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Combining risk communication strategies to simultaneously convey the risks of four diseases associated with physical inactivity to socio-demographically diverse populations

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Abstract A single risk factor can increase the risk of developing multiple diseases, but most risk communication research has been conducted in the context of a single disease. We explored which combination of three recommended risk communication strategies is most effective in simultaneously conveying risk estimates of four diseases associated with physical inactivity: colon cancer, stroke, diabetes, and heart disease. Participants (N = 1161, 50% no college experience, 50% racial/ethnic minority) were shown hypothetical risk estimates for each of the four diseases. All four diseases were placed at varying heights on 1 of 12 vertical bar charts (i.e., "risk ladders") to indicate their respective probabilities. The risk ladders varied in a 2 (risk reduction information: present/absent) × 2 (numerical format: words/words and numbers) × 3 (social comparison information: none/somewhat higher than average/much higher than average) full factorial design. Participants were randomly assigned to view one of the risk ladders and then completed a questionnaire assessing message comprehension, message acceptance, physical activity-related risk and efficacy beliefs, and physical activity intentions. Higher message acceptance was found among (1) people who received risk reduction information versus those who did not ($p = .01$), and (2) people who did not receive social comparison information versus those told that they were at higher than average risk ($p = .03$). Further, absolute cognitive perceived risk of developing "any of the diseases shown in the picture" was higher among people who did not receive social comparison information ($p = .03$). No other main effects and only very few interactions with demographic variables were found. Combining recommended risk communication strategies did not improve or impair key cognitive or affective precursors of health behavior change. It might not be necessary to provide people with extensive information when communicating risk estimates of multiple diseases.

Keywords Risk communication · Decision making · Physical activity · Health disparities

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Introduction

Physical inactivity is one of the 10 leading risk factors for death worldwide and is responsible for diseases causing significant morbidity and mortality such as colon cancer, stroke, diabetes, and heart disease (World Health Organization, 2016). Nearly half of people in the US do not obtain the recommended amount of physical activity (Centers for Disease Control and Prevention, 2011), and few laypeople understand that insufficient physical activity substantially raises the risk of each of these diseases (Claassen et al., 2011; Wang et al., 2010; Wold et al., 2005). Illustrating the relationship between a single behavior like physical activity and multiple health outcomes could help people understand how their behavior affects their overall health and well-being. This study sought to identify the strategy or strategies that most effectively communicated the relationship between insufficient physical activity and four diseases: colon cancer, stroke, diabetes, and heart disease.

Health risk communication strategies

Decades of research have provided insight into communicating health risk information (Fischhoff et al., 2011; Garcia-Retamero & Cokely, 2013; Hoffrage et al., 2000; Lipkus, 2007; National Cancer Institute, 2001; Waters et al., 2016; Weinstein et al., 1991; Weinstein et al., 1989). Effective strategies can include providing information about the risk of the average person (Dillard et al., 2011; Fagerlin et al., 2007; Klein, 2002, but see also: French et al., 2004; Harris & Smith, 2005 for mixed findings), how changing behavior will affect future risk (Weinstein et al., 1998; Witte, 1992), and, in more complex risk communication circumstances such as choosing among medical treatments, adding numeric probability estimates to qualitative descriptors of absolute risk (Peters et al., 2014; Sinayev et al., 2015). However, the decision about which strategies and numerical formats to use to convey risk information should be guided by the specific goals of the study (Brewer, 2011; Cuite et al., 2008). For example, numerical information might be useful for people who are engaged in evaluating the risks and benefits of taking a medication (Peters et al., 2014), but it might be less beneficial for situations in which the goal is merely to alert people that they are vulnerable to developing a disease in the future (Reyna, 2008; Zikmund-Fisher, 2013). Furthermore, not only can numeric probabilities be difficult for people to understand (Nelson et al., 2008; Nelson et al. 2013), but providing very precise personalized numeric information can diminish information comprehension, perceived personal relevance of the information, perceived necessity of changing a particular behavior, and trust in the reliability of the information (Han et al., 2013; Witteman et al., 2011). Nevertheless, because many risk communicators recommend providing numerical information (Waters et al., 2009; Woloshin et al., 2003), it is important to continue to examine this issue.

Despite the multitude of studies examining the conditions under which certain risk communication strategies are and are not effective, much research has overlooked two key issues. First, although many studies have applied these strategies individually (i.e., providing specific risk reduction information, adding numbers to words, and providing social comparison information), relatively little research examined them in combination (Lipkus, 2007) (but see Fagerlin et al., 2010; Nair et al., 2008). This is an important gap because providing information that reflects a broad conceptualization of risk can help people build a more coherent and meaningful picture of the relationship between behavior and overall health. However, even though providing multiple types of risk information might be useful, it is important to avoid overwhelming people with information that they may not need or may not find useful (Peters et al., 2007; Zikmund-Fisher et al., 2010; Zikmund-Fisher, 2013).

Second, most studies convey only the risk of a single negative health outcome. This represents a potential missed opportunity to help people contextualize their risk by comparing their risk of one disease to their risk of other key diseases (Keller et al., 2009; Waters et al., 2016; Weinstein, 1999). Making it clear that changing one behavior could reduce the risk of many diseases could help people better understand the link between physical activity and overall health.

Study objective and exploratory research question

This study sought to determine how to best communicate risk estimates of four diseases simultaneously: heart disease, stroke, diabetes, and colorectal cancer. To accomplish this, we asked the following exploratory research question: Which of three risk communication strategies (i.e., risk reduction information, numerical format, and social comparison information), alone or in combination, produce the most beneficial changes in key cognitive and affective precursors of health behavior change? We did not have any specific hypotheses regarding which main effects or interactions among the communication format variables might produce the most favorable results.

