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Are Photographs Worth More Than A Thousand Words? Examining the Effects of
Photographic-textual and Textual-only Frames on Public Attitude Toward Nuclear Energy
and Nanotechnology

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Abstract

This study examines the impact of photographic-textual and risk-benefit frames on the level of visual attention, risk perception, and public support for nuclear energy and nanotechnology in Singapore. Using a 2 (photographic-textual vs. textual-only frames) x 2 (risk vs. benefit frames) x 2 (nuclear energy vs. nanotechnology) between-subject design with eye-tracking data, the results showed that photographic-textual frames elicited more attention and did have partial amplification effect. However, this was observable only in the context of nuclear energy, where public support was lowest when participants were exposed to risk frames accompanied by photographs. Implications for theory and practice were discussed.

Keywords: Photographic framing; visual framing; risk perception; nanotechnology; nuclear energy

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Communication of scientific issues in modern times is often multimodal in nature, where the complementary use of texts and visuals is almost inextricable (Brantner, Lobinger, & Wetzstein, 2011). While communication scholars do ascribe partial attitudinal changes to science due to media influence (Cobb, 2005; Yun, Nah, & McLeod, 2008), much of the research on media *framing* in science communication focus primarily on the effects of *textual framing*—the study of how manipulation of words influences attitude and behaviors (Stewart, Dickerson, & Hotchkiss, 2009; Yun et al., 2008)—and less so on the use of photographs in the framing process (Parry, 2010). *Photographic-textual framing*, which refers to the use of photographs, with accompanying texts in making a perceived reality salient (Dahmen, 2009; Entman, 1993), constitutes an important component of the framing process as much as textual framing. As science news are often accompanied by photographs (Dahmen, 2012), there is a need to empirically verify the old adage—*a picture is worth a thousand words*—and examine if the assumption holds in the context of science communication.

There are calls in recent years to examine both photographic-textual as well as textual-only framing mechanisms together (Dahmen, 2009, 2012) as research has found a significant relationship between the exposure to visuals and subsequent attitudinal changes on a variety of issues (Landau, Groscurth, & Wright, 2009; Von Sikorski, Schierl, Möller, & Oberhäuser, 2012). Given these considerations, assessing the impact of both photographic-textual and textual-only frames on the public is important for understanding why people may perceive the pursuit of science to be risky, or explain why they hold a favorable or unfavorable stance toward their government's plan to invest in scientific research (Dahmen,

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2009). Currently, there are three gaps in framing theory, specifically in the area of the use of photographic-textual framing in science communication. First, the main critique given by scholars examining photographic-textual framing is that there is an incoherence and mismatch between its conceptualization and operationalization (Rodriguez & Dimitrova, 2011). Poorly defined concepts impede the advancement of framing theory if scholars use different meanings for similar terms. Second, the assumption that photographic-textual frames can contribute to biases in cognitive processing and decision making due to its attention grabbing nature though widely accepted, has seldom been verified empirically (Dahmen, 2012; Gamliel & Kreiner, 2013).

Third, very often, framing effects are implicitly assumed to have a degree of *universality* across different science contexts. However, this may not always be true due to the multiple and complex qualitative differences between different types of sciences. For instance, even though there is a certain level of controversy surrounding the use of nuclear energy and nanotechnology, both types of sciences are distinct and differ in many aspects ranging from their applications to potential risks (Besley & McComas, 2015; Friedman, 2011; He, Mol, Zhang, & Lu, 2014).

This study aims to bridge these gaps associated with photographic-textual framing in the context of science communication. First, we argue that a coherent and systematic way of defining and operationalizing a photographic-textual frame can be drawn from existing framing literature. Second, we will examine how photographic-textual frames moderate the effects of risk-benefit frames on individuals' attention, risk perception and public support for sciences. Third, we will test the effects of photographic-textual and textual-only frames, as well as risk-benefit frames on attention, risk perception, and public support for sciences in two contexts—nuclear energy and nanotechnology. Nuclear energy and nanotechnology are chosen as the context of study because they are similar in terms of having a degree of

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controversy surrounding their use. Yet, they are also distinct and differ in many aspects ranging from their applications, degree of risks, to public's familiarity and understanding of the technologies.

Theoretical Framework—Framing Theory

Framing is a widely researched theory across diverse academic disciplines (D'Angelo, 2002; Matthes, 2009; Scheufele & Tewksbury, 2007), and it has both sociological (Goffman, 1974) and psychological roots (Kahneman & Tversky, 1983; Tversky & Kahneman, 1981). Scholars from the sociological paradigm are primarily interested in "*frames in communication*" or "*media frames*" (Chong & Druckman, 2007, p. 100), which refer to how words, pictures, and presentation styles are used to convey information to audiences (Gamson & Modigliani, 1987). Scholars from the psychological camp, on the other hand, are concerned with "*frames in thought*" (Chong & Druckman, 2007, p. 101). While *frames in communication* reveal what the communicator thinks are the most important issues, *frames in thought* are what the audience perceive as the most salient aspect of the information presented to them. Though the two paradigms are clearly distinct, there is a strong association between them such that when frames in communication influence frames in thought, a framing effect is said to have occurred (Druckman, 2001).

