The Invisible Danger of Bunker Gear Transfer: A Theory-Based Intervention to Increase Post-Fire Decontamination to Reduce Cancer Risk in Firefighters

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Abstract

Studies show significant association between cancer risk and being a firefighter. Firefighter bunker gear often contains carcinogens that firefighters may absorb through contact or inhale through off-gassing, thereby increasing cancer risk. Awareness of increased cancer risk has given rise to policies and practices focused on gear cleaning and decontamination processes to decrease risk, yet these efforts are in their infancy and tend to be somewhat piecemeal in nature. This study presents a theory-based communication intervention tailored to the unique context of a high reliability organization (HROs). The intervention focused on increasing post-fire decontamination behaviors to reduce exposure to carcinogens among firefighters. Results of the intervention across nine fire stations show significant increases in attitudes, norms, self-efficacy, and response-efficacy, decreases in perceived barriers, and increased intention to engage in decontamination processes. The results of this study provide valuable evidence for utilizing theoretical elements in message design for interventions in HROs.

Key words: cancer, firefighters, Integrated Model of Behavioral Prediction, EPPM, communication design, high reliability organizations

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Firefighters are at increased risk of developing cancer compared to the general public. Results of meta-analysis reveal a 1.2 to 2.0 increased risk for certain types of cancer among firefighters compared to the general public (LeMasters et al., 2001). Additionally, studies that examine female firefighter cancer risk have demonstrated up to 6 times the risk of certain reproductive cancers compared to the general public (Fangchao, et al., 2006). Overall, firefighters appear to be at about a 14% increased lifetime cancer risk compared to the general public (NIOSH, 2016). Research shows that both seasoned firefighters (Anderson, Harrison, Yang, Wendorf Muhamad, & Morgan, 2017) and new recruits (Solle, et al. under review) are extremely concerned about cancer risk.

One key area of firefighter exposure to carcinogens is through firefighter bunker gear (the gear worn to fight fires, including pants, jacket, boots, gloves, and hood). Bunker gear gets exposed to contaminants in two primary ways – diesel exhaust from rescue trucks and fire engines while at the station (firefighters often store bunker gear in open lockers near the exhaust of rescue trucks and engines) and from on-scene exposures at fires and on rescue calls. While the primary purpose of bunker gear is to protect firefighters from fire, recent research has focused on carcinogens and toxins on bunker gear (Alexander & Baxter, 2014; Fent et al., 2014; 2015). Alexander and Baxter (2014) swabbed bunker gear from one station, and each piece of gear tested positive for at least one carcinogen (22 different carcinogens total). In addition, every piece of gear tested positive for DEHP (a known carcinogen in mice and a probable human carcinogen) at levels of 52 – 875 times higher than the PAHs (another known carcinogen found on bunker gear) present on the gear. Fent and colleagues' (2014) study consisted of two series of three controlled burns with firefighters in full gear, complete with self-contained breathing apparatus (SCBA), and had them move 30 meters away from the fire before doffing their gear (typical of ideal normal procedure). Firefighters in this study had elevated levels of volatile organic compounds (VOCs) in both breath and urine, demonstrating that exposure to carcinogens is likely occurring through the inhalation from off-gassing when gear is doffed (toxins on the gear becoming aerosolized and inhaled) and through absorption through the skin from contact with dirty gear or from incomplete protection of the skin from the gear. Fent and colleagues' (2015) follow up study of off-gassing leads the authors to conclude that decontamination processes that clean both gear and skin would help reduce carcinogenic exposures, and thus, reduce cancer risk.

A recent qualitative study suggests that a combination of firefighter culture, occupational practice, and structural influences contributes to the risk of carcinogenic contamination, with dirty or contaminated bunker gear as one of the major areas of concern (Harrison, et al. 2017). Cultural artifacts that highlight firefighters as masculine, rugged, and reliable are central to firefighter culture (Thurnell-Read & Parker, 2008). Dirty bunker gear is one historically important cultural artifact that firefighters used to demonstrated expertise and reliability (Harrison, et al. 2017), which is one of the key elements necessary to gain trust in high reliability organizations (HROs: Myers, 2005). Additionally, Maglio et al. (2016) show that firefighters are influenced by their peers in the use of personal protective equipment (PPE). Promisingly, though, culture in at least one fire department is changing, with the majority of firefighters recognizing the risks of dirty gear, and that norms and culture are changing to support clean gear (Harrison, et al. 2017).

