Problem-Solving in Technology-Rich Environments and Cancer Screening in Later Life

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Abstract

Objectives: Routine cancer screening is widely recognized as an effective preventive strategy to reduce cancer mortality – the second leading cause of death in the U.S. However, cancer screening requires a complex array of tasks such as seeking up-to-date guidelines, making appointments, planning hospital visits, and communicating with health care professionals. Importantly, modern health care largely relies on technology to disseminate the latest information and administer the system. Yet, little is known about the technology-related skills that are relevant to regular cancer screening. This study examined the association between problem-solving skills in the technology-rich environment (PSTRE) and cancer screening in later life.

Methods: Using 2012/2014 Program for International Assessment of Adult Competencies data, binary logistic regressions with survey weights were used to estimate the association between PSTRE and four cancer screening behaviors among the corresponding target populations aged between 45 to 74 years old (n = 1,374 for cervical screening; n = 1,373 for breast screening; n = 1,166 for prostate screening; n = 2,563 for colon screening).

Results: Results showed that greater PSTRE scores (0 – 500 points) were significantly and positively associated with prostate cancer screening (OR = 1.005, $p < 0.05$) among men, but not with colon (men and women) or cervical or breast (women) cancer screenings.

Conclusions*:* Improvement in PSTRE may promote specific cancer screening behaviors. Our findings inform future policy discussions and interventions that seek to improve cancer screening among a vulnerable section of older populations.

Keywords: preventive health care, cancer, ehealth

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Cancer is the second leading cause of death in the United States, with a 606,880 cancer-specific mortality projected in the United States in 2019 (American Cancer Society, 2019a). The incidence of cancer generally increases in middle and older age (White et al., 2014). Regular screening, early detection, and treatment are known to reduce cancer mortality and to increase survival time (Martínez-Donate, 2014; Smith, Cokkinides, Brooks, Saslow & Brawley, 2010). The American Cancer Society guidelines recommend that women ages 45 to 65 receive a pap smear to test for cervical cancer every three years, and a mammogram to test for breast cancer every year (American Cancer Society, 2019b). Guidelines also recommend a prostate-specific antigen (PSA) test for prostate cancer every two years in men ages 50 to 75, and a colonoscopy to test for colon cancer every two years for both, men and women ages 45 to 75 (American Cancer Society, 2019b). However, cancer screening requires a complex array of tasks such as seeking up-to-date guidelines, making appointments, planning hospital visits, arranging transportation, and communicating with health care professionals. Consequently, cancer detection may be delayed because of these barriers to regular screening.

Several individual-level factors are linked to cancer screening behaviors. Low income, lack of health insurance, poor understanding of the benefits of regular screening, and low educational status are all associated with lower rates of cancer screening (Freund, 2010; Katz et al., 2014; Krok-Schoen, Oliveri, Young, Katz & Paskett, 2015; Paskett, McLaughlin, Lehman, Katz, Tatum & Oliveri, 2011). For instance, the level of education is positively associated with adherence to cervical and breast cancer screening guidelines (Damiani et al., 2012). Furthermore, basic skills such as literacy and numeracy are linked to regular breast and colon cancer screening (Kobayashi, Wardle & Von Wagner, 2014; Koo, Brackett, Eisenberg, Kieffer & Hyams, 2017;

Krok-Schoen et al., 2015; Smith et al., 2010). Similarly, poor health literacy, which is a lack of skills to understand and utilize health information (Nielsen-Bohlman, Panzer & Kindig, 2004), is linked to less frequent screening (Sentell, Tsoh, Davis, Davis & Braun, 2015). Basic skills may reflect a set of skills that enable individuals to evaluate health information and navigate through the health care system, and therefore, and therefore such skills are important individual competencies associated with cancer screening (Kim & Han, 2015).

Nevertheless, significantly less is known about another critical competency indicator – problem-solving skills in technology-rich environments (PSTRE). PSTRE refers to “using digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks” (Organisation for Economic Co-operation and Development [OECD], 2012, p. 46). PSTRE skills are highly relevant to health management, as modern health care increasingly relies on technology for communication and dissemination of health information (Gordon & Hornbrook, 2018). Indeed, emerging evidence shows that PSTRE is associated with health-related outcomes (Millar, Sahoo, Yamashita & Cummins, 2019). Health information and patient-physician communications are increasingly being integrated through emerging web-based modalities and other digital technologies (Gordon & Hornbrook, 2018). A lack of familiarity with these new technologies may present challenges for health care service utilization, particularly in older ages (Gordon & Hornbrook, 2018; Mackert, Mabry-Flynn, Champlin, Donovan & Pounders, 2016). A digital divide in the health care context is a widely known issue for older populations (Mitchell, Chebli, Ruggiero & Muramatsu, 2019). Therefore, there is a need to investigate whether there is an association between the ability to effectively use technology to solve everyday problems (i.e., PSTRE) and cancer screening behaviors in later life.