Studies that examine media frames in sciences often classify messages into thematic tracks, such as political, economic, scientific breakthrough, or medical frames (e.g., Dahmen, 2012; Donk, Metag, Kohring, & Marcinkowski, 2012; Groboljsek & Mali, 2012). Even with the different nomenclatures, these frames can be classified as *valence news frames*. Valence news frame refers to frames that present issues either in a positive or negative light (Schuck & de Vreese, 2006). These frames that are commonly identified in science communication research can be considered as valence frames because regardless of the content or the organizing idea, there is ultimately a positive or negative evaluation that comes along with it

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(Allan, Anderson, & Petersen, 2010). The risk frame emphasizes the negative aspects by highlighting the potential risks associated with the usage of the technology; benefit frame on the other hand, focuses on the positive by making salient the advantages that come along with the usage of the technology. The effects of valence framing have been well documented in existing literature (Garcia-Retamero & Cokely, 2011; Gerend & Maner, 2011; Gifford & Comeau, 2011).

Attention, risk perception, and public support

Particularly for this study, we are interested in the framing effects on three important outcome variables in science communication—*attention*, *risk perception*, and *public support for sciences*. Understanding public attention to media content in the coverage of science issues is often a key focus for scholars studying science-related topics (e.g., E. W. J. Lee & Ho, 2015; Qin & Peng, 2016; Zhao, Leiserowitz, Maibach, & Roser-Renouf, 2011). In a world where individuals are constantly exposed to a myriad of information through the media, attention to media content—defined as a mental focus on a subject or topic (Eveland, 2001)—is considerably a scarce resource in which individuals need to consciously decide what content to focus on, and what to ignore. When individuals pay more attention to certain content, it may signify that the individuals ascribe more relevance and importance to the issue. In addition, attention is an important outcome in science communication as it is an antecedent to knowledge and familiarity, both of which influence eventual attitude toward the support of sciences (Ladwig, Dalrymple, Brossard, Scheufele, & Corley, 2012; E. W. J. Lee & Ho, 2015).

Existing research suggests that risk frames may elicit more attention from individuals as compared to benefit frames. First, risk frames are more likely to contain information that induce negative affect and emotions (Seo & Dillard, 2016). As individuals are more likely to show a greater response to negative stimuli (Saqib, 2014), they will pay more attention when

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presented with risk frames as compared to benefit frames. Moreover, research in prospect theory have found that people are risk-averse by nature (e.g., Kahneman & Tversky, 1983). Thus, they are more likely to seek out and pay attention to media content to reduce uncertainty (Lu, 2016; Yang & Kahlor, 2012). For instance, in an experimental study that examined the level of attention to different media frames related to stem-cell research, the eye-tracking data showed that individuals were most attentive to frames containing “risk” elements (Dahmen, 2012).

The second outcome of interest in this study is risk perception. Risk perception refers to “the judgments people make when they are asked to characterize and evaluate hazardous activities and technologies” (Slovic, 1987, p. 280). Individuals’ risk perception are formed from personal experience or through any available information, and it is an important factor affecting attitude toward nuclear energy (Ho, *in press*; Ho, Leong, Looi, Chen, Pang, & Tandoc, *in press*). In the context of science communication, apart from formal education, the media play an instrumental role in helping individuals form their perceptions about science (Zhao et al., 2011). This is because the lay public does not always have first-hand exposure of the positive or negative effects of science—the media thus provide the necessary scientific information and heuristics for evaluating sciences (Friedman & Egolf, 2011). The effects of media frames on public’s risk perception are well documented (Ho, Scheufele, & Corley, 2011). When the media emphasize the risks of using a technology, the public may develop a negative sentiment and a high level of risk perception of the technology (Marks, Kalaitzandonakes, Wilkins, & Zakharova, 2012). For instance, Cobb (2005) found that when participants were exposed to frames highlighting threats to health, economy, and the environment, they associated more risks than benefits with the usage of nanotechnology.

Last but not least, the third outcome variable—public support for sciences—can be understood as how favorable the people are in supporting government’s pursuit of science

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research (Ho, Scheufele, & Corley, 2010). Apart from risk perception, we postulate that exposure to risk-benefit framing messages can influence public support for science research. For instance, whenever the media emphasize the positive aspects of a particular technology, the public becomes more favorable of its use (e.g., Bainbridge, 2002; He et al., 2014; Pidgeon, Lorenzoni, & Poortinga, 2008). Bolsen, Druckman, and Cook (2014) found that exposure to risk frame that highlighted health risks of nuclear energy decreased general public support. Delshad and Raymond (2013) found that in a media environment where risks were frequently highlighted, people's support for biofuels decreased significantly. As such, we postulate the following:

H1: Participants who are exposed to the risk frame will pay more attention to the framing stimuli, as compared to participants who are exposed to the benefit frame.

H2: Participants who are exposed to the risk frame will indicate a higher level of risk perception as compared to participants who are exposed to the benefit frame.

H3: Participants who are exposed to the risk frame will indicate a lower level of support for the sciences as compared to participants who are exposed to the benefit frame.

Photographs in Framing Research

Despite generating a wealth of knowledge from framing studies in science communication, much of the research primarily focused on the effects of textual manipulation. There are significantly less studies on the role of visuals, especially the use of photographs, in the framing process (Dahmen, 2012). Photographs are important communication tools and their roles in attitudinal formation cannot be undermined as research has shown that images evoke stronger media effects than words (Domke et al., 1997; Messaris & Abraham, 2001). Moreover, the news media rely on both literal and visual devices in the construction of their news stories (Entman, 1991; Von Sikorski et al., 2012). To ignore how visuals are used in the framing process in a media-saturated environment

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impedes the understanding and development of a holistic framing theory (Dauber, 2001; Messaris & Abraham, 2001).