The increase in perceptions of cancer risk in the fire service has given rise to policies and practices designed to decrease risk, but these efforts are in their infancy, and tend to be somewhat piecemeal in nature. For example, Boston Fire Department has taken steps to encourage cleaning bunker gear using an extractor (commercial grade washing machine designed for use on bunker gear) showering, and exercising

within 24 hours of a structure fire, but their process does not include on scene decontamination of gear (Cancer Prevention in the Boston Fire Department, 2016). While these efforts are expanding, there has been no evaluation of how firefighters respond to these new policies or the effectiveness of the messages used to convince firefighters the need to engage in decontamination practices to reduce cancer risk. Additionally, while attitudes and policies toward decontamination are improving, there are barriers to decontamination and regular cleaning that many new policies may or may not specifically address, including a lack of knowledge of the best ways to clean gear, lack of resources, time, concerns over efficacy, perceived norms, and concerns about how cleaning processes impact firefighters' ability to perform their jobs (Harrison, et al. 2017).

These findings suggest the need for a theory-based communication intervention and evaluation designed to increase decontamination behaviors to reduce exposure to carcinogens.

Health Campaigns in HROs (High Reliability Organizations)

Organizations are key sites of health interventions (Harrison & Williams, 2016), but to date there are few studies designed to address health promotion/prevention issues in HROs. HROs in general, and firefighters in particular, have distinct characteristics compared to many other types of organizations, including 24 or 48 hour shifts where they live with other firefighters, inherent risk from fighting fires, and a reliance on trust (e.g. Banes, 2014; Myers, 2005). Harrison and colleagues (2011; Harrison, 2016) argue that organizations have unique physical, social, and information structures influence message effectiveness in health campaigns, and campaign in HROs need to be tailored to their unique characteristics. One key example of health promotion that has utilized unique elements of firefighter culture successfully is PHLAME (Promoting Healthy Lifestyles: Alternative Models' Effects) approach (Elliot et al. 2007; Moe et al., 2002). The PHLAME studies focus on fitness and diet and used a team based intervention (drawing on the unique nature of firefighting structure and culture) or individualized motivational interviewing to promote diet and physical activity. They found both approaches were effective, but that the team based approach provided more social support for both diet and physical activity (Elliot et al., 2007), lending support to the importance of peer support and organizational norms. Similarly work by Staley, Weiner, and Linnan, (2011) suggests that intrapersonal, interpersonal, and organizational factors influence physical activity, with peer support and organizational policy playing key roles in increased exercise. Overall, these studies point to the importance of designing interventions suited specifically to the unique characteristics of the fire service, an approach advocated by Harrison (2014).

The findings of previous qualitative research (Harrison, et al. 2017) provides insight into designing a cancer risk reduction intervention for the fire service. The findings of the research map nicely onto the Integrated Model of Behavioral Prediction (IMBP; Fishbein, 2000; 2008) and elements of both the Health Belief Model (HBM; Rosenstock, 1974; Carpenter, 2010) and the Extended Parallel Process Model (EPPM; Witte, 1994), and are further discussed below. Thus, the IMBP, along with the key theoretical components from HBM and EPPM, was adopted as the theoretical framework for designing and evaluating this intervention for reducing cancer risk among firefighters.

