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Psychological factors and social processes influencing wildfire smoke protective behavior: Insights from a case study in Northern California

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ABSTRACT

The health impacts of wildfire smoke are an important and growing global issue, as extreme wildfire events are expected to increase in frequency and intensity throughout this century due to climate change. Research into individual protective health decision-making can elucidate how wildfire smoke exposure contributes to adverse health outcomes and aid in public health interventions to mitigate risks. In this study we investigate the role of psychological factors (threat and efficacy perceptions) and social processes (social norms and social support) in shaping protective behavior in