Another focus of this study is to understand how photographs moderate the effects of textual framing. The use of photographs is an important component of the framing process and communication scholars have highlighted the power of images to persuade as they possess unique qualities that are distinct from texts (Dahmen & Miller, 2012). These unique properties of images are known as “*analogical quality*” and “*specific indexicality*” (Messaris & Abraham, 2001, p. 217). *Analogical quality* refers to the association between what is shown by the image and the meaning it represents. As what is portrayed by images is relatively *analogous* to the actual objects shown, viewers do not need to learn specific language or grammar rules to understand the pictures (Messaris & Abraham, 2001). *Specific indexicality* refers to the accuracy of portraying perceived reality, which is a feature more dominant in photographs than other visual forms (Rodriguez & Dimitrova, 2011, p. 52). As such, the capacity to achieve a shock effect and evoke affective response is greater with the use of photographs (Dahmen, 2012; Goodwin, 1983). Moreover, as photographs bear a high resemblance to reality, audiences tend to read news photographs as evidences (Messaris & Abraham, 2001; Pfau et al., 2006), making them susceptible to embedded persuasive messages.

Defining a photographic-textual frame

While the potential effects of photographs are recognized (Messaris & Abraham, 2001), there is a lack of conceptual clarity and methodological consistency in operationalizing *photographic-textual* frames (Rodriguez & Dimitrova, 2011). Similar to the general definition of framing, photographic-textual framing specifically refer to the selection of both photographs and texts and in making salient a certain aspect of reality (Dahmen, 2012; Entman, 1993). Some have suggested using a thematic approach in defining

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photographic-textual frames, such as labeling a picture of U.S. President Barack Obama as a *political* frame while a picture of scientists as a *scientific* frame (Dahmen, 2012). Research has also conceptualized photographic-textual frames as the ideological positions taken by the news journalists (e.g., Griffin, 2004), while others have examined photographic-textual frames by solely focusing on the visual manipulation of photographs (Von Sikorski et al., 2012).

Clearly these different definitions have further divided an already fractured framing theory (Entman, 1993). Currently there are no known guiding criteria for what is a photographic-textual frame. As such, we put forth three theoretical propositions drawn from existing framing literature that may be useful in defining a photographic-textual frame. First, to qualify as a photographic-textual frame, the use of photographs and texts must have been selected and organized in such a way as to make salient an aspect of a perceived reality—this is in line with the classical definition of framing, which is the selection of certain parts of perceived reality and making them salient (Entman, 1993). The deliberate use of a photograph that only presents certain aspects of realities (while excluding others) is an important trait of a photographic-textual frame. Like texts, the choice of photographs constitutes part of the journalists' attempts to persuade (Dauber, 2001).

The second theoretical proposition is that the context of the photographic-textual frame should be explained by accompanying texts (Brantner et al., 2011; Leckner, 2012). Dauber (2001) argued that images are always embedded within a context, and the context is often constructed with words, be it through a voice over from a reporter, a caption, or a headline. Thus, the use of photographs and words are complementary and necessary in a photographic-textual frame.

Third, the presence and length of the textual element must not significantly shift the focus away from the photograph. Taking this into consideration, a news photograph that is

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embedded in a full broadsheet story is not considered a photographic-textual frame. The reasoning is straightforward—while the broadsheet format satisfies the second criterion, the text eventually becomes the central focus even though readers may initially pay more attention to the photographs. As such, the use of photographs becomes peripheral. Based on the three theoretical propositions, we propose that an “image-nuclear news story” fits the proposed conceptual definition of a photographic frame (Caple & Bednarek, 2012). An image-nuclear news story is a style of newspaper reporting that features a dominant photograph as the central focus, combined with a heading and a short caption. To produce an image-nuclear news story, journalists need to engage in photograph selection for their news angle—this satisfies the first criterion of selecting visuals in making salient an aspect of perceived reality. Second, while the headline and the caption provide the context for the photograph; yet the limited text length does not divert the attention away from the main photograph. This fulfills both the second and third criteria. In line with our reasoning that a photographic-textual frame which is richer in visual cues will be more attention grabbing as compared to a textual-only frame (Dahmen, 2012), we hypothesize that:

H4: Participants who are exposed to the photographic-textual frame will pay more attention to the framing stimuli as compared to participants who are exposed to the textual-only frame.

Existing research has documented the effects of exposure to textual risk-benefit frame (Cobb, 2005). Considering that photographs can be an effect-amplifier due to the richness of visual cues, we postulate that there will be interaction between photographic-textual and risk-benefit framing on attention, risk perception, and public support. First, we argue that there will be interaction between photographic-textual as well as risk-benefit framing on attention, especially in conditions where individuals are exposed to photographs highlighting risks. This is because risks and photographs have the propensity to command more attention due to their

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shock factor and richness in visual cues respectively (Chang & Lee, 2008; Rodriguez & Dimitrova, 2011). Next, we hypothesize that there will be an additive effect between photographic-textual and risk-benefit framing on risk perception. This is because showing a pictorial consequence of technology use together with text (e.g., Fukushima accident) is more impactful than textual description of the risks alone. Landau et al. (2009) found that participants exposed to nanotechnology images that evoked uncomfortable feelings gave a negative evaluation of nanotechnology. One of the pictures used in Landau's study was a nano-carrier visibility injected into a person's blood stream—this was perceived to be a highly invasive procedure. Participants who saw this picture reported negative valence and evaluated nanotechnology negatively. In another example, Arpan et al. (2006) found that visuals with a “conflict” theme had a significantly more negative effect on how viewers perceive street protestors as compared to those who were exposed to the “peaceful” photo condition. Thus, we argue that outcome changes in risk perception will be greater for participants exposed to photographic-risk frame than those who are exposed to photographic-benefit frame, such that those exposed to photographic-risk frame will indicate a significantly higher level of risk perception as compared to those in other conditions.