Integrated Model of Behavioral Prediction

The Integrated Model of Behavioral Prediction (IMBP; Fishbein, 2000, 2008) assumes that human beings are rational actors who process information and the corresponding underlying rationale to determine motivation for performing a certain behavior. IMBP draws from the Theory of Reasoned Action (TRA; Fishbein & Ajzen, 1975) and the Theory of Planned Behavior (TPB; Ajzen, 1985). TRA models individual attitude and subjective norms as the two predictors of behavioral intention (Ajzen & Fishbein, 2000). TPB introduces perceived behavioral control over behavioral performance as an additional

cognitive construct that can significantly predict one's behavioral intention. Thus, according to IMBP, there are three determinants that could significantly predict behavioral intention: attitude, perceived norm, and self-efficacy. Attitude refers to the evaluation of how favorable or unfavorable the enacting of a certain behavior would be. Attitude toward performing a certain behavior will be determined by specific beliefs about the outcomes of performing the behavior (outcome beliefs) and the corresponding valence of the evaluations of these outcomes. The more a person believes a certain behavior will lead to positive outcomes and the outcomes are good/favorable, the more possibilities that he or she will perform that behavior. Historically, firefighters had positive attitudes toward dirty gear, but those attitudes are starting to shift, largely as a result of perceived cancer risk (Authors, *in press b*). Perceived norms refer to perceptions of the extent to which important social network members perform this behavior themselves and the extent to which they would approve of the individuals own performance of this behavior. The stronger the perceived norm is, the stronger the behavioral intention is. Norms are likely to be especially important in influence behavior in HROs, with their cultural emphasis on trust and reliability, as can be seen in Myers (2005) account of the socialization process of new recruits and Maglio et al. (2016) finding on peer pressure and firefighter use of PPE. Findings from interventions on diet and exercise in the fire service further support the importance of peer support (e.g. Elliot et al. 2007; Staley, 2011). Self-efficacy is the perceived capability of performing a behavior, and it is a function of efficacy beliefs and perceived control, which refers to the extent to which various environmental factors make it easy or difficult to carry out the behavior. Firefighters in the formative research (Harrison, et al. 2017) identified barriers in both policy and practice toward decontamination processes which decreased perceptions of self efficacy. Ultimately, IMBP argues that attitudes, perceived norm, and self-efficacy jointly determine the strength of intention to perform a certain behavior, and this behavioral intention is the single strongest factor in predicting actual behavior (Ajzen & Fishbein, 2000; Yzer, 2012). Thus, the following hypotheses were proposed:

H1: Firefighter's attitude toward gear cleaning will increase significantly after the intervention.
H2: Firefighter's perceived norms toward gear cleaning will increase significantly after the intervention.
H3: Firefighter's self-efficacy toward gear cleaning will increase significantly after the intervention.
H4: Firefighter's behavioral intention toward gear cleaning will increase significantly after the intervention.

Extended Parallel Process Model and Health Belief Model

In addition, IMBP suggests formative research needs to account for other key variables related to behavior change. While previous research (Authors, *in press b*) suggests that firefighters feel very susceptible to cancer risk, and have high perceptions of cancer severity, it is unclear how they view the risk from dirty/contaminated turnout gear, or whether they see benefits of cleaning their gear. Additionally, significant actual and perceived barriers to decontamination are likely to influence behavior. While the IMBP places many of these issues as background variables that indirectly influence behavior (Yzer, 2012), many of the variables identified by Authors (*in press b*) fit well with the extended parallel process model (EPPM, Witte, 1994) and the health belief model (HBM, Rosenstock, 1974), and with the unique nature of HROs. As such, they are worth investigating as direct predictors. EPPM (Witte, 1994) and HBM (Rosenstock, 1974) both contain perceived susceptibility and perceived severity as part of their models of behavior prediction. HBM further focuses on perceived benefits, barriers, and cues to action,

while EPPM relies on self-efficacy (in line with IMBP) and response-efficacy as key predictors of behavior change.