Conceptual model

We identified the specific cognitive and affective variables of interest using a conceptual model that was adapted from the Health Action Process Approach (HAPA) (Schwarzer, 2001). In brief, HAPA states that volitional behavior change occurs in two phases: first people become motivated to act, then they initiate and, ideally, maintain action. In the *motivation phase*, cognitive perceived risk and response efficacy (i.e., expecting that engaging in the behavior will reduce risk) work together with perceived severity of the disease and action self-efficacy (i.e., confidence in one's ability to initiate a new behavior) to increase intentions to change behavior. Then, in the *action phase*, other intrapersonal, interpersonal, social, and environmental factors influence the extent to which motivated individuals actually initiate and maintain behavior change (Schwarzer, 2001). We do not discuss the action phase further because this paper focuses on describing the development of an intervention component to target the motivation phase.

We supplemented the motivation phase with five elements drawn from risk perception and communication research, which are not identified in HAPA. We added information comprehension and message acceptance because they are necessary precursors to attitude change (Barnes et al., 2013; Brennan et al., 2011; Fisher et al., 2003; Jones et al., 2003; McGuire, 1985). We added affectively-laden risk beliefs because ample research demonstrates that feelings of risk, worry, and anticipated regret are important for increasing motivation to change behavior and in behavior change itself (Abraham & Sheeran, 2004; Brewer et al., 2007; Brewer et al., 2016; Ferrer & Klein, 2015; Finucane et al., 2000; Hay et al., 2006; Janssen et al., 2012; Weinstein et al., 2007). We added socio-demographic variables because people with less formal education, who are racial or ethnic minorities, and who have limited numeracy or graph literacy may have particular difficulty understanding and using health and risk information (Galesic & Garcia-Retamero, 2011; Kutner et al., 2006; Nelson et al., 2008; Nelson et al., 2013).

For the analyses described below, we focus on the constructs directly targeted by our communication strategies: information comprehension, message acceptance, cognitive and affective risk beliefs, and response efficacy. We also examined the effects of the strategies on intentions because, according to the HAPA model, it is an appropriate target of interventions aimed at the motivational phase. We explored whether socio-demographic characteristics moderated the effect of communication strategy on outcomes to evaluate the extent to which the same communication strategies could be applied to multiple populations.

Methods

Data source

The study was conducted between November 11, 2015 and December 7, 2015 using GFK KnowledgePanel®, a probability-based Internet panel designed to be representative of the U.S. population. Potential panel participants are identified by a random selection of telephone numbers and residential addresses. Persons in selected households are invited to participate in KnowledgePanel®. For those who agree to participate but do not have Internet access, GFK provides at no cost a laptop and ISP connection. People who already have computers and Internet service participate using their own equipment.

GFK randomly selected a subsample of individuals from its English language database who met the age requirement (30–65 years old) and emailed them an invitation to participate. Those who agreed completed an online eligibility screener assessing their physical activity. Respondents who did not meet current guidelines for aerobic activity (i.e., at least 150 min per week of moderate intensity aerobic physical activity) were invited to complete the survey. Recruitment was stratified so that at least 50% of the sample had no more than vocational-technical training and at least 50% were racial/ethnic minorities.

Procedure and study conditions

Participants who consented completed a Pre-Intervention Questionnaire and read a short hypothetical scenario that described the purpose of a risk assessment tool and asked them to imagine that they had just entered their information into such a tool:

> Imagine you are looking for health information on the internet. You find a website that calculates your chances of getting different types of illnesses. The calculator is based on high-quality scientific studies. The calculator asks for information like your age, sex, height, weight, and family history of different diseases. There are also questions about your diet, physical activity, and smoking. You enter the information and the calculator shows you the following information. The picture on the next page shows your chances of getting colon cancer, heart disease, diabetes, and stroke in the next 10 years. Carefully look at the picture, think about how you would react, and then answer the questions that follow.

Participants were then randomly assigned to view one of 12 risk communication scenarios in a 2 (risk reduction information: present/absent) × 2 (numerical format: words/words and numbers) × 3 (social comparison information: none/somewhat higher than average/much higher than average[1]) full factorial experimental design. Participants viewed the hypothetical risk calculator results in which all four diseases (i.e., colon cancer, stroke, diabetes, heart disease) were placed at varying heights on a single vertical bar (i.e., "risk ladder") to indicate their respective probabilities (see Fig. 1 and Supplemental Material). After

[1] The original intent was to show participants either no social comparison information, information that they were at lower than average risk, or information that they were at higher than average risk. However, an error resulted in participants who should have been assigned to the lower than average condition instead being shown information that they were at somewhat higher than average risk. We collapsed the two higher than average conditions into 1 "higher than average" category, resulting in 2 social comparison conditions (i.e. absent/higher than average).