Third, as photographs are more efficacious than words in eliciting emotional response and in influencing attitude (Pfau et al., 2006), we postulate that there will be an additive effect between photographic-textual and risk-benefit framing on public support for the sciences. In the context of science communication, risk messages are more effective than benefit messages in changing attitudes because people tend to trust risk messages due to negativity bias (Cobb, 2005). Therefore, participants exposed to photographic-risk frame will indicate a significantly lower level of public support than those exposed to the photographic-benefit frames. As such, we hypothesize:

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H5: Differences in (a) attention, (b) risk perception, and (c) the level of support for sciences between the risk and benefit conditions will be magnified in the photographic condition, as compared to those in the textual condition.

We postulate that differential interaction patterns could be observed for photographic-textual and risk-benefit frames across nuclear energy and nanotechnology, such that the effects of photographic-textual and risk-benefit frames on the three dependent variables will be greater among individuals exposed to nuclear energy stories as compared to those exposed to nanotechnology news stories. First, as the coverage of nuclear energy is often accompanied by some form of visuals (e.g., photos of past nuclear accidents, nuclear power plants) than nanotechnology, it may gain more attention from the public as compared to a nanotechnology story. Even if the nuclear energy stories are not accompanied by visuals, any coverage may activate *cognitive accessibility*—the ease of retrieval of stored information or schemata that help individuals with the organizing information and making sense of experience (Schuldt & Roh, 2014)—where individuals may conjure up mental images of past negative effects of nuclear energy, and thus elicit more attention. As such, we expect that the interaction between photographic-textual and risk-benefit frames to be amplified for individuals exposed to nuclear energy news stories.

Similarly, we argue that the effects of photographic-textual frames and risk-benefit frames on risk perception and public support will be magnified in nuclear energy conditions as compared to nanotechnology conditions. Disparities in framing effect across different contextual settings have often been observed, with some arguing for a stronger framing effect when there is greater understanding of the issue presented by the frame (Cobb, 2005; Druckman & Bolsen, 2011; LeBoeuf & Shafir, 2003). Research suggests that perceptions of risks and benefits explain more variances in people's support of nuclear energy as compared to nanotechnology because people are largely familiar with nuclear energy as compared to

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nanotechnology (Besley & McComas, 2015). After all, nuclear energy has been around for a much longer period than nanotechnology. A recent research showed that in the online sphere, tweets surrounding nuclear energy discussions are significantly more than tweets about nanotechnology (Su et al., 2017). This supports the notion that people are more cognizant of nuclear energy as compared to nanotechnology. As such, we postulate the following hypothesis:

H6: Photographic-textual and risk-benefit frame will interact, such that the increased effects on (a) attention, (b) risk perception, and (c) support for sciences when adding photographs to the risk benefit frame will be concentrated among participants exposed to nuclear energy stories; the interaction effects will be negligible for participants exposed to nanotechnology news stories.

Method

After obtaining ethics approval from the Institutional Review Board, a total of 445 undergraduate students from a large public university in Singapore participated in a 2 x 2 x 2 between-subject factorial experimental design (Photographic-textual frame vs. Risk-benefit frame vs. Science Topics) from February to March in 2013. Participants were randomly assigned to one of the eight experimental conditions mounted onto the Tobii eye-tracker located at a computer lab at the university: (1) Nanotechnology photographic-benefit frame; (2) Nanotechnology textual-benefit frame; (3) Nanotechnology photographic-risk frame; (4) Nanotechnology textual-risk frame; (5) Nuclear photographic-benefit frame; (6) Nuclear Textual-benefit frame; (7) Nuclear Photographic-risk frame; and (8) Nuclear Textual-risk frame. For each of the eight conditions, participants were exposed to five news stories on either the risks or benefits of the technology they were assigned to (nuclear energy or nanotechnology). After the exposure to the experimental stimuli, participants were required to fill out a pen-and-paper questionnaire containing measures for the dependent variables. A

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debrief email was then sent to all participants at the end of the data-collection period explaining the true purpose of the study.

Experimental stimuli

The experimental stimuliⁱⁱ were a construction of an online photo story of a Singapore English newspaper—*The Straits Times*. The photographic-textual frame consisted of the masthead of *The Straits Times* online, a headline, a photograph, and a photo caption. The textual-only frame was designed to be similar to the photographic-textual frame, except that no photographs were used. The texts and the photographs in the photographic-benefit frame emphasized the benefits of using nuclear energy and nanotechnology. The photographs chosen for the nuclear photographic-benefit frames were: (1) A boy living near nuclear reactors mowing his lawn; (2) Nuclear reactors against the backdrop of a clear blue sky; (3) A lady and her green crops that benefitted from the usage of nuclear energy; (4) Lighted up nuclear reactors on a map; and (5) Prime Minister Lee Hsien Loong affirming the benefits of nuclear energy. The photographs chosen for the nanotechnology photographic-benefit frames were: (1) A man whose life was saved by an artificial windpipe created with nanotechnology; (2) Prime Minister Lee Hsien Long affirming the benefits of nanotechnology; (3) A man with a bionic leg which utilized nanotechnology; (4) Scientist with an artificial ear grown using nanotechnology; and (5) Quantum dots in the use of cancer treatment.