Theoretical Framework

The current study draws from two relevant theoretical frameworks: Andersen's Health Care Utilization Model (Andersen's model hereafter), and Paasche-Orlow and Wolf's model (health literacy model hereafter) of health literacy and health outcomes (Gelberg, Andersen & Leake, 2000; Paasche-Orlow & Wolf, 2007). Briefly, Andersen's model suggests that predisposing (e.g., sociodemographic characteristics), enabling (e.g., health insurance), and need (e.g., health status) factors jointly determine one's health care utilization behaviors (Gelberg et al., 2000). The health literacy model suggests that heath literacy skills are linked to health-related outcomes through informed decision-making (Paasche-Orlow & Wolf, 2007). Health literacy generally refers to a set of skills necessary to understand health information to promote health (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011). Since PSTRE skills can be considered both an enabling factor as well as a specific component of health literacy, the integration of Anderson's model and the health literacy model provide a theoretical proposition to the current study. Specifically, the models suggest that greater PSTRE skills can contribute to regular cancer screening by equipping individuals with the skills necessary for identifying cancer-related information, for understanding the benefits of regular screening, and for navigating the current health care systems. In this theoretical standpoint, PSTRE skills are an important enabling factor and a domain of health literacy that has the potential to promote cancer screening behaviors in aging adults.

In view of the literature, this study addresses one research question:

Are PSTRE skills associated with four selected screening behaviors for cervical, breast, prostate, and colon cancers among middle age and older women and men in the U.S.?

We hypothesize that there is a positive association between PSTRE skills and participation in all types of cancer screening, for both women and men.

Methods

Data

Data are obtained from the 2012/2014 Program for the International Assessment of Adult Competencies (PIAAC) U.S. public use file. The PIAAC data provide a sophisticated PSTRE measure (see the section below for more details) in addition to a range of background and sociodemographic characteristics. PIAAC includes final sampling and replicate weights to allow for the estimation of nationally representative figures (The American Institutes for Research [AIR] PIAAC Team, n.d.). Additional technical information about PIAAC is available elsewhere (National Center for Education Statistics, 2017). This study looked at women ages 45 to 65 for cervical and breast cancer screening, men between the ages of 50 to 75 for prostate cancer screening, and women and men between the ages of 45 to 75 for colon cancer screening. The decision for this age-specific sample selection is based on recommendations by the American Cancer Society (American Cancer Society, 2019b).

Measures

Dependent variables (4 variables). Four preventative screening behaviors for cervical, breast, prostate, and colon cancer are measured in PIAAC and included in this study according to the (2019b) specific age recommendations. PIAAC respondents were asked the following question: "In the past year, have you had a… [pap smear] … [mammogram]" or "In the past year, have you been screened for [prostate cancer] … [colon cancer]." For the analysis, cervical, breast, prostate, and colon cancer screenings were recorded as a dichotomous measure (Yes vs. No).

Predictor variable. PSTRE was measured by a set of 10 estimated scores ranging from 0 to 500, which quantify individuals' ability to use digital devices and software applications to solve everyday tasks (OECD, 2012). This set of 10 plausible values (statistically estimated means), is based on the respondents' performance on a series of PSTRE-related interactive tasks (OECD, 2012). For example, one of the assessment items is a task requiring individuals to sort large numbers of digital files according to the specific order or adjusting software program settings according to the instructions (see OECD, 2012 for more details).

Covariates. Age was measured in five- year intervals (i.e., 45–49, 50–54, 55–59, 60–65, 66-70, 71+) for the recommended age categories corresponding to screening-specific recommendations. On a related note, the PIAAC public use file does not provide a continuous age variable. The PIAAC respondents who did not meet the age criterion (e.g., 35-39, 40-44, 66-70, and 71+) for each cancer screening were excluded, as the current guideline does not recommend screenings for those ages (American Cancer Society, 2019b). Accordingly, sample sizes varied for each cancer screening based on the gender and age criterion (see Figure 1 for the sample selection process). Given the small number of non-White PIAAC respondents, race/ethnicity was dichotomized to reflect whether a respondent identified themselves as White or other race/ethnicity (White vs. others). Similarly, educational attainment was dichotomized to indicate college degree or higher vs. less than a college degree. Income was recorded based on quintiles (1 – 5: Lowest income to highest income). Given that the income question was administered only to those who were employed, non-employed (both unemployed and out of labor force) participants were assigned to the lowest income quintile to avoid missing values in income. Finally, a dichotomous variable was used to denote whether a respondent had health insurance or not (insured vs. uninsured).