EPPM suggests that severity and susceptibility have to be high enough to arouse fear, but not so high that they invoke a fear control response (Witte, 1994). Previous research reports that firefighters have very high perceived susceptibility to cancer, many to an almost fatalistic degree (Authors, *in press a; b*). As such, presenting a realistic understanding of cancer risk and susceptibility may reduce the risk of fear control and enhance a danger control response. Additionally, perceived severity is already extremely high; most firefighters know at least one firefighter who has died of cancer. As such, the intervention does not seek to increase perceived severity. However, given historical beliefs about dirty gear, susceptibility to contamination from dirty gear needs to be addressed. Additionally, given the occupational demands of firefighters, barriers and benefits (HBM; Rosenstock, 1994) and response efficacy (EPPM; Witte, 1994) will likely influence behavior. Thus, the following hypotheses were proposed:

H5: Firefighter's perception of cancer risk will decrease significantly after the intervention.
H6: Firefighter's perceived severity of cancer will remain constant after the intervention.
H7: Firefighter's perceived susceptibility of cancer will decrease significantly after the intervention.
H8: Firefighter's perceived threat of cross-contamination will increase significantly after the intervention.
H9: Firefighter's response-efficacy toward gear cleaning will increase significantly after the intervention.
H10: Firefighter's perceived benefits of gear cleaning will increase significantly after the intervention.
H11: Firefighter's perceived barriers to decontamination will decrease significantly after the intervention.

While the IMBP (Yzer, 2012) predicts that attitudes, norms, and self-efficacy will be the primary predictors of behavior change, the unique characteristics of HROs identified in the previous research provides a unique context to test these predictions, especially as we are also measuring key variables from EPPM (Witte,1996) and HBM (Rosenstock, 1974). As such, we ask the following research questions:

RQ1: What variables predict current decontamination behavior?
RQ2: What variables predict changes in behavioral intent?

Methods

Participants

One battalion (141 firefighters) from Palm Beach County Fire Rescue were asked to participate in our study. The battalion is composed of 9 stations with three 24-hour shifts (A, B, and C) per station. Each station has approximately 6 firefighters on duty (3 on rescue truck and three on fire engines) at any given time, with some stations have additional administrative personnel or extra trucks, depending on the size of the station. Overall, we had a 93% completion rate within the battalion (n= 130), with 4 firefighters choosing not complete the research. Additionally, two rescue trucks (6 firefighters) were unable to participate as they were on rescue calls and missed either pre- or post-test elements of the intervention; their data were not used in analysis.

The participants of the intervention ranged in age from 19 – 60 years old (M = 41.2, SD = 9.2). Females made up 9.2% (n = 12) of participants. Eighteen (13.8%) participants consider themselves

Hispanic or Latino, 88.5% white, 5.4% black, 1.5% American Indian, 0.8% Asian, and 1.5% Native Hawaiian or Pacific Islander. Most had some college (n = 76, 58.5%) or a college degree (n = 41, 31.5%).

Design of Intervention Messages and Materials

Messages were designed based on formative research focusing on key variables of the theoretical models. We used the approach advocated by Yzer (2012) of conducting formative research to identify key environmental, cultural, and personal variables that influence performance of the desired action. Formative research included 150+ hours of ride-alongs in 15 different fire stations in PBCFR, four focus groups with firefighters of different ranks, and multiple meetings with key informants in PBCFR (see Anderson et al. 2017, and Harrison, et. Al, 2017 for more detail). This approach to formative research allowed us to use principals of communication design to situate the messages and interventions to this specific site of interaction (Harrison, 2014). All materials were created in collaboration with researchers and firefighters, and focus group tested with firefighters prior to implementation.

There were six primary elements to the intervention. First, there was discussion of firefighters and cancer, and identification of accurate firefighter risk. These messages were designed to provide more realistic information on cancer risk and susceptibility (to help correct the overly fatalistic views held by many firefighters (Anderson, et al., 2017; Harrison, et al., 2017).

Second, messages included discussion of firefighter culture as it pertains to dirty gear and high reliability organizations, with an emphasis on changing meanings and reframing current views of "dirty gear as a badge of honor" to "clean gear as a badge of honor." These messages were designed to show that norms and culture were shifting toward clean gear and gear cleaning. Both of these discussion segments included quotes from firefighters to add credibility and relevance.

