td>genetic testing</td>
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<td>[0.026]</td>
<td>(17)</td>
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<td>[-0.687]</td>
<td>[-0.345]</td>
<td>(20)</td>
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<td>IV. Consequences of</td>
<td>83%&lt;sup&gt;a&lt;/sup&gt; (20)</td>
<td>72% (20)</td>
<td>68% (18)</td>
<td>75%</td>
<td>70%&lt;sup&gt;a&lt;/sup&gt; (17)</td>
<td>61% (17)</td>
<td>57% (16)</td>
<td>63%</td>
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<td>(18)</td>
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<td></td>
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<td>&lt;0.205&gt;</td>
<td>&lt;0.424&gt;</td>
<td>&lt;-0.570&gt;</td>
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<tr>
<td>Total declarative</td>
<td>74%&lt;sup&gt;a&lt;/sup&gt; (16)</td>
<td>67% (14)</td>
<td>56% (13)</td>
<td>66%</td>
<td>75%&lt;sup&gt;a&lt;/sup&gt; (17)</td>
<td>67% (14)</td>
<td>55% (15)</td>
<td>66%</td>
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<tr>
<td>knowledge test</td>
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<td>[-0.712]</td>
<td>[-0.422]</td>
<td>(15.6)</td>
<td>[-1.479]</td>
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<td>[-0.585]</td>
<td>(16.3)</td>
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<tr>
<td></td>
<td>&lt;0.765&gt;</td>
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<td>&lt;0.015&gt;</td>
<td>&lt;-0.401&gt;</td>
<td>&lt;2.593&gt;</td>
<td>&lt;0.848&gt;</td>
<td>&lt;0.111&gt;</td>
<td>&lt;-0.574&gt;</td>
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<tr>
<td></td>
<td>&lt;0.500&gt;</td>
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<td></td>
</tr>
</tbody>
</table>

Note: Standard deviations are in parentheses, skew in brackets, and kurtosis in angle brackets.

a. BRCA Gist > NCI Web and control, P < 0.0001.
b. BRCA Gist > control, P < 0.001.

Prediction 2: BRCA Gist Will Improve Judgments and Decisions about Genetic Testing

Risk Assessment

In both experiments, BRCA Gist and NCI participants were significantly more accurate in categorizing risk than were control participants (see Table 3). In experiment 1, for condition, F(2, 194) = 12.61, P < 0.0001, η² = 0.1129. The BRCA Gist mean percentage correct was 60.60, the NCI mean was 0.55, and the control group mean was 0.47. In experiment 2, for condition, F(2, 204) = 16.85, P < 0.0001, η² = 0.1359. The BRCA Gist mean percentage correct was 0.61, the NCI mean was 0.57, and the control group mean was 0.48.

Genetic Testing Decisions

We asked participants whether women depicted in the scenarios should undergo genetic testing. Participants uniformly recommended genetic testing at high rates for women at high genetic risk (see Figure 2). More than 80% of high-risk scenarios yielded genetic testing recommendations, with no differences among condition, Fs < 1. Most people fitting the medium risk criteria (e.g., Ashkenazi Jewish heritage) do not have BRCA mutations and may not be good genetic testing candidates. For scenarios depicting women with medium genetic risk, in experiment 1, BRCA Gist participants were significantly less likely to recommended testing than NCI or control participants, F(2, 194) = 4.64, P = 0.011, η² = 0.0478. Control group participants recommended genetic testing for 67% of the scenarios compared with 54% for BRCA Gist participants (see Figure 2). This was not replicated in experiment 2; medium-risk differences were not significant, F < 1.