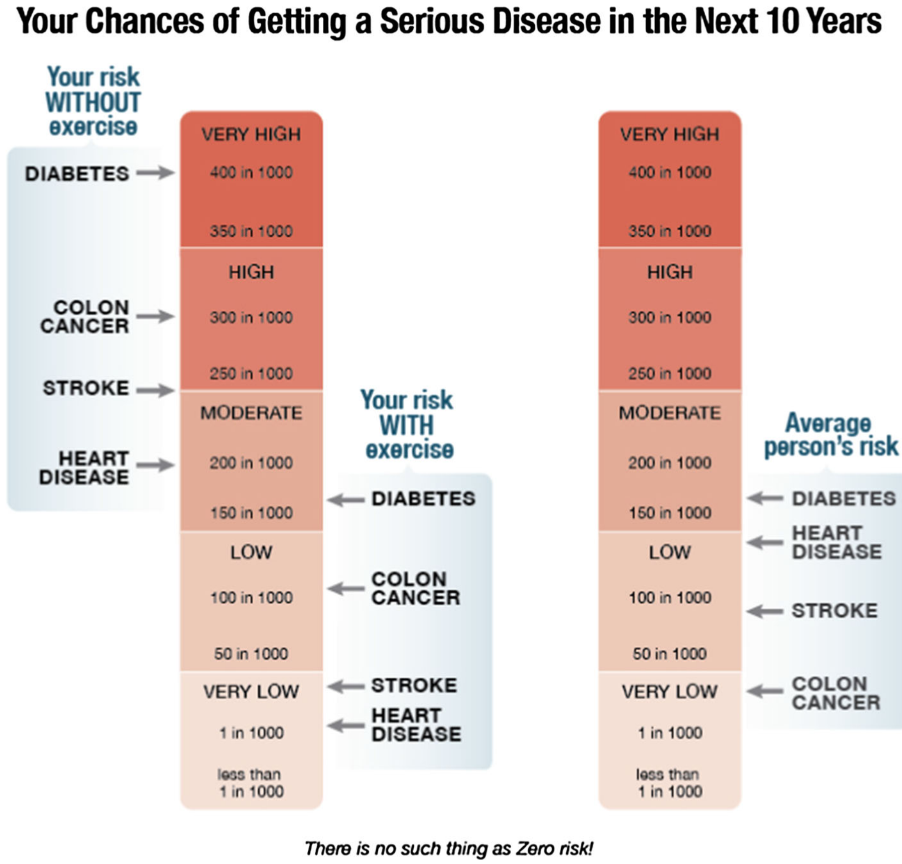

Fig. 1 Risk ladder including all three strategies (i.e., words + numbers, risk reduction information present, social comparison information present)

viewing the results, participants completed the Post-Intervention Questionnaire and the risk ladder was no longer viewable.

Risk ladders help people quickly derive meaning from complex information, can accommodate social comparison and risk reduction information, and are particularly useful for people with limited numeracy (Keller et al., 2009). The risk ladders were developed by a visual designer. Cognitive interviews (N = 10) (Willis, 2004) were conducted to develop, refine, and test the risk ladders, to ensure that the pre- and post-intervention surveys would take no more than 20 min on average to complete, that the questions were comprehensible and interpreted in a way consistent with their intended meaning, and that the response options were used appropriately. The study was approved by the Washington University in St. Louis Human Research Protection Office.

Measures

Most items were obtained from prior sources and, where necessary, adapted based on feedback from the cognitive interviews (see Table 1 for a full description of the items including Cronbach alphas). The Pre-Intervention Questionnaire assessed participants' physical activity behavior. The Post-Intervention Questionnaire assessed message comprehension (Tait et al., 2010), message acceptance (Brennan et al., 2011, supplemented by the 2 author-created items "clear" and "true" and excluding "relevance"), absolute and comparative cognitive perceived risk (National Cancer Institute, 2009), absolute and comparative feelings of risk (adapted from Janssen et al., 2010), response-efficacy (Schwarzer & Fuchs, 1995), worry (National Cancer Institute, 2009), anticipated regret (adapted from Weinstein et al., 2007), and intentions (Conner & Norman, 1995) To reduce participant burden, perceived risk, response-efficacy, intentions, worry, and anticipated regret were asked only twice instead of four times: once for colon cancer and once for "any of the diseases shown in the picture". We used 4-point unipolar scales for nearly all variables because there is relatively little statistical advantage of using longer scales (Sullivan & D'Agostino, 2003; Weinstein et al., 2007) and they are often more usable for participants than 5-point bipolar scales (Barlas & Thomas, 2017; Thomas & Barlas, 2017). The perceived risk and feelings of risk items included an additional "don't know" response option.

The Post-Intervention Questionnaire also assessed several background variables including perceived health status (National Cancer Institute, 2014), body mass index (BMI),