Third, a video was produced to highlight susceptibility and severity of exposure of carcinogens from dirty bunker gear (EPPM). The video used the type of invisible dye usually found in bank robberies as a way demonstrate how soot and contaminants from a fire may lead to cross-contamination of carcinogens. This video was five minutes in length and simulated firefighters fighting a fire, transporting dirty gear to the station, activities around the station, contamination from hauling gear in a personal vehicle, and cross contamination from activities with children. These messages were designed to highlight how normal occupational practice leads to unseen risk and included additional narration by an epidemiologist discussing how contaminants lead to cancer risk. The processes illustrated in the video were led by firefighters for accuracy and authenticity. The video discussed the need for improved decontamination practices, but provided no discussion of how to accomplish this. Both this video segment and the subsequent video were produced by an award-winning documentary filmmaker in consultation with cancer specialists, firefighters, and communication researchers, with the narrative structure designed to address key principles from theories of behavior change.

Fourth, discussion occurred around key barriers firefighters had identified to cleaning gear, providing messages to show how those barriers were either false or could be overcome. As demonstrated in formative research (Harrison, et al. 2017), there are both actual and perceived barriers to conducting the desired decontamination processes, including available time to perform decontamination, fears of wet gear and getting steamed (heat from a fire causing water in the gear to turn to steam, burning the firefighter), and difficulties in accessing extractors and/or exchanging dirty gear for clean gear. Again, direct quotes from firefighters were used for relevance and authenticity.

An additional 10-minute video was produced that showed the process of post fire decontamination the fire department was rolling out. The video was produced to incorporate the elements of IMBP, HBM, and EPPM, including risk, knowledge, norms, efficacy, benefits, and barriers. The video featured interviews with highly admired firefighters, discussions of the need (and existence) of cultural change,

and discussions of cancer risk. Overall, the 40-minute presentation had message segments designed to address all elements of our theoretical models.

Finally, posters, magnets, and bumper stickers were produced that promoted desired behavior (detailing seven steps to perform as part of the decontamination process) and norms ("Clean gear is the new badge of honor"). These materials were developed in collaboration with advertising and public relation practitioner faculty, communication researchers, and firefighters to address cultural preferences and needs of the population. The presentation was broken into segments for appropriate flow and with the goal of keeping firefighters' attention.

Procedure

The study was approved by the institutional review board (IRB approval #20160502). This intervention was rolled out in Palm Beach County Fire Rescue (PBCFR), as part of a trial implementation of field decontamination process in one full battalion of firefighters. Since the fire service is composed of three 24-hour shifts, trainings took place over three days (1 day per shift), with three sets of trainings on each day to make sure there was adequate coverage of fire and rescue services in the field at all times. Approximately 15 – 18 firefighters attended each session (141 total). Firefighters were pulled out of service and knew beforehand that the presentation would focus on cancer, gear cleaning, and decontamination, and that the department was initiating new protocols. Each session began with an introduction to the research and informed consent. Firefighters then completed a series of measures (described below) related to our intervention. The intervention materials described above were then delivered, and then a post-test survey was administered. This intervention was conducted during a planned organizational roll out of new policies and procedures, complete with necessary equipment to conduct the desired decontamination process. While it would have been desirable to have a control condition, pulling firefighters out of service present challenges to the ability to conduct operations and meet the fire and rescue service needs of the community. Pulling an entire battalion out of service over a three-day period required that we conduct a full intervention with all members. As such, this study was designed as a pilot test using a matched sample pre-test/post-test design, with the pre-test serving as baseline.

Measures

All the responses of the measures (except the ones that are specifically described) were assessed on 7-point scale, where 1 stands for *strongly disagree* and 7 stands for *strongly agree.*

Attitudes toward gear cleaning was measured using 8 items adopted from the results of previous research on firefighters' perceptions of cancer and gear cleaning (Authors, *in press b*). The scale included items like: "Cleaning gear is a sign of professionalism", "I trust firefighters who keep their gears clean", "Cleaning gear is a badge of honor", and "I like having clean gear" (Cronbach's $\alpha = .84$).

Norms toward gear cleaning were measured using 3 items: "Most firefighters I work with clean their gear after structure fires", "Firefighters I respect most keep their gear clean", and "My station prides itself on having clean gear". The items were adapted from social norms studies (e.g., Lapinski, Anderson, Shugart, & Todd, 2014) and studies on firefighters' perceptions of peer norms (e.g., Authors, *in press b*). The scale showed acceptable reliability ($\alpha = .72$).