Analytical Approach

Weighted descriptive statistics were estimated for all variables of interest by the type of cancer screening. To address the research question, binary logistic regression was used to model each of the four cancer screenings as a function of PSTRE scores. Unadjusted models were evaluated first to establish the baseline association. If a significant association was identified, a fully adjusted model including covariates was constructed. All analyses were conducted using SAS version 9.4 (SAS Institute Inc., 2013). IDB Analyzer application version 4.0.14 (IEA, 2017), was used to generate the SAS macro program to incorporate the sampling weights (SPFWT0), replicate weights (SPFWT1- SPFWT80), and PSTRE plausible values into the statistical analysis (AIR PIAAC Team, n.d.).

Results

Figure 1 presents a flow diagram of the sample selection process and sample sizes by type of cancer screening. Briefly, we illustrate the selection criteria by showing first, (a) the total number of PIAAC respondents, (b) followed by a breakdown of those for which cancer screening questions were asked in PIAAC, (c) our analytical sample based on age cut-offs suggested by the American Cancer Society (2019b), and finally (d) the distribution of participants based on self-reported cancer screening behavior. The final sample sizes were 1,374 for cervical cancer screening, 1,373 for breast cancer screening, 1,166 for prostate cancer screening, and 2,563 for colon cancer screening.

[Insert Figure 1 here]

Table 1 presents weighted descriptive statistics by cancer screening use. Briefly, more than half of female respondents had a cervical cancer screening (59.55%) and a breast cancer screening (59.31%). Also, more than half of male respondents had a prostate cancer screening

(54.37%). Finally, more than half of male respondents (52.83%) and a smaller number of female respondents (47.16%) had a colon cancer screening. Note that these weighted percentages are not presented in Table 1 to avoid any confusion with the unweighted sample sizes. The average weighted PSTRE score was 261 out of 500 in the full sample. Respondents with a cervical cancer screening had higher PSTRE scores than those who did not have one (265 and 259, respectively), and similar results are seen for breast cancer screening (265 and 258, respectively), prostate cancer screening (265 and 254, respectively), and colon cancer screening (259 and 258, respectively).

[Insert Table 1 here]

Table 2 presents the estimated Odds Ratios (OR) from weighted binary logistic regression models. In the unadjusted models, PSTRE skills were statistically significantly associated only with prostate cancer screening (OR = 1.005, $p < 0.05$). The finding remained consistent even after accounting for covariates in the fully adjusted model (OR = 1.005, $p < 0.05$). PSTRE skills were not associated with cervical cancer screening (OR = 1.004, $p > 0.05$), breast cancer screening (OR = 1.004, $p > 0.05$), or colon cancer screening (OR = 1.001, p > 0.05). Therefore, we did not consider fully adjusted models for these three cancer screenings.

[Insert Table 2 here]

Discussion

We hypothesized that there would be a positive association between PSTRE skills and participation in cancer screening for cervical, breast, prostate and colon cancer, among both women and men. However, results from the analysis did not fully support our hypothesis. We found no significant associations between PSTRE skills and cervical, breast, or colon cancer screening. At the same time, an increase in PSTRE skills was associated with a greater likelihood of prostate cancer screening in men. Given the gendered findings in our primary analysis, we did a separate analysis for colon screening for men and women; and found no significant result for colon cancer screening between men and women.

As discussed earlier, drawing both from Anderson's model and the health literacy model, PSTRE skills can be considered both an enabling factor as well as a specific component of health literacy linked to cancer screening behaviors (Gelberg et al., 2000; Paasche-Orlow & Wolf, 2007). Although only applied to a specific type of cancer screening (i.e., prostate cancer) in the current study, PSTRE might have differentiated the screening rate by the capacity to handle a series of health care utilization tasks (e.g., scheduling and making an appointment). Our finding suggests that higher PSTRE scores might be an additional competency leading to more consistent cancer screening in men. By the same token, PSTRE skills might have functioned as a heath literacy component, which promotes cancer screening in general. However, it is not clear why high PSTRE skills are only linked to prostate cancer. Future research needs to disentangle pathways between PSTRE skills and specific cancer screening.