Table 1 Description of the measures

Pre-Intervention Questionnaire	
Physical activity behavior	Moderate intensity physical activities make you breathe harder than normal but you are not "out of breath." You will sweat a little and can have a conversation, but you cannot sing
	Examples of moderate intensity activities are:
	Walking quickly
	Dancing
	Vacuuming
	Mowing the lawn with a push mower
	Bicycling at a regular pace
	Regular physical activity means getting at least 30 min of moderate intensity activity on 5 days a week, or at least 2½ h per week
	In the last 7 days, how many days did you do any physical activity of at least moderate intensity? _____days;
	On the days that you did any physical activity of at least moderate intensity, for how long did you do these activities? _____minutes
Post-Intervention Questionnaire	
Comprehension	According to the picture you saw, how high is the risk of getting colon cancer? [1 = very low risk; 5 = very high risk; The picture didn't say]. Responses were dichotomized (correct [High] vs. incorrect [All others])
Cognitive risk perception	How likely do you think it is that you will get [colon cancer/sick from any of the diseases shown in the picture in the next 10 years], if you do not get regular physical activity? [1 = not likely; 4 = very likely; I don't know];
	Compared to other people your age and sex, how likely do you think it is that you will get [colon cancer/sick from any of the diseases shown in the picture] in the next 10 years, if you do not get regular physical activity? [1 = much less likely; 5 = much more likely; I don't know]
Feelings of risk	How much do you agree with the following statement: "I feel like I could easily get [colon cancer/sick from any of the diseases shown in the picture] in the next 10 years if I do not get regular physical activity [1 = do not agree; 4 = strongly agree; I don't know];
	Compared to other people your age and sex, how easily do you feel you could get [colon cancer/sick from any of the diseases shown in the picture] in the next 10 years if you do not get regular physical activity? [1 = much less easily; 5 = much more easily; I don't know]
Response-efficacy ($\alpha = 0.90$ for colon cancer; $\alpha = 0.91$ for other diseases)	Getting regular physical activity will reduce my chances of getting [colon cancer/sick from the diseases shown in the picture] [1 = do not agree; 4 = strongly agree];
	Getting regular physical activity is a good way for me to prevent [colon cancer/getting sick from the diseases shown in the picture] [1 = do not agree; 4 = strongly agree]
Intention ($\alpha = 0.91$)	I intend to get regular physical activity in the next 3 months [1 = do not agree; 4 = strongly agree];
	I want to get regular physical activity in the next 3 months [1 = do not agree; 4 = strongly agree];
	I am likely to get regular physical activity in the next 3 months [1 = do not agree; 4 = strongly agree]
Worry	How worried are you about getting [colon cancer/sick from any of the diseases shown in the picture?] [1 = not worried; 4 = very worried]
Anticipated regret ($\alpha = 0.93$ for colon cancer; $\alpha = 0.95$ for other diseases)	I would regret it if I got [colon cancer/if I got sick from the diseases shown in the picture] because I did not get regular physical activity [1 = do not agree; 4 = strongly agree];
	I would be mad at myself if I got [colon cancer/if I got sick from the diseases shown in the picture] because I did not get regular physical activity [1 = do not agree; 4 = strongly agree]
Message acceptance ($\alpha = 0.92$)	The information in the picture is [easy to understand/written clearly/seems like it could be true/is believable] [1 = do not agree; 4 = strongly agree];

Table 1 continued

Background variables[a]	
Perceived health status	In general, would you say your health is: …. [1 = excellent; 5 = poor]
Body mass index	About how tall are you without shoes? _____ feet and _____inches;
	About how much do you weigh? _____pounds
Numeracy	Imagine that we flip a fair coin 1000 times. What is your best guess about how many times the coin would come up heads in 1000 flips? _____ times;
	Imagine that the chance of getting a disease is 1%. If there were 1000 people, about how many would be expected to get the disease? _____ people
	All correct answers were summed for a possible range of 0–2
Graph literacy	The graph below shows the percentage of people who die from different types of cancer. About what percentage of people who die from cancer die from cancer B, cancer C, and cancer D combined? _____ %;
	The graph below shows the number of men and women with disease X. The total number of circles is 100. How many more men than women are there among 100 patients with disease X? _____ men;
	You see two magazine advertisements on separate pages. Each advertisement is for a different drug for treating heart disease. Each advertisement has a graph showing the effectiveness of the drug compared to a placebo (sugar pill). Compared to the placebo, which treatment leads to a larger decrease in the percentage of patients who die? [1 = Crosicol, 2 = Hertinol, 3 = They are equal, 4 = Can't say];
	You see two newspaper advertisements on separate pages. Each advertisement is for a different treatment of a skin disease. Each advertisement has a graph showing the effectiveness of the treatment over time. Which of the treatments shows a larger decrease in the percentage of sick patients? [1 = Apsoriatin, 2 = Nopsorian, 3 = They are equal, 4 = Can't say]
	All correct answers were summed for a possible range of 0–4

[a]GfK provided information about gender, age, education [1 = vocational technical training or less; 2 = education beyond vocational technical training], and racial/ethnic background [1 = non-white; 2 = white]

and the socio-demographic characteristics sex, age, education, racial background, numeracy (Lipkus et al., 2001; National Cancer Institute, 2014), and graph literacy (Galesic & Okan, 2013). Numeracy and graph literacy scores were created by summing all correct answers for the given scale.

Other psychosocial variables that were assessed included information seeking, knowledge about physical activity-related diseases (open-ended), interest in engaging in physical activity, attitudes about physical activity, perceived message effectiveness, present/future time orientation, defensive processing, and family history of colon cancer, stroke, diabetes, and heart disease. These questions were not included in the present analyses because they were outside the scope of the research question. The full questionnaire can be obtained from the corresponding author.

Statistical analysis

Descriptive statistics were examined to describe background variables. To examine the effect of the communication strategies on the outcome variables, $2 \times 2 \times 2$ factorial ANCOVAs and logistic regression analyses were conducted. Predictors were: risk reduction information (present/absent), numerical format (words/words + numbers), social comparison information (absent/higher than average), and all two-way and three-way interaction terms among the experimental variables. Education, race, numeracy, graph literacy, sex, perceived health status, and age (if related to the outcome variable) were included as covariates. Analyses were conducted using SPSS version 24.0 and statistical significance was defined as $p < .05$.

Results

Participant characteristics

A total of 1161 participants completed the questionnaire. The analytic dataset for this study included people who completed all items needed for the analyses and who completed the questionnaire within an acceptable time frame (i.e., between the 3rd and 97th percentiles, or

Table 2 Sample Characteristics (N = 835)

Socio-demographic characteristic	n (%)
Sex	
Men	365 (42.6)
Women	479 (57.4)
Education	
Vocational-technical training or less	387 (46.4)
More than vocational-technical training	448 (53.7)
Race	
Non-white	390 (46.7)
White	445 (53.3)
	M (SD)
Age	48.34 (10.22)
Numeracy[a]	1.29 (0.76)
Graph literacy[b]	2.18 (1.10)
BMI	29.89 (7.75)
Perceived health status[c]	3.10 (0.91)
Minutes physical activity per week	52.54 (44.98)

[a]Scores range from 0 (lowest level of numeracy) to 2 (highest level of numeracy)

[b]Scores range from 0 (lowest level of graph literacy) to 4 (highest level of graph literacy)

[c]Scores range from 0 (lowest level of perceived health) to 5 (highest level of perceived health)

7.00–7144.34 min). The median time to completion was 21 min. Characteristics of the final analytic sample (N = 835) are depicted in Table 2. Post hoc power analyses showed that the final analytic sample had 82% power to detect a small effect size of $\eta^2_P = 0.01$ with $\alpha = .05$, which was the largest effect size we report.