Self-efficacy to cleaning gear was measured using four items adapted from Witte (1996). The scale included items like: "I know how to do an effective gross field decontamination" and "I know all the steps involved with routine cleaning of my gear" ($\alpha = .88$).

Decontamination behavior was measured as self-reported behavior at the pretest and intent to behave at the posttest. The scale for measuring decontamination behaviors was designed based on best practices and developed in collaboration with firefighters. Items were measured on a 7 point Likert-type

scale ranging from *never* to *always*. Behaviors measured in the scale included swapping out dirty hoods, completing gross decontamination of gear in the field, showering within the hour, using wipes to clean face hands and arms, cleaning gear when firefighters get back to the station, sending gear out for advanced cleaning, bagging gear before transporting to the station, cleaning gear before transporting in a personal vehicle, and using a sealed container or bag transport to gear in a personal vehicle. The items demonstrated reliability with Cronbach's α of .89.

Cancer risk was measured through one item asking the participants to indicate their perceptions on the probability of developing cancer: "I think my current risk of getting cancer is ____%". The response of this measure could range from 0 to 100.

Cancer severity was measured using three items adopted from Witte (1996): "If I got cancer it would ruin my life, "If I got cancer, I believe it would probably kill me", and "If I developed cancer, I would not live longer than five years" (α = .84).

Cancer susceptibility was measured using two items adapted from Witte (1996): "It is likely I will get cancer in the future" and "I feel I will get cancer sometime during my life" (α = .94).

Threat of contamination from dirty gear was measured using three items: "Cross contamination of certain toxins on my gear is a serious problem", "Contaminants on my gear could have a negative impact on my home and family", and "Toxins on my gear can easily spread throughout the station". The items were adapted from Witte's study (1996) with Cronbach's α of .81.

Response-efficacy to decontamination was measured using four items adapted from Witte's study (1996). The scale included items like: "Performing a gross decontamination after fire will help keep me safe from contaminants on my gear", "If I perform gross decontamination after fire, I will be less like to be harmed by carcinogens", and "If I perform a routine cleaning after fire, I am less likely to be harmed by carcinogens". Cronbach's α was .91.

Perceived benefits to decontamination was measured using three items adapted from (Rosenstock, 1974): "Cleaning my gear will reduce my chance of getting cancer", "Cleaning my gear will keep me healthy", and "Cleaning my gear will help me stay healthy to take care of my family". The scale showed high reliability with Cronbach's α = .96.

Barriers to gear cleaning and decontamination were measured using eight items, including: "Cleaning my gear after fire or incident takes too much time", "I have other problems more important than cleaning my dear", "Having wet gear from gross decontamination is a big problem for me", and "Wet gear leads to steam burns". The items were developed based on formative research and adapted from the results of previous research on firefighters' perceptions of cancer and gear cleaning (Authors, *in press b*). The items demonstrated reliability with Cronbach's α of .89.

Results

Paired sample t-tests were conducted to examine for change in pre-intervention to post-intervention of theoretical variable for hypotheses 1 - 11. Overall, all hypotheses except H10 (perceived benefits) were fully supported (see Table 1 for details). All other key variables changed in the predicted directions, with attitudes toward clean gear, perceived norms among firefighters, self-efficacy for gear cleaning, response-efficacy, threat of contamination, and intent to engage in decontamination behaviors increasing, and perceived barriers to decontamination decreasing. Perceptions of individual cancer risk decreased, as did susceptibility, but there was no significant change in severity (it should be noted the messages designed in this study did not target the severity of cancer because formative research demonstrated no deficits in perceptions of the severity of cancer by firefighters).