Our findings may reflect the underlying gendered aspects of cancer screening awareness. For instance, women usually discuss preventive services, including regular cancer screening with their primary care physicians, gynecologists, or urologists (Davis, Buchanan, Katz & Green, 2011; Rees & Bath, 2000). On the other hand, men are less likely to engage in regular medical visits or to seek specialized care (e.g., urologists) when compared to women (Banks & Baker, 2013). Similarly, women's health and cancer awareness are widely publicized in the media (e.g., magazines) and social marketing, whereas health information for men does not seem to reach the same level of dissemination (Costa et al., 2017). This greater awareness of cancers in women might have negated the effect of PSTRE skills and proficiencies on their cancer screening.

PSTRE skills have the potential to enable men to participate more in cancer screenings, as it will equip them with increased knowledge to better navigate the health care system. It should be noted that our non-significant findings for cervical, breast, and colon cancer screening may reflect a discrepancy between the PIAAC assessment of cancer screening (i.e., within the last year) and the recommended time frames varying from every three-years for cervical screening to every year for breast screening.

PSTRE skills are an emerging and complex measure that assesses individuals' cognitive ability through problem-solving using technology (OECD, 2012). The integration of cognitive ability and technology use provides a new multifaceted measure that bridges previous avenues of investigations related to the study of technological information seeking in older adults (Berkowsky & Czaja, 2018). More research is needed to establish the uniqueness of PSTRE as one of the health literacy domains which are important for health care service utilization. A better understanding of PSTRE in the current heath care environment may lead to improvements in the existing digital divide among older populations. Importantly, future research needs to both identify promoting factors (e.g., lifelong learning) and develop interventions to enhance PSTRE skills. Although this study only found a link between PSTRE skills and prostate cancer screening, greater PSTRE skills are most likely an advantage for navigating the complex health care systems, and in turn, for promoting general health in later life.

Limitations

This study has a few limitations. The analysis uses cross-sectional data which limits the ability to infer any causation. Second, the PIAAC public use files do not provide a continuous age variable. Given the association of advancing age and problem-solving skills, age in categorical groups is unable to capture precise trends. Third, respondents who had no computer experience or failed a test of basic computer skills were not included in the PSTRE assessment in PIAAC. Therefore, a potential selection bias cannot be fully ruled out. Fourth, while not available in PIAAC, traditional demographic characteristics such as marital status and crude income measures could have provided additional insights in the individual's cancer screening behaviors. Lastly, questions on cancer screening included whether the individual was screened in the past year; therefore it was not possible to include all respondents who followed the guidelines and had a screening longer than a year ago.

Contributions

Despite limitations, this study addresses a gap in this literature by studying an understudied adult competency indicator of PSTRE, which is highly relevant to the technology-filled modern society (Kimbler, 2013; Millar et al., 2019). This study adds new empirical evidence on PSTRE and cancer screening in later life to the literature in multiple fields such as adult health education, behavioral medicine, and social epidemiology. Enhancing PSTRE could be an effective and responsible way for self-care as well as navigating health care systems, not only in terms of cancer screening but also other health-promoting behaviors. Furthermore, to the best of our knowledge, our findings on the PSTRE and cancer screenings is one of the first empirical evidence with the nationally representative data. Our findings emphasize the significance of technological problem-solving to address the digital divide and health care disparities among aging individuals.

Conclusion

The leading public health concern and second leading causes of death in the U.S. – cancer – can be reduced through regular screening. However, utilizing cancer screening services requires a series of tasks in increasingly technology-rich complex health care systems. Using nationally representative data of middle-aged and older adults, we found that problem-solving skills in technology-rich environments are positively associated with prostate cancer screenings in men ages 50 to 75. Our findings highlight the importance of promoting technological problem-solving skills to enable middle-aged and older adults to understand and utilize health information in the technology-filled modern health care system. This study provides a foundation for further research to identify specific pathways between PSTRE and cancer screening behaviors. More refined measures of cancer screening reflecting the existing guidelines and qualitative data on the barriers to cancer screening would be valuable in future PIAAC data collection. In the meantime, even with the preliminary empirical evidence, legislative and regulatory efforts by government and professional organizations should focus on eliminating possible digital divides in cancer screening through a systematic promotion of PSTRE skills.