Main analyses (main effects and interactions among the three experimental variables)

See Table 3 for descriptive statistics of the outcome variables. The means for most of the items were in the approximate mid-point of the scale (i.e., between 2 and 3 on items with a range of 1–4).

There were few significant main effects of any of the experimental variables on any of the outcomes. As shown in Tables 4, 5 and 6, all the effect sizes were negligible ($\eta^2_P \leq .01$) and the mean difference between conditions was never greater than 0.16, even for the few significant effects identified. The small number of significant effects were primarily related to message acceptance and perceived risk. Specifically, a significant main effect of risk reduction information was found on message acceptance ($F(1, 821) = 6.24$, $p = .01$, $\eta^2_P = .01$). Message acceptance was slightly higher among people who received risk reduction information (M = 3.04, SE = 0.04) than among those who did not (M = 2.92, SE = 0.04). There was also a significant main effect of social comparison information on message acceptance ($F(1, 821) = 4.61$, $p = .03$, $\eta^2_P = .01$), in which message acceptance was slightly higher among people who did not receive social comparison information (M = 3.03, SE = 0.04) than among those told that they were at higher than average risk (M = 2.92, SE = 0.03). Moreover, a significant main effect of social comparison information was found for absolute cognitive perceived risk of developing "any of the diseases shown in the picture" ($F(1, 711) = 4.95$, $p = .03$, $\eta^2_P = .01$). Perceived risk of any diseases were slightly higher among people who did not receive social comparison information (M = 2.65, SE = 0.06) than among those told that they were at higher than average risk (M = 2.49, SE = 0.04).

Of 68 possible 2-way and 3-way interactions among the experimental variables on the outcome variables, only two were statistically significant, and only for items assessing colon cancer beliefs. Social comparison and numerical format interacted to affect both absolute and comparative cognitive perceived risk of colon cancer ($F(1, 618) = 7.23$, $p = .01$, $\eta^2_P = .01$ and $F(1, 662) = 4.96$, $p = .03$, $\eta^2_P = .01$ for absolute and comparative, respectively). Simple effects analyses revealed that, in the absence of social comparison information, adding numbers significantly decreased cognitive absolute perceived risk (M = 2.05, SD = 0.92 versus M = 2.35, SD = 0.99 for numbers and no numbers respectively) and had no effect on cognitive comparative perceived risk. However, in the presence of social comparison information, adding numbers had no effect on cognitive absolute perceived risk but it significantly increased cognitive comparative perceived risk (M = 3.23, SD = 1.00 vs. M = 2.99, SD = 1.01 for numbers and no numbers respectively).

Sensitivity analyses

We conducted two sets of sensitivity analyses. First, we restricted the sample to those who completed the study in 10–45 min, which was consistent with the time it took our cognitive interview participants to complete the study in person. Second, we expanded our sample to include individuals who indicated uncertainty about their risk by answering "don't know" to items assessing perceived risk of disease. These individuals are more likely to be members of socio-demographically vulnerable populations, may have unique communication needs, and, therefore, should be identified and included in all health communication intervention development activities (Hay et al., 2015; Waters et al., 2013). The results of the sensitivity analyses did not differ substantially from the main findings and did not alter our conclusions about the (non)effects of the experimental variables on study outcomes (see Supplemental Material).

Moderating effects of socio-demographic characteristics

We wanted to ensure that the communication strategy or strategies that we chose to incorporate into the personalized risk assessment tool were also understandable by individuals from underserved socio-demographic groups. However, we first needed to identify the overall strategy that would be implemented in the actual tool. We chose to include risk reduction information, exclude numbers, and exclude social comparison information (see Fig. 2). This decision was based on the following reasons: (1) the few potentially beneficial main effects from our data were limited to providing risk reduction information, (2) to enable behavior change people need information about how changing behavior can reduce their risk (Witte, 1992), (3) many people have difficulties understanding numerical information (e.g., Lipkus, 2007; Lipkus et al., 2001; Peters et al., 2007), (4) the benefits of numerical information are often seen in the context of complex medical treatment decisions (Peters et al., 2014), but simply alerting people that they may be personally vulnerable to a hazard does not necessarily require numerical information (Zikmund-Fisher, 2013), (5) findings related to the benefits of social

Table 3 Descriptive statistics of outcome variables (N = 835)

Outcome variable	n (%)
Comprehension	
Correct	465 (55.7)
Incorrect	370 (44.3)
	M (SD)
Message acceptance[a]	2.96 (0.69)
Response-efficacy colon cancer[a]	2.29 (0.78)
Response-efficacy any disease[a]	2.94 (0.75)
Cognitive perceived absolute risk colon cancer[a]	2.07 (0.94)
Cognitive perceived absolute risk any disease[a]	2.54 (0.93)
Cognitive perceived comparative risk colon cancer[b]	3.15 (1.01)
Cognitive perceived comparative risk any disease[b]	3.28 (0.96)
Feelings of absolute risk colon cancer[a]	2.10 (0.91)
Feelings of absolute risk any disease[a]	2.49 (0.89)
Feelings of comparative risk colon cancer[b]	3.12 (0.96)
Feelings of comparative risk any disease[b]	3.26 (0.94)
Worry colon cancer[a]	1.78 (0.87)
Worry any disease[a]	2.15 (0.90)
Anticipated regret colon cancer[a]	2.82 (0.95)
Anticipated regret any disease[a]	2.86 (0.92)
Intention[a]	2.83 (0.77)