Table 1: Results of Pre-Post Intervention Comparisons (*n*= 130)

Variables	***Pre-test***		***Post-test***		***Comparison***		
	M	SD	M	SD	Test statistics (*df* = 129)	*p*	Effect sizes
Attitudes	5.26	0.8	5.44	0.79	-3.64	<.001	d = .23
Norms	4.24	1.05	4.52	1.09	-3.52	0.001	d = .26
Self-efficacy	4.44	1.38	5.32	1.08	-9.39	<.001	d = .71
Behavior and Intention	3.38	1.12	6.12	0.91	-26.06	<.001	d = 2.67
Cancer risk	64.07	22.3	59.2	23.85	2.89	0.005	d = .21
Cancer severity	4.14	1.25	4.06	1.27	0.93	0.355	d = .06
Cancer susceptibility	5.27	1.22	5.02	1.1	3.17	0.002	d = .22
Threat of contamination	5.78	0.8	6.17	0.8	-6.13	<.001	d = .49
Response-efficacy	5.75	0.83	5.96	0.78	-3.97	<.001	d = .26
Benefits	5.92	0.87	6.04	0.84	-1.79	0.075	d = .13
Barriers	5.1	1.12	4.6	1.31	6.46	<.001	d = .41

One key component that needs to be highlighted in the results table is behavioral intention for gear cleaning. The IMBP (e.g., Yzer, 2012), argues behavioral intention may be the single strongest predictor for individual's actual behavior. The results of the comparison for firefighters' behavioral intention to clean their gears revealed a significant jump from pre-intervention to post-intervention ($t(129) = 26.06$, $p < .001$), with the effect size of $d = 2.67$, indicating the success of this theory-based intervention.

RQ1 and RQ2 were tested using stepwise regressions with norms, benefits, barriers, threats of contamination, response-efficacy, self-efficacy, and attitudes as predictors of behavior and behavioral intention. The results of the regression analysis for firefighter's current decontamination behavior (RQ1; Table 2) indicate that current cleaning behaviors are predicted by their perceived norms of other firefighters ($\boldsymbol{\beta} = .45$, $t(124) = 5.82$, $p < .001$) and their attitudes toward gear cleaning ($\boldsymbol{\beta} = .26$, $t(124) = 3.33$, $p = .001$), largely in line with predictions from IMBP (Yzer, 2012). These findings also indicate that perceived norms play a relatively more important role than attitudes toward gear cleaning in forming firefighter's current behaviors, which support the arguments in HRO studies that firefighter's behaviors could be heavily influenced by their peers (e.g., Myers, 2005; Maglio et al., 2016).

Table 2: Predictors of Current Decontamination Behavior

Overall Model	R	R^2	R^2_{chg}	F_{chg}	*df*	*p*	b(SE)	*β*	t	*p*	Partial *r*
Constant							-.47(.57)		-.81	.420	
Norms	.52	.27	.27	46.20	1, 125	<.001	.47(.08)	.45	5.82	<.001	.46
+Attitudes	.57	.33	.06	11.10	1, 124	.001	.36(.11)	.26	3.33	.001	.29

However, the results of the regression analysis for firefighter's behavioral intention to clean their gears in the near future revealed that the predictors of behavioral intention (post-intervention) were attitudes ($\boldsymbol{\beta} = .37$, $t(123) = 4.24$, $p < .001$), threat of contamination ($\boldsymbol{\beta} = .26$, $t(123) = 3.02$, $p = .003$), and perceived barriers ($\boldsymbol{\beta} = -.17$, $t(123) = -2.35$, $p = .020$; see Table 3 for details). The results indicate that two of the key components in the IMBP failed to predict firefighter's intention to clean their gear in the near future, while key theoretical components from other communication theories (e.g., HBM and EPPM)

predict the intention successfully. In other words, the results support that the IMBP for current decontamination behavior, but suggest that it is not the most accurate model for future behavioral intention in HROs.