For scenarios depicting women without genetic risk factors, in experiment 1, BRCA Gist and NCI participants were significantly less likely to recommend genetic testing than control participants, F(2, 194) = 11.30, P < 0.0001, η² = 0.1165; control participants recommended 50% of low-risk women for genetic testing compared with 24% for BRCA Gist participants (see Figure 2). In experiment 2, BRCA Gist participants were significantly less likely than NCI participants to recommend genetic testing for women without risk factors, and both were significantly lower than control participants, F(2, 204) = 23.88, P < 0.0001, η² = 0.2313. Control participants...
## Table 3  Mean for Key Outcomes by Condition

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Grand Mean</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Grand Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRCA Gist</td>
<td>NCI Web</td>
<td>Control</td>
<td>Grand Mean</td>
<td>BRCA Gist</td>
<td>NCI Web</td>
</tr>
<tr>
<td>Green and others knowledge</td>
<td>76.6% (11.8)</td>
<td>70.2% (10.6)</td>
<td>62.2% (9.9)</td>
<td>69% (12.2)</td>
<td>72.8% (9.1)</td>
<td>74.4% (8.5)</td>
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<tr>
<td>test: percentage correct</td>
<td>[-1.125]</td>
<td>[-0.478]</td>
<td>(9.9)</td>
<td>[-0.390]</td>
<td>[-0.473]</td>
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<td>&lt;1.089&gt;</td>
<td>&lt;0.506&gt;</td>
<td>[-0.510]</td>
<td>[-0.147]</td>
<td>&lt;0.130&gt;</td>
<td>&lt;2.785&gt;</td>
</tr>
<tr>
<td>Gist comprehension (1 = strongly disagree to 7 = strongly agree with correct responses)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5.34a (0.68)</td>
<td>4.98 (0.42)</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>[-0.489]</td>
<td>[0.223]</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>&lt;0.734&gt;</td>
<td>&lt;0.306&gt;</td>
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<td></td>
<td></td>
<td>&lt;0.106&gt;</td>
<td>&lt;0.78&gt;</td>
</tr>
<tr>
<td>Risk assessment: percentage correct</td>
<td>59.6% (16.5)</td>
<td>55.4% (15.2)</td>
<td>46.8% (12.7)</td>
<td>53% (15.8)</td>
<td>61.3% (15.7)</td>
<td>56.8% (15.7)</td>
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<tr>
<td></td>
<td>[-0.419]</td>
<td>[-0.274]</td>
<td>[-0.342]</td>
<td>(15.8)</td>
<td>[-0.521]</td>
<td>[0.065]</td>
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<td>&lt;0.530&gt;</td>
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<td></td>
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<td></td>
<td></td>
<td>&lt;0.166&gt;</td>
<td>&lt;0.89&gt;</td>
</tr>
<tr>
<td>Interest in genetic testing</td>
<td>2.85a (1.45)</td>
<td>2.30 (1.22)</td>
<td>1.79</td>
<td>2.33</td>
<td>2.76b (1.24)</td>
<td>2.31 (1.25)</td>
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<tr>
<td>(1 = extremely to 5 = not at all)</td>
<td>[2.117]</td>
<td>[0.621]</td>
<td>(1.01)</td>
<td>(1.31)</td>
<td>[0.194]</td>
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<td>&lt;1.292&gt;</td>
<td>&lt;0.696&gt;</td>
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<td>&lt;0.389&gt;</td>
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<td>&lt;2.232&gt;</td>
<td></td>
<td>&lt;0.593&gt;</td>
<td>&lt;0.721&gt;</td>
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<tr>
<td>Worry about breast cancer</td>
<td>1.20</td>
<td>1.28</td>
<td>1.24</td>
<td>1.24</td>
<td>1.20</td>
<td>1.16</td>
</tr>
<tr>
<td>(1 = low to 4 = high)</td>
<td>(0.32)</td>
<td>(0.37)</td>
<td>(0.36)</td>
<td>(0.35)</td>
<td>(0.31)</td>
<td>(0.26)</td>
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<tr>
<td></td>
<td>[2.833]</td>
<td>[3.486]</td>
<td>[1.453]</td>
<td>[2.558]</td>
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<td>[1.741]</td>
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<tr>
<td></td>
<td>&lt;10.166&gt;</td>
<td>&lt;17.468&gt;</td>
<td>&lt;1.289&gt;</td>
<td>&lt;9.270&gt;</td>
<td>&lt;2.584&gt;</td>
<td>&lt;2.456&gt;</td>
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<tr>
<td>State of anxiety (20 = low to 80 = high)</td>
<td>45.14</td>
<td>45.16</td>
<td>45.82</td>
<td>45.39</td>
<td>42.50</td>
<td>43.12</td>
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<tr>
<td></td>
<td>(8.10)</td>
<td>(8.53)</td>
<td>(8.40)</td>
<td>(8.31)</td>
<td>(15.39)</td>
<td>(13.99)</td>
</tr>
<tr>
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<td>&lt;0.186</td>
<td>&lt;0.020</td>
<td>&lt;0.381</td>
<td>[-0.192]</td>
<td>[-1.287]</td>
<td>[-1.137]</td>
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<td>&lt;0.440&gt;</td>
<td>&lt;0.165&gt;</td>
<td>&lt;0.104&gt;</td>
<td>&lt;1.883&gt;</td>
<td>&lt;2.470&gt;</td>
</tr>
</tbody>
</table>