[a]Scores range from 1 (lowest levels of message acceptance, response-efficacy, risk perception, worry, anticipated regret, and intention) to 4 (highest levels of message acceptance, response-efficacy, risk perception, worry, anticipated regret, and intention)

[b]Scores range from 1 (lowest level of risk perception) to 5 (highest level of risk perception)

Table 4 Main effects of risk reduction information (N = 835)

Outcomes	Risk reduction information				
	OR[a]	*p*		95% CI lower	95% CI upper
Message Comprehension	0.42	.60		0.02	11.02
	F	*p*	η_P^2	M(SE) info present	M(SE) info absent
Message acceptance	6.24	.01	.01	3.04 (0.04)	2.92 (0.04)
Response-efficacy colon cancer	2.06	.15	.00	2.74 (0.04)	2.66 (0.04)
Response-efficacy any disease	0.58	.45	.00	2.97 (0.04)	2.92 (0.04)
Cognitive absolute colon cancer risk	3.83	.05	.01	2.18 (0.05)	2.03 (0.06)
Cognitive absolute any disease risk	1.32	.25	.00	2.61 (0.05)	2.52 (0.05)
Feelings of absolute risk colon cancer	1.12	.29	.00	2.14 (0.05)	2.07 (0.05)
Feelings of absolute risk any disease	2.25	.13	.00	2.56 (0.05)	2.46 (0.05)
Cognitive comparative colon cancer risk	0.54	.46	.00	3.19 (0.06)	3.13 (0.06)
Cognitive comparative any disease risk	0.52	.47	.00	3.32 (0.05)	3.27 (0.05)
Feelings of comparative risk colon cancer	0.11	.74	.00	3.14 (0.05)	3.11 (0.05)
Feelings of comparative risk any disease	2.73	.10	.00	3.33 (0.05)	3.22 (0.05)
Worry colon cancer	1.09	.30	.00	1.82 (0.04)	1.76 (0.04)
Worry any disease	2.25	.13	.00	2.20 (0.05)	2.10 (0.05)
Anticipated regret colon cancer	0.76	.38	.00	2.85 (0.05)	2.79 (0.05)
Anticipated regret any disease	2.75	.10	.00	2.92 (0.05)	2.81 (0.05)
Intention	0.64	.42	.00	2.85 (0.04)	2.80 (0.04)

[a]OR < 1 indicates that people who saw risk reduction information had lower odds of answering correctly

Table 5 Main effects of numerical format (N = 835)

Outcomes	Numerical format				
	OR[a]	*p*		95% CI lower	95% CI upper
Message comprehension	0.09	.14		0.00	2.24
	F	*p*	η_P^2	M(SE) words only	M(SE) words + numbers
Message acceptance	2.07	.15	.00	3.01 (0.04)	2.94 (0.04)
Response-efficacy colon cancer	0.08	.78	.00	2.69 (0.04)	2.71 (0.04)
Response-efficacy any disease	0.07	.79	.00	2.94 (0.04)	2.95 (0.04)
Cognitive absolute colon cancer risk	1.71	.19	.00	2.15 (0.06)	2.05 (0.05)
Cognitive absolute any disease risk	0.41	.52	.00	2.54 (0.05)	2.59 (0.05)
Feelings of absolute risk colon cancer	0.03	.86	.00	2.11 (0.05)	2.10 (0.05)
Feelings of absolute risk any disease	0.51	.47	.00	2.48 (0.05)	2.53 (0.05)
Cognitive comparative colon cancer risk	0.43	.51	.00	3.14 (0.06)	3.19 (0.06)
Cognitive comparative any disease risk	1.04	.31	.00	3.26 (0.05)	3.33 (0.05)
Feelings of comparative risk colon cancer	0.12	.73	.00	3.11 (0.05	3.14 (0.05)
Feelings of comparative risk any disease	0.41	.52	.00	3.30 (0.05)	3.25 (0.05)
Worry colon cancer	0.34	.56	.00	1.77 (0.04)	1.81 (0.04)
Worry any disease	0.87	.35	.00	2.12 (0.05)	2.18 (0.05)
Anticipated regret colon	0.92	.34	.00	2.79 (0.05)	2.85 (0.05)
Anticipated regret any disease	2.19	.14	.00	2.82 (0.05)	2.91 (0.05)
Intention	1.59	.21	.002	2.79 (0.04)	2.86 (0.04)

[a]OR < 1 indicates that people who saw numerical information had lower odds of answering correctly

Table 6 Main effects of social comparison information (N = 835)