The texts and photographs in the photographic-risk frame made salient the risks of using nuclear energy and nanotechnology. The photographs that were chosen for nuclear photographic-risk frame were: (1) Explosion at Fukushima Nuclear Power plant; (2) A child screened for nuclear radiation; (3) Protest against the usage of nuclear energy; (4) People in chemical suit paying respect to the dead in Fukushima; and (5) Prime Minister Lee Hsien Loong warning people about the risks of nuclear energy. The photographs that were chosen for the photographic-risk frames of nanotechnology were: (1) A protest picture; (2) Prime

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Minister Lee Hsien Loong warning people about the risks of nanotechnology, (3) A lady with skin problems; (4) Fruit injected with needles; and (5) Quantum dots in a laboratory mouse.

The photographs used in the photographic-textual frames were selected after multiple rounds of pretests with different groups of participants. Specifically, only the top five photographs (out of twenty shortlisted for each condition) that were consistently rated as a clear depiction of risks or benefits of nanotechnology and nuclear energy were selected to be part of the experimental stimuli.

Measures

Among the 445 participants, 154 (34.6%) were males and 290 (65.2%) were females. Chinese made up the majority of the sample (88.8%), followed by Indians (3.82%), Malays (2.25%), Others (3.15%), and Eurasians (0.90%). The age for the participants ranged from 17 to 28 years old (*Median* = 22.0, *M* = 21.6, *SD* = 1.83). Monthly household income ranged from 1 (“SGD1,000 and below”) to 11 (“above SGD10,000”) (*Median* = 4.00 or “SGD3001 to SGD4000,” *SD* = 3.16).

Attention. The Tobii eye-tracking machine provided the data indicating participants’ level of attention to the experimental stimuli. One feature of the eye-tracking machine is that it can capture the *total visit duration*, which is the total amount of time spent (in seconds) by the participants looking at specific Area of Interests (AOIs). The designated AOIs for the photographic-textual frame were the headline, the photograph, and the photo caption; the AOIs designated for the textual-only frame were the headline and the caption. An individual’s *total visit duration* for all five experimental stimuli was summed to become *attention* (*Combined attention*: *M* = 44.81, *SD* = 20.2; *Attention to nuclear energy*: 47.16, *SD* = 21.33; *Attention to nanotechnology*: *M* = 42.24, *SD* = 18.61). As attention was a positively skewed variable, we applied $\log_{10}(1 + \text{value})$ transformation before conducting further statistical analyses.

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Risk perception of nuclear energy/nanotechnology. Risk perception of nuclear energy and nanotechnology was measured using three items adapted from Kellstedt, Zahran, and Vedlitz (2008). Participants were asked to rate on a five-point scale (“1” = “no risk at all” and “5” = “a lot of risk”) how much risk they perceived the usage of nuclear energy/nanotechnology would bring: (a) “What is the risk of nuclear energy/nanotechnology exerting a significant impact on public health in Singapore?” (b) “What is the risk of nuclear energy/nanotechnology exerting a significant impact on economic development in Singapore?” and (c) “What is the risk of nuclear energy/nanotechnology exerting a significant impact on the environment in Singapore?” For participants who were assigned to nanotechnology conditions, they were only required to evaluate the perception of risks in relation to nanotechnology. Similarly, for participants assigned to nuclear energy conditions, they were asked to evaluate the risks in relation to nuclear energy only. The three items were averaged to form a composite scale called *risk perception (Combined risk perception: $M = 3.21$, $SD = .76$, Cronbach’s $\alpha = .87$; Risk perception of nuclear energy: $M = 3.48$, $SD = .86$, Cronbach’s $\alpha = .82$; Risk perception of nanotechnology: $M = 2.97$, $SD = .82$, Cronbach’s $\alpha = .74$)*.

Public support for nuclear energy/nanotechnology. Public support for nuclear energy/nanotechnology was measured by two items on a ten-point scale (“1” = “not at all,” “10” = “very much”). The two items were: (a) “Overall, I support the use of nuclear energy/nanotechnology” and (b) “Overall, I support Singapore government’s funding for nuclear energy/nanotechnology.” The two items were adapted from Lee and Scheufele (2006) and they were averaged to form a composite scale for *public support for the sciences (Combined public support: $M = 6.20$, $SD = 2.22$, $r = .83$, $p < .001$; Public support for nuclear energy: $M = 5.18$, $SD = 2.05$; $r = .75$, $p < .001$; Public support for nanotechnology: $M = 7.12$, $SD = 1.95$ $r = .87$, $p < .001$)*.