Note: Standard deviations are in parentheses, skew in brackets, and kurtosis in angle brackets.

a. BRCA Gist > NCI Web and control, P < 0.0001.
b. BRCA Gist > control, P < 0.001.
recommended genetic testing for 52% of low-risk women compared with 19% for BRCA Gist (see Figure 2).

**Interest in Genetic Testing**

As predicted, in experiment 1, BRCA Gist participants reported significantly lower levels of stated interest in having a genetic test than did NCI or control participants (see Table 3), $F(2, 194) = 11.17, P < 0.0001, \eta^2 = 0.1152$. The BRCA Gist mean on a scale ranging from 1 to 5 (1 = extremely interested to 5 = not at all interested) was 2.85, the NCI mean was 2.30, and the control group mean was 1.79. This was partially replicated in experiment 2, as BRCA Gist participants (2.76) showed significantly lower levels of interest in genetic testing than control participants (1.99), with NCI (2.31) not significantly different from either (see Table 3), $F(2, 189) = 6.79, P = 0.0014, \eta^2 = 0.2072$.

**Prediction 3: BRCA Gist Will Not Increase Anxiety or Worry about Breast Cancer**

**Anxiety and Worry about Breast Cancer Risk**

We found no evidence that BRCA Gist provoked anxiety or worry about breast cancer. For anxiety, $F < 1$ in both experiments. In experiment 1, there were no significant differences for worry, $F < 1$. In experiment 2, BRCA Gist and NCI participants reported significantly lower levels of worry than control participants did, $F(2, 204) = 5.68, P = 0.004, \eta^2 = 0.0557$. The BRCA Gist mean for worry was 1.20 (1 = worry not at all or rarely to 4 = almost all the time) 1.16 for NCI, and 1.34 for the control.

To assess genetic breast cancer risk, we asked 5 questions from the PAT about family members with breast cancer, ovarian cancer, and Ashkenazi Jewish heritage. Self-reported risk factors did not predict or significantly interact with condition to predict outcomes.

**DISCUSSION**

Our results strongly support the concept that a gist-based intervention grounded in FTT can improve knowledge, gist comprehension, and decision making about genetic testing over and above what is achievable from the NCI’s detailed materials. Our predictions that BRCA Gist participants would perform better on measures of knowledge and gist comprehension and make better judgments and decisions about genetic testing were confirmed in both studies. We found large effect sizes in measures of knowledge, risk assessment, gist comprehension, and decision making about genetic testing. People who interacted with BRCA Gist often scored significantly higher than those spending the same amount.
of time reading comparable information from the NCI Web site. The BRCA Gist group exhibited more declarative knowledge than the control group for all 4 content areas. They scored higher than NCI participants on knowledge of breast cancer, genes, and genetic risk; BRCA mutations and genetic testing; and consequences of genetic testing (indeed, the NCI Web group performed no better than controls on genetic testing consequences). Even for the detailed knowledge conveyed in the risk factors and risk estimation module, the BRCA Gist group scored as well as the NCI group, illustrating the importance of gist understanding to learning.73