Outcomes	Social comparison information				
	OR[a]	P		95% CI lower	95% CI upper
Message comprehension	0.26	.38		0.01	5.37
	F	p	η_P^2	M(SE) info present	M(SE) info absent
Message acceptance	4.61	.03	.01	2.92 (0.03)	3.03 (0.04)
Response-efficacy colon cancer	0.46	.50	.00	2.68 (0.03)	2.72 (0.05)
Response-efficacy any disease	0.19	.66	.00	2.93 (0.03)	2.96 (0.04)
Cognitive absolute colon cancer risk	4.59	.03[b]	.01	2.02 (0.05)	2.18 (0.06)
Cognitive absolute any disease risk	4.95	.03	.01	2.49 (0.04)	2.65 (0.06)
Feelings of absolute risk colon cancer	1.25	.26	.00	2.07 (0.04)	2.15 (0.06)
Feelings of absolute risk any disease	3.27	.07	.00	2.45 (0.04)	2.57 (0.06)
Cognitive comparative colon cancer risk	1.78	.18	.00	3.11 (0.05)	3.22 (0.07)
Cognitive comparative any disease risk	0.60	.44	.00	3.27 (0.04)	3.32 (0.06)
Feelings of comparative risk colon cancer	0.07	.78	.00	3.11 (0.05)	3.13 (0.06)
Feelings of comparative risk any disease	2.14	.14	.00	3.22 (0.04)	3.33 (0.06)
Worry colon cancer	0.71	.40	.00	1.77 (0.04)	1.82 (0.05)
Worry any disease	0.34	.56	.00	2.13 (0.04)	2.17 (0.05)
Anticipated regret colon cancer	0.03	.86	.00	2.81 (0.04)	2.83 (0.06)
Anticipated regret any disease	0.05	.81	.00	2.86 (0.04)	2.87 (0.05)
Intention	0.01	.92	.00	2.83 (0.03)	2.82 (0.04)

[a]OR < 1 indicates that people who saw social comparison information had lower odds of answering correctly

[b]This significant main effect occurred in a model in which social comparison information interacted with numerical format, we therefore do not describe its effects

comparison information both from the existing literature (French et al., 2004; Harris & Smith, 2005) and the data from this study were mixed at best, and 6) the sensitivity analyses did not yield data suggesting that a different combination of risk communication strategies would be superior.

Next, we explored whether the relationship between the selected strategy and the outcomes differed by socio-demographic characteristics by creating a dichotomous variable in which one category included the selected strategy and the other category included all other strategies combined. Then, interactions between this new variable and potential socio-demographic moderators (i.e., race, education, numeracy, graph literacy) were examined for each outcome variable. Of 68 possible effects, only 3 were statistically significant. One significant interaction was found between the selected strategy and graph literacy to affect response-efficacy towards colon cancer (F (1, 823) = 5.21, $p = .02$, and two significant interactions were found between the selected strategy and education to affect worry towards colon cancer (F (1, 823) = 4.27, $p = .04$) and worry towards other diseases (F (1, 823) = 4.34, $p = .04$). However, the follow-up simple effect analyses were not significant and therefore we do not describe them further. Based on the very small proportion of significant interactions, all of which produced non-significant follow-up simple effects analyses, we concluded that the effects of the selected strategy were likely similar for people from various socio-demographic backgrounds (see supplemental material for similar findings regarding "don't know" responses to risk perception items).

Discussion

We investigated the unique and combined effects of three risk communication strategies (i.e., risk reduction information, numerical format, and social comparison information) to simultaneously convey the risks of 4 chronic diseases associated with physical inactivity. Direct effects were only found for message acceptance and absolute cognitive perceived risk of developing "any of the diseases shown in the picture". Message acceptance was slightly higher for people who received risk reduction information and for people who did not receive social comparison information indicating they were at higher or much higher

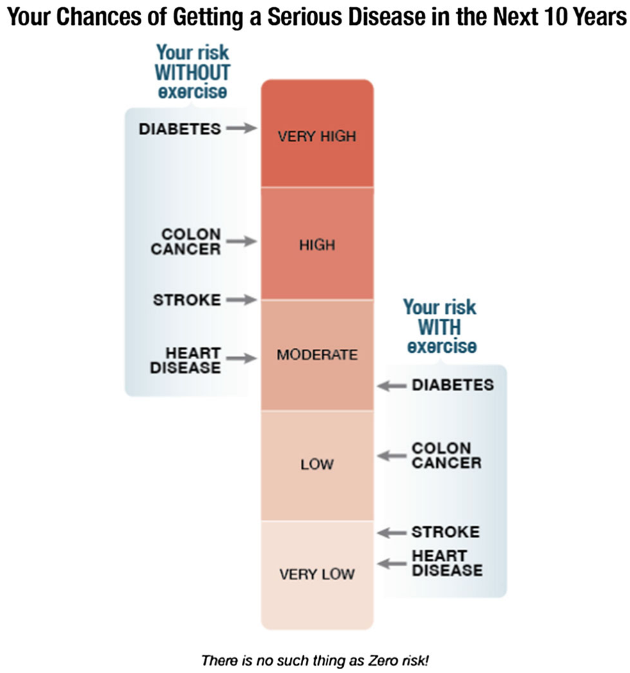

Fig. 2 Risk ladder including risk reduction information and excluding numbers and social comparison information

than average risk. Moreover, risk perception was slightly higher among people who had not received social comparison information. None of the three risk communication strategies directly influenced message comprehension, other cognitive risk beliefs, affective risk beliefs, response efficacy, or intentions. As illustrated by the very large number of non-significant interactions, combining the three strategies had virtually no effect on any of the outcomes, suggesting that a simpler and more parsimonious communication approach might be acceptable when communicating risk estimates of multiple diseases.

These results contrast with research suggesting these individual strategies might be helpful (Dillard et al., 2011; Fagerlin et al., 2007; Klein, 2002; Peters et al., 2014; Sinayev et al., 2015; Weinstein et al., 1998). One possible reason for the differences between this study and prior research could be that the highly comprehensible nature of the risk ladder, particularly for people with limited numeracy (Keller et al., 2009; Lipkus, 2007), overwhelmed the effects of the other communication strategies. In other words, any benefit conferred by the communication strategies tested in this study might have been less relevant and impactful in the context of this potentially powerful way of visualizing multiple disease risks while simultaneously limiting the amount of text to read. This hypothesis—that null effects of the communication strategies we tested would *not* be found in the absence of a risk ladder—needs to be tested in a study that directly compares the effect of including versus excluding a risk ladder. Such a finding would be consistent with research showing that providing a graphical display can increase accuracy and reduce biased reasoning when evaluating hypothetical medical scenarios (Fagerlin et al., 2005; Garcia-Retamero & Cokely, 2013; Waters et al., 2006).)