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Manipulation Check

A manipulation check was conducted for both the photographic-textual frame and the risk-benefit frame. Two questions (“1” = “Strongly disagree”; “10” = “Strongly agree”) were used as manipulation checks for photographic-textual and textual-only frames: (a) “The main focus of the newspaper articles is the photographs,” and (b) “The main focus of the newspaper articles is the text.” We asked participants if the focus was photographs or texts as manipulation check for photographic-textual frame because photographs should be the visual primacy in a photographic-textual frame, while textual content should be the prominent focus of a textual-only frame (Dahmen, 2012; Van Der Heide, D’Angelo, & Schumaker, 2012).

Two questions (“1” = “Strongly disagree”; “10” = “Strongly agree”) were used as manipulation check for risk-benefit frames: (a) “The newspaper articles I have read emphasized the benefits of using nuclear energy/nanotechnology;” and (b) “The newspaper articles I have read emphasized the risks of using nuclear energy/nanotechnology.”

T-test result showed that participants assigned to the photographic-textual condition indicated that the focus was the photographs ($M = 7.01$, $SD = 2.09$) as compared to those assigned to the textual condition ($M = 2.27$, $SD = 1.67$, $t[443] = -15.2$, $p < .001$). For the risk-benefit framing manipulation, participants assigned to risk condition indicated that the experimental stimuli focused on the risk ($M = 8.38$, $SD = 1.43$) as compared to those assigned to benefit condition ($M = 2.94$, $SD = 1.53$) ($t[443] = -38.8$, $p < .001$).

Resultsⁱⁱⁱ

The data was analyzed using three-way MANCOVA in SPSS Statistics 20, where participants’ age, gender, ethnic groups, and income were treated as covariates. Four dummy variables (Malays, Indians, Eurasians, and Others) were created, with Chinese Singaporeans being treated as the baseline group. Photographic-textual frame (1 = Textual-only frame; 2 = Photographic-textual frame), risk-benefit frame (1 = benefit frame; 2 = risk frame), and

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science topics (1 = Nanotechnology; 2 = Nuclear Energy) were treated as independent variables, while attention, risk perception and public support, were treated as dependent variables. Tables 1 to 3 summarized the results of the analyses.

[Insert Tables 1 to 3 about here.]

H1-H3 postulated that exposure to risk frame would lead to a higher level of attention, risk perception, and public support respectively. Results showed that there was no statistically significant difference in participants' attention to the stimuli between those assigned to risk and benefit conditions, thus H1 was not supported. However the results supported H2—participants exposed to the risk frame indicated a higher level of risk perception ($M = 3.34$, $SD = .69$) as compared to those exposed to the benefit frame ($M = 2.81$, $SD = .74$), $F(1, 430) = 77.94$, $p < .001$, $\eta^2 = .15$. H3 received support as well—participants exposed to risk frame showed a significantly lower level of support for the sciences ($M = 5.27$, $SD = 2.08$) as compared to those who were exposed to the benefit frame ($M = 7.08$, $SD = 1.98$), $F(1, 430) = 129.98$, $p < .001$, $\eta^2 = .23$.

Next, we found support for H4—participants exposed to the photographic-textual frame ($M = 1.68$, $SD = .20$) were more attentive to the framing stimuli as compared to participants exposed to the textual-only frame ($M = 1.56$, $SD = .29$), $F(1, 430) = 25.96$, $p < .001$, $\eta^2 = .06$.

H5a, H5b, and H5c postulated that photographic-textual and risk-benefit frames would interact. However, there were no significant two-way interaction patterns observed for attention and risk perception, thus H5a and H5b were not supported. However, results supported H5c. For participants in the risk frame condition, those exposed to the photographic-textual condition ($M = 4.89$, $SD = 2.30$) showed a significantly lower level of support as compared to those exposed to the textual-only condition ($M = 5.55$, $SD = 1.81$); the difference in the level of support indicated by participants in the photographic-textual (M

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= 7.11, $SD = 1.84$) and textual benefit ($M = 6.97$, $SD = 2.10$) frames were negligible, $F(1, 430) = 6.16$, $p < .05$, $\eta^2 = .01$.

[Insert Figure 1 about here.]

H6 postulated that there would be three-way interaction between exposure to the sciences, photographic-textual, and risk-benefit framing on (a) attention, (b) risk perception, and (c) public support. However, results showed that there were no significant interaction patterns observed for attention and risk perception, thus H6a and H6b were not supported. However, a significant three-way interaction was found for public support—H6c was thus supported. Among participants assigned to the nuclear energy condition, those exposed to the photographic-textual frame ($M = 3.81$, $SD = 2.00$) in the risk condition showed a statistically significant lower level of support as compared to those in the textual-only condition ($M = 5.32$, $SD = 1.90$), $F(1, 430) = 7.31$, $p < .01$, $\eta^2 = .02$). However, among participants who were assigned to the benefit condition, those exposed to photographic-textual condition ($M = 5.78$, $SD = 1.60$) did not differ significantly from those assigned to textual-only condition ($M = 5.63$, $SD = 2.13$) with respect to the level of support. No interaction effect was observed for participants in the nanotechnology condition.

[Insert Figures 2a and 2b about here.]

Discussion

So, do photographs speak a thousand words? We set out in this study to examine how photographs amplify the effects of risk-benefit framing effects on attention, risk perception, as well as support for the sciences. There are a few notable findings. First, in terms of main effects, we found that risk-benefit framing had an effect on public's risk perception and support for sciences, such that those exposed to risk frame had higher risk perception and lower support than those exposed to benefit frame. However, we did not find any main effect for risk-benefit frame on attention. Next, participants exposed to photographic-textual frames

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indicated higher level of attention as compared to their counterparts assigned to textual-only frames. As for exposure to different types of sciences, we found that participants who were assigned to the nuclear energy condition were more attentive, had higher risk perception, as well as showed lower public support as compared to those in the nanotechnology condition. Last but not least, perhaps the most notable finding in this study is the significant three-way and two-way interaction patterns, which gives partial support to the old adage that photographs are worth more than a thousand words in certain contexts.