The similarity in BRCA Gist and NCI factual content suggests that the key to this improved performance is learning with gist understanding rather than rote memorization of verbatim facts.74 Gist comprehension accounted for about 60% of the variance in declarative knowledge, suggesting that the locus of the effectiveness of BRCA Gist is enhancing gist representations. Furthermore, FTT formal models of recall indicate that improving gist comprehension positively affects conventional knowledge measures by helping people to better organize their knowledge and reconstruct details from gist memory.52

Most participants, regardless of group, recognized the advantages of genetic testing for high-risk women with a significant family history of breast and ovarian cancer. However, BRCA Gist led participants to appropriately recommend genetic testing at much lower rates for women without genetic risk factors. BRCA Gist apparently helped participants form a gist understanding that most women do not have known genetic risks and are not good testing candidates. Judgments of genetic risk for medium-risk scenarios fell between those for high- and low-risk scenarios and were somewhat lower for BRCA Gist than NCI participants in both experiments.

BRCA Gist participants performed well on instruments not designed specifically for this content. BRCA Gist scores on the Green and others knowledge instrument in experiment 1, 77% correct, were similar to the 80% correct Green and others reported for participants receiving genetic counseling.55 However, experiment 2 performance was somewhat lower (73% correct), and performance in both experiments was lower than the 91% correct in Green and others’ computer-based instruction condition. Although the Cronbach’s α was low, this may be because only some items assessed content covered by BRCA Gist and the NCI Web site.

Limitations

BRCA Gist should be tested and developed through randomized controlled experiments with women from different ethnic, cultural, and socioeconomic backgrounds; older women; and women at higher risk. Controlled experiments should assess the relative contributions of different aspects of BRCA Gist (i.e., explanation dialogues and displays grounded in FTT). Nevertheless, key findings were replicated at 2 sites in both experiments. Differences between experiments appear to be well within scientific expectations for replication.75

We did not assess actual genetic testing decisions. The question regarding level of interest in having a genetic test is suboptimal. For example, some participants may have expressed interest in learning from testing, even though they understood it had little practical medical value for themselves. The “worry about breast cancer” instrument68 is also suboptimal because some items asking about worry during the past week. Both BRCA Gist interactions and testing on outcome measures were conducted in a single experimental session. It is unknown whether BRCA Gist would continue to outperform other groups if follow-up assessments were conducted after longer time intervals.

The NCI Web site comparison provides a rigorous test of the gist-based approach grounded in FTT. We assembled materials scattered across the NCI Web site into a convenient form, removing hyperlinks to scholarly references, which sometimes confuse laypeople; we also kept participants focused on the Web site. Instructions and time on task were identical for all groups. However, removing hyperlinks may have made it more difficult to follow personal interests, potentially limiting effectiveness. It is also possible that BRCA Gist is simply more engaging than the NCI Web site. Although participants in the laboratory were not permitted to talk, browse the Web, check cells phones, and so on, it is possible that NCI participants may have been less attentive than BRCA Gist participants because the latter was interactive.

CONCLUSIONS

BRCA Gist is not a substitute for genetic counseling. However, a Web-based ITS is a scalable and cost-effective way to reach people across the globe. Experts reviewing the literature have concluded
that decision aids are rarely grounded in theory. Yet, when guided by a sound theoretical understanding, emerging discourse technologies may be fruitfully used to create gist-based interventions, guiding people to explain the gist of complex medical information in their own words, thus facilitating better medical decision making.

ACKNOWLEDGMENTS

The authors thank the National Cancer Institute for its support. Special thanks to consulting medical expert Dr. Nananda Col, MD, MPH (University of New England College of Osteopathic Medicine); consulting SKO creator Dr. Xiangen Hu, PhD (University of Memphis); graphics designer Jenny Miller, BA (Miami University); and undergraduate research assistants Sharjeel Chaudhry, BA (Cornell University), Andrew Gircelli (Miami University), Isabella Damas Vannucchi, BA (Miami University), Suveera Dang, BA (Cornell University), Anna Catherine Morant, BA (Cornell University), Zachary W. Nollet, BA (Cornell University), Amrita Rao, BA (Cornell University), Jessica Reigrut, BA (Miami University), Nicole Rodgers, BA (Miami University), and Mandy Withrow, BA (Miami University)

REFERENCES