Table 3: Predictors of Post Intervention Decontamination Behavioral Intent

Overall Model	R	R^2	R^2_{chg}	F_{chg}	*df*	*p*	b(SE)	β	t	*p*	Partial *r*
Constant							2.70(.63)		4.29	<.001	
Attitudes	.55	.31	.31	54.76	1, 125	<.001	.41(.10)	.37	4.24	<.001	.36
+*Contamination*	.59	.35	.05	8.56	1, 124	.004	.29(.10)	.26	3.02	.003	.26
+*Barriers*	.61	.38	.03	5.52	1,123	.02	-.15(.07)	-.17	-2.35	.020	-.21

Discussion

Overall, the results of our intervention were highly successful. The intervention successfully increased firefighters' attitudes toward decontamination, perceived norms for gear cleaning, self-efficacy and response-efficacy toward cleaning their gear and engaging in decontamination processes. The intervention also managed to reduce the perceived barriers to decontamination among firefighters. Additionally, the intervention successfully reduced firefighter's perceived cancer risk and susceptibility of developing cancer as designed. As expected, cancer severity did not exhibit change since messages were not targeted to the theoretical component of severity. While increases in perceived benefits did not reach statistical significance, this could because of a ceiling effect, with mean scores at pretest of 5.92 on a 7 point scale. Overall, the intervention was significant in increasing firefighter's intention to engage in decontamination behaviors.

The overall success of the results of this study highlight the significance of designing health interventions and messages that pay close attention to theoretical frameworks of behavior change and message design. Additionally, these results demonstrate support for using formative research on specific organizational cultures, occupations, and work processes, as well as on individual variables to aid in the creation of messages for interventions. Each element of the intervention was targeted toward one or more key variables in IMBP, EPPM, or HBM, and addressed key issues identified in formative research. Importantly, key elements of the intervention featured firefighters delivering messages and demonstrating behaviors. Formative research pointed to this as a key element of message receptiveness among firefighters.

The regression model of current behavior fit with the IMBP, with norms and attitudes as the strongest predictors of firefighters' current decontamination behavior, and supports findings about the importance of peer influence from interventions related to diet and physical activity (e.g. Moe et al., 2002; Staley, Weiner, & Linnan, 2011). These findings also fit well with research on high reliability organizations that shows the importance of learning and adhering to organizational practices as a way to demonstrate reliability and trust with other firefighters (Myers, 2005). While the intervention was successful in increasing perceived norms, the regression model of future behavioral intention only included one variable, attitudes, of the IMBP (Yzer, 2012). Fear of contamination and barriers to decontamination emerged as additional key predictors, suggesting that EPPM (Witte, 1994) and HBM (Rosenstock, 1974) variables play a direct role in behavioral intention. Importantly, this also demonstrates that organizations with strong norms and cultures can still exhibit change with well-crafted messages with strong production values. Additionally, the messages targeted specific issues related to contamination from gear, rather than trying to raise fears of cancer, highlighting key risks from firefighters' routine occupational practices. However, given the occupational demands of firefighters who often run 20 – 30

calls in a day, a reduction in barriers to the desired decontamination behavior emerged as a key predictor. This supports Staley, Weiner, and Linnan's (2011) findings that having strong organizational policy is key to implementing change, and supports the timing of this intervention to coincide with key policy changes within the fire service.

While the intervention was successful in targeting and changing key variables, we were not able to test which elements of our message were responsible for the changes. While it is possible that the integration of all materials is important, future research should focus on testing different elements of message design (such as the fear appeal around contamination versus the efficacy of cleaning).

In summary, the findings of the study shed theoretical and practical light on designing and evaluating workplace interventions for promoting cancer prevention behaviors and reducing cancer risk among firefighters. This study theoretically contributes to the understanding of how key communication components may contribute to the success of positive behavioral change, and practically provides implications for utilizing and integrating organizational components and cultural factors for health interventions and campaigns.

Conclusion

Firefighters are at increased risk of cancer. Contamination from gear post-fire increases exposure to carcinogens through absorption and inhalation. However, firefighters do not engage in consistent decontamination processes, in part because of occupational demands and an organizational culture where dirty gear has historically signified trust and reliability. An intervention using messages developed from formative research, and based on theoretical models of behavior change and principals of communication design, was able to improve attitudes, perceived norms, perceived benefits, self-efficacy, response-efficacy, and decrease barriers to decontamination. Firefighters' intention to engage in decontamination behaviors showed significant increases, which should result in decreased exposure to carcinogens and a corresponding decrease in cancer risk that results from those exposures.

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