Our study extends existing framing research within science communication by partially addressing three perennial questions in science and visual communication literature: (1) *What* constitutes a photographic-textual frame; (2) *How* do they influence the outcomes of interest in science communication; and (3) *Why* is it important to scholars and communication practitioners? With regard to our attempt to address *what* is a photographic-textual frame, this is one of the few studies among a growing body of research that has attempted to conceptualize and operationalize photographic-textual framing (Dahmen, 2009, 2012), and systematically examine how it impacts attention, risk perception, and support for sciences. Framing theory has often been criticized as a fractured paradigm (Entman, 1993), and this criticism has been extended to the sub-field of visual and photographic framing as well. Scholars who conduct photographic or visual framing studies often find themselves facing the uphill task of navigating the conceptually murky mud-field and providing an adequate definition of what is a photographic frame (Rodriguez & Dimitrova, 2011). While far from perfect, our proposed conceptualization and operationalization of a photographic-textual frame falls largely within the boundaries of what scholars accept as *media frames* (Geise & Baden, 2015; Scheufele, 1999), and at the same time preserving a degree of ecological validity—this is considering that the usage of image-nuclear news story format is the widely adopted manner of news reporting in major newspapers worldwide (Caple &

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Bednarek, 2012).

The second extension to framing research in this study is our attempt to show *how* photographic-textual frames (as well as textual-only frames) influence the three outcomes variables—attention, risk perception, and public support. In our study, we only observed a significant framing effect on public support for photographic-textual frames if risk was emphasized—participants in the photographic-risk frame indicated a significantly lower level of support for nuclear energy than those in the photographic-benefit and textual-risk conditions. This finding is in line with research that has found that when both visuals and texts emphasize negativity, its impact is stronger (Chang & Lee, 2008) than messages with positive valence. Second, the photographic-textual and risk-benefit interaction on public support is only observed for nuclear energy condition. This is consistent with research that claims that framing effects are only stronger if people are familiar with the issue; these frames then activate pre-existing attitude (Chong & Druckman, 2007; Nelson, Oxley, & Clawson, 1997). Nuclear energy is a highly charged hot-button issue that splits public opinion (He et al., 2014). With much coverage in the press, people will have some pre-conceived notions about its risk and benefits. Thus, when exposed to photographic framing conditions, the photographs accentuate these pre-existing values. In contrast, no such effects were found for nanotechnology due to the sense of nano-optimism propagated by the Singapore media, as well as the public's general lack of understanding of nanotechnology (Liang et al., 2015).

We would like to point out that for this study, we departed from the conventional way of assessing attention (e.g., E. W. J. Lee & Ho, 2015) by choosing to incorporate physiological data from the eye-tracker. Using the eye-tracker is a novel way to measure attention, and we have empirically shown that photograph-textual frames were more attention grabbing as compared to textual-frames—a notion that has been widely accepted but rarely

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verified in existing framing literature. The usage of the eye-tracker allows a more fine-grained and less-biased estimate of attention as compared to self-report measures (Van Gog, Paas, & Van Merriënboer, 2005).

Beyond addressing questions related to *what* and *how* of photographic-textual framing, it is pertinent for both academics and science communicators such as scientists and journalists to know *why* the results of this research matter, specifically with regard to understanding the mechanisms of photographic-textual and risk-benefit framing in tandem. For scholars, our results call for a revisit of some of the widely-held assumptions in framing studies. For instance, our findings show that photographic-framing effect is amplified only in the context of nuclear energy, but not in nanotechnology. This in turn begs the question: Are there any instances where an amplification effect can be observed in nanotechnology or similar emerging technologies? In addition, we did not find support for our hypothesized three-way interactions on risk perception. This could be due to the multidimensionality of risk perception (Malenka, Baron, Johansen, Wahrenberger, & Ross, 1993; Tyler & Cook, 1984); we only measured one general dimension of risk in our study. In science communication, there have been attempts to distinguish between impersonal and personal risks (Ho, Detenber, Rosenthal, & Lee, 2014; Kahlor, 2006). Future research should examine the effects of photographic-textual framing on both impersonal and personal risk perception. These are research questions that warrant more in-depth investigation in future. As for science communicators, our findings point to several practical implications. When reporting on risks of salient sciences, scientists and journalists need to be mindful as they may sway public support for research and development. To prevent the spread of hysteria fueled by emotionalism and media sensationalism, governments may engage and consult the public by holding dialogue sessions pertaining to nuclear energy policies—when the public perceives that the decision making process is transparent, they will develop greater trust in the policy-

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makers (Ho, in press). As for nanotechnology, our findings showed that photographic-textual and risk-benefit framing had negligible effect. This suggests that the public may not have sufficient information to make an informed decision on where they stand pertaining to their support of science. As such, science communicators may want to focus on increasing awareness and public education for emerging sciences like nanotechnology.