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Shalini Sahoo and Roberto J. Millar designed the research, conducted the data analysis and wrote a substantial portion of the texts. Dr. Takashi Yamashita assisted with the data analysis and wrote a part of the results and discussion sections. Dr. Phyllis Cummins involved in the conceptualization of the project, wrote a part of the introduction section, and contributed to the discussion section.

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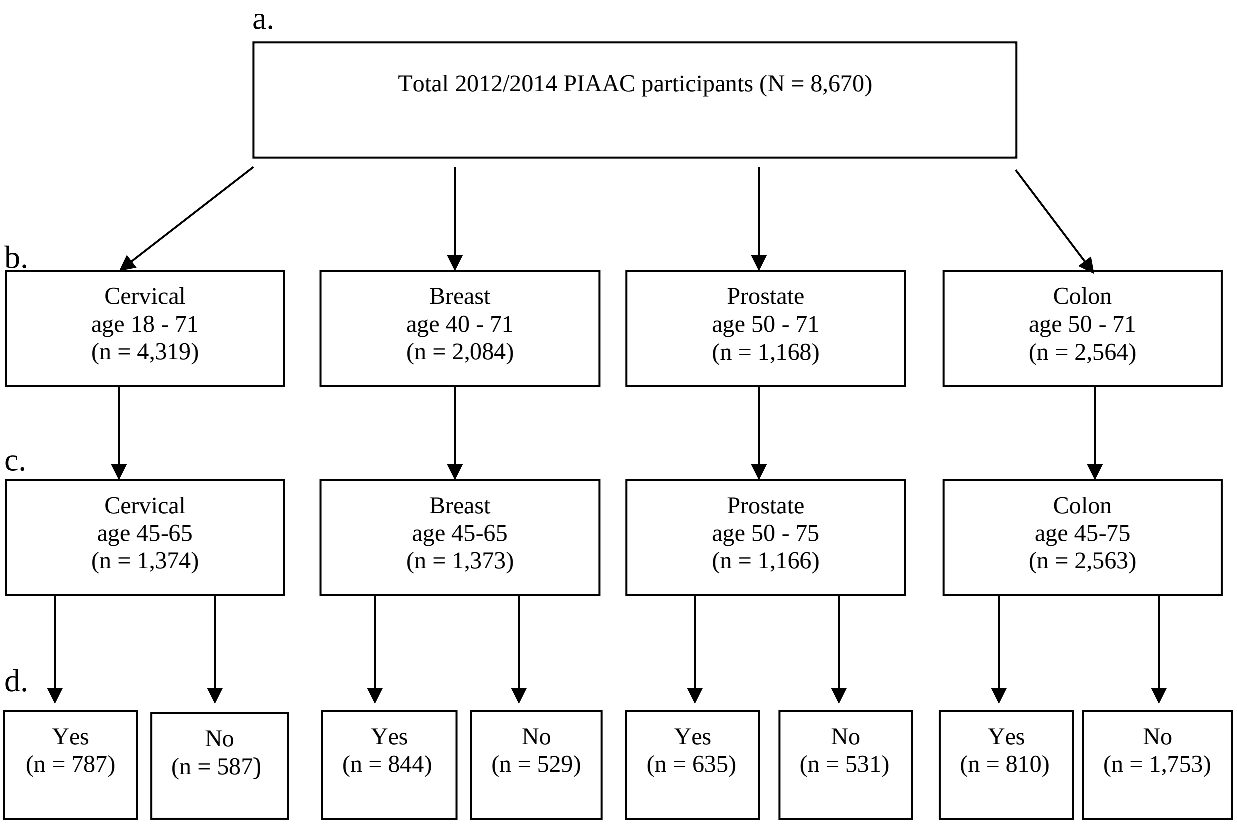
Fig. 1. Flow diagram of the Sample Selection Criterion and Final Sample Sizes for Each Cancer Screening Behavior in the 2012/2014 PIAAC.



[a] Total sample. PIAAC = Program for the International Assessment of Adult Competencies

[b] Sub-sample 1. Age selection criteria for specific cancer screening used by PIAAC

[c] Sub-sample 2. Age selection criteria for specific cancer screening suggested by the American Cancer Society (2019)

[d] Final analytic sample by response to specific cancer screening (1= Yes and 0= No)

Table 1. Weighted Descriptive Statistics for Full and Stratified Analytic Samples by Cancer Screening Status