The lack of effects of communication format on affective variables, including feelings of risk, may be because the three formats that we directly evaluated were relatively affectively pallid in comparison with communication strategies that are more strongly affectively-laden. For example, research has shown that narrative information (Janssen et al., 2012; McQueen et al., 2011) and graphic visual elements [e.g., pictures of diseased tissue (Evans et al., 2015)] elicit strong affective responses. Supplementing the risk ladder with elements that are specifically designed to elicit affective responses may produce different findings than we report here.

The large number of null effects for the risk communication strategies could also be because the hypothetical nature of the task reduced the study's ecological validity for participants, who in turn attended less carefully to the items. However, many risk communication studies use hypothetical scenarios (e.g., Fagerlin et al., 2007; Harris & Smith, 2005), so it is unlikely that our findings are due solely to this issue. In addition, sensitivity analyses that restricted the dataset to those who completed the study in 10–45 min did not yield meaningfully different results. It is also possible that, by providing four disease risks instead of one, it was either more difficult for participants to imagine receiving the results or it provided them more opportunities to think about how the risk information would not apply to them, which resulted in null effects between groups. Because this is the first study investigating the effectiveness of combining risk communication strategies to communicate multiple disease risks instead of the risk of a single disease, and participants were asked to imagine a hypothetical situation, replication of these findings is warranted in a study that provides non-hypothetical personalized risk information.

Differences in sample characteristics may also explain the differences between our study and prior research. Although we did not find that race, education, numeracy, or graph literacy moderated the effect of the selected strategy on the outcomes (i.e., the effects of the selected strategy were similar for vulnerable and non-vulnerable groups), it is possible that the samples differed in some other unmeasured way. For example, perhaps our sample had more comorbidities than other research that recruited samples that were more highly educated and less racially diverse (French et al., 2004; Klein, 2002; Peters et al., 2007, 2014; Windschitl et al., 2002; Zikmund-Fisher et al., 2010). If this is the case, the information in our study may have been more salient and relevant to our study sample, which may have resulted in people from underserved backgrounds devoting more attention to the information and effort in processing it, which in turn resulted in negligible differences in responses based on communication strategy.

It is also possible, given our large sample size and the negligible effect sizes, that the findings represent genuine null effects. If this is the case, this study could be a valuable datapoint for future meta-analyses.

Strengths, limitations, and future directions

This was the first study to investigate the effects of combining risk communication strategies to communicate multiple disease risks instead of the risk of a single disease. Very few lifestyle behaviors affect the risk of only one disease, so determining how best to communicate the relationship between a single behavior and the risk for multiple diseases is important. In the next phase of our research, we will incorporate the results of this research into a fully functional, smartphone based risk assessment tool that also includes a self-regulation intervention and examine its efficacy in increasing actual physical activity behavior (in accordance with HAPA; Schwarzer, 2001). Future research should also examine whether providing information about the risk of multiple diseases is more motivating than providing information about the risk of only one disease. This study also included a sample comprised of a large proportion of individuals who were from minority racial and ethnic backgrounds, who had relatively limited formal education, and who had low health and graph literacy. Yet, the effects of the selected strategy generally did not seem to vary between groups. This finding increases confidence that our results are generalizable to people from diverse socio-demographic backgrounds.

Nevertheless, our results should be considered in light of the following limitations. First, numerical format had only 2 conditions: words versus words plus numbers. Therefore, we were not able to investigate the effects of quantitative descriptors exclusively. However, since our study was conducted within a persuasive context (i.e., convincing people of the beneficial health effects of physical activity) instead of an informed decision making context, solely providing numbers was considered to be less meaningful and beneficial (Brewer, 2011; Zikmund-Fisher, 2013). Second, due to an error during development, the social comparison condition did not provide hypothetical "lower than average risk" information. Consequently, findings are limited to a comparison of none, much higher risk or somewhat higher than average risk information. Third, some constructs were measured with single items. Although multi-item measurement might improve the reliability of these constructs (but see Weinstein et al., 2007), experimental evidence suggests that longer questionnaires reduce data quality (Galesic & Bosnjak, 2009). Therefore, we limited the number of survey questions by adapting single measures used in nationally representative surveys and in published empirical research. Moreover, the response scales for the perceived absolute and comparative risk items were not counterbalanced (i.e., 4 point scales were used for absolute questions and 5 point scales for comparative questions). As it might be difficult for people to switch between scales especially for similar constructs, using similar scales may benefit the reliability of these constructs. However, there were very few significant effects for the perceived risk items, and so it is difficult to determine the extent to which this was a problem. Finally, this study did not have a true control group that compared the effectiveness of the risk ladder to text only. Our future research will examine this key issue.

Conclusion

To the best of our knowledge, no other large-scale empirical studies have investigated the use of a risk ladder to communicate risk information about four common diseases simultaneously. By systematically testing the importance of several aspects of risk perception, we obtained necessary information about the unique and combined effects of each component. We conclude that it might not be necessary to provide people with highly detailed information when communicating risk estimates of multiple diseases. These insights could advance the science of disease prevention by facilitating the translation of basic epidemiological risk prediction research to public health impact via improved health risk communication.

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Compliance with ethical standards

Conflict of interest Eva Janssen, Robert A. C. Ruiter, and Erika A. Waters declare that they have no conflicts of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

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