Like all studies, this research has its limitations. First, there is limited external validity as the sample consists mainly of university students. Second, participants in our research were only exposed to one-sided frames, but research suggests that framing effects may be attenuated or augmented when individuals are presented with competing information from different frames (Borah, 2011). Last but not least, it is not known how permanent or temporal the effects of the photographic-textual and risk-benefit frames are—future research should examine if repetitive exposure to frames result in stronger attitudinal changes toward sciences.

Conclusion

Framing is an important mechanism for understanding the formation of public opinion in science communication. This study began in part as a response to scholarly criticisms of framing, and we seek to bridge conceptual and methodological gaps in photographic-textual framing research. By providing a conceptual and working definition of a photographic-textual frame and testing it in different science contexts, we found empirical support for the synergistic effects of photographic-textual and risk-benefit frames, and demonstrated how the additive effects differ across the two sciences. We conclude from our findings that there is partial truth to the old adage—photographs may be worth more than what a thousand words could convey in science communication, albeit the effect is observable contingent on the science context.

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Figure 1. Two-way Interaction of Photographic-textual Frame, and Risk-benefit Frame on Public Support for Sciences.

Note: Scale ranges were only partially displayed on the y-axis.

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Figure 2. Three-way Interaction of Photographic-textual Frame, Risk-benefit Frame, and Types of Science on Public Support for Sciences.

Note: Scale ranges were only partially displayed on the y-axis.

Note: Scale ranges were only partially displayed on the y-axis.

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Table 1. Three-way MANCOVA for Attention

Test of between-subject effects

Dependent variable: Attention

Source	Type III Sum of Squares	df	Mean square	F	Sig	Partial Eta Squared
Corrected Model	2.61	13	.20	3.29	.00	.09
Intercept	2.14	1	2.14	35.09	.00	.08
Risk-Benefit Frame	.13	1	.13	2.08	.15	.01
Photographic-Textual Frame	1.58	1	1.58	25.96	.00	.06
Science Topic	.13	1	.13	2.16	.14	.01
Photographic-Textual*Risk-Benefit	.01	1	.01	.23	.64	.00
Photographic-Textual*Science Topic	.00	1	.00	.02	.88	.00
Risk-Benefit*Science Topic	.00	1	.00	.04	.85	.00
Science Topic*Photographic- Textual*Risk-Benefit	.01	1	.01	.08	.78	.00
Error	26.16	430	.06			
Total	1187.16	444				
Corrected Total	28.77	443				

Note: R-Squared = .09 (Adjusted R-Squared = .06); Participants' age, gender, and ethnicity were treated as control variables.

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Table 2. Three-way MANCOVA for Risk Perception

Test of between-subject effects

Dependent variable: Risk Perception

Source	Type III Sum of Squares	df	Mean square	F	Sig	Partial Eta Squared
Corrected Model	76.54	13	5.89	13.96	.00	.30
Intercept	.15	1	.15	.35	.56	.00
Risk-Benefit Frame	32.88	1	32.88	77.94	.00	.15
Photographic-Textual Frame	.09	1	.09	.22	.64	.00
Science Topic	28.82	1	28.82	68.30	.00	.14
Photographic-Textual*Risk-Benefit	.22	1	.22	.51	.48	.00
Photographic-Textual*Science Topic	.30	1	.30	.71	.40	.00
Risk-Benefit*Science Topic	1.75	1	1.75	4.14	.04	.01
Science Topic*Photographic- Textual*Risk-Benefit	1.42	3	1.42	3.38	.07	.01
Error	181.40	430	.42			
Total	4442.11	444				
Corrected Total	257.95	443				

Note: R-Squared = .30 (Adjusted R-Squared = .28); Participants' age, gender, and ethnicity were treated as control variables.

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Table 3. Three-way MANCOVA for Public Support

Test of between-subject effects

Dependent variable: Public Support

Source	Type III Sum of Squares	df	Mean square	F	Sig	Partial Eta Squared
Corrected Model	991.22	13	76.26	27.56	.00	.45
Intercept	15.06	1	15.06	5.44	.02	.01
Risk-Benefit Frame	359.65	1	359.65	129.98	.00	.23
Photographic-Textual Frame	7.39	1	7.39	2.67	.10	.01
Science Topic	430.71	1	430.71	155.66	.00	.27
Photographic-Textual*Risk-Benefit	17.04	1	17.04	6.16	.01	.01
Photographic-Textual*Science Topic	19.42	1	19.42	7.02	.01	.02
Risk-Benefit*Science Topic	50.56	1	50.56	18.27	.00	.04
Science Topic*Photographic- Textual*Risk-Benefit	20.23	1	20.23	7.31	.01	.02
Error	1189.82	430	2.77			
Total	19249.50	444				
Corrected Total	2181.04	443				

Note: R-Squared = .45 (Adjusted R-Squared = .44); Participants' age, gender, and ethnicity were treated as control variables.

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ⁱ The term “nuclear” in “image-nuclear news story” should not be confused with the use of “nuclear” when referring to nuclear energy.

ⁱⁱ To request for a copy of the experimental stimuli, contact the first author of this manuscript.

ⁱⁱⁱ While this study is primarily focused on examining additive effects of exposure to science stories, photographic-textual, and risk-benefit frames, we acknowledge that risk perception may mediate the relationship between exposure to science and public support. Using the classical Baron and Kenny (1986) mediation test, we found that risk perception was a partial mediator of exposure to science and public support ($B = -.73, p < .001$).