Variables	**Full Sample**	**Cervical**		**Breast**		**Prostate**		**Colon**	
Age criterion	Age 45-75	Women 45-65		Women 45-65		Men 50-75		Men & Women 45-75	
	(N = 3,279)	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
		(n = 787)	(n = 587)	(n =844)	(n = 529)	(n = 635)	(n = 531)	(n = 810)	(n = 1,753)
PSTRE score (0-500), Mean (*SE*)	261.239(1.459)	265.286(2.127)	259.217(2.859)	265.139(2.141)	258.692(2.871)	265.097(2.535)	254.755(3.476)	259.779(2.932)	258.719(1.838)
Age-group, %									
45-49	20.621	30.074	20.853	25.773	26.802	0.000	0.000	100.000	100.000
50-54	20.964	25.262	26.211	24.346	27.817	20.193	34.176	23.716	27.545
55-59	19.141	21.417	23.825	22.098	22.991	22.347	27.725	21.943	24.906
60-65	20.186	23.247	29.112	27.783	22.39	29.121	19.873	25.861	25.823
66-70	12.189	0.000	0.000	0.000	0.000	20.111	12.845	17.941	14.405
≥71	6.899	0.000	0.000	0.000	0.000	8.228	5.381	10.539	7.321
Sex, %									
Female	52.900	100.000	100.000	100.000	100.000	0.000	0.000	47.163	55.011
Male	47.100	0.000	0.000	0.000	0.000	100.000	100.000	52.837	44.989
Race, %									
White	73.059	70.275	71.449	72.025	68.728	75.075	74.516	70.036	76.433
Other race	26.941	29.725	28.551	27.975	31.272	24.925	25.484	29.964	23.567
Income quintile, %									
1st quintile	49.135	40.511	57.504	43.022	55.187	48.399	41.612	56.172	53.617
2nd quintile	9.494	14.300	12.900	12.156	16.132	5.510	8.722	7.829	9.035
3rd quintile	11.679	13.217	12.747	13.262	12.632	8.711	14.220	9.401	10.864
4th quintile	13.739	15.733	9.136	15.129	9.452	13.723	19.002	10.288	13.405
5th quintile	15.954	16.240	7.713	16.431	6.596	23.657	16.444	16.310	13.079
Education, %									
College degree or higher	37.586	45.137	30.899	44.850	29.695	45.508	29.832	39.538	35.111
High school or less	62.414	54.863	69.101	55.150	70.305	54.492	70.168	60.462	64.889
Health insurance, %									
Has health insurance	86.543	90.156	76.563	91.706	72.469	94.390	81.110	93.828	85.639
Does not have health insurance	13.457	9.844	23.437	8.294	27.531	5.610	18.890	6.172	14.361
Self-rated health, %									
Good health	77.955	81.495	71.780	80.881	71.626	79.198	75.992	75.358	76.329
Poor health	22.045	18.505	28.220	19.119	28.374	20.802	24.008	24.642	23.671

Note: PSTRE = Problem-Solving in Technology-Rich Environments. SE= standard error. PSTRE significance test and other estimates based on weighted values. PSTRE score estimate is weighted and calculated using sampling weights and replicate weights. Cancer Screening was a dichotomous measure. [e.g. Yes Prostate Screening = 1 and No = 0]
Non-employed individuals, or those with no income, were aggregated to the lowest income quintile given PIAAC's classification of the unemployed as non-earners.

Table 2. Estimated Odds Ratios for Binary Logistic Regressions Models of PSTRE and Cancer Screening

Variables	**Cervical**	**Breast**	**Prostate**		**Colon**
Age Criterion	Women 45-65 (N = 1,374)	Women 45-65 (N = 1,373)	Men 50-75 (N = 1,166)		Women & Men 45-75 (N = 2,563)
	OR(SE)	OR(SE)	OR(SE)		OR(SE)
PSTRE score	1.003 (0.002)	1.004 (0.002)	1.005 (0.002)**	1.005 (0.002)*	1.001 (0.002)
Age				1.356 (0.132)**	
Female					
White				0.624 (0.170)	
Income				0.991 (0.085)	
Education				1.634 (0.336)*	
Health insurance				2.875 (1.140)*	
Good Self-rated health				0.705 (0.234)	

Note: PSTRE = Problem-Solving in Technology-Rich Environments. OR = Odds Ratio, SE = Standard Error. Cancer Screening was a dichotomous measure [i.e. Yes to Pap Smear = 1 and No to Pap Smear = 0]. A one-unit increase represents 1-point increment in PSTRE score. Logistic regression estimates were calculated using plausible values and replicate weights using IDB Analyzer (Version 3.1).

*p<.05, **p<.01, ***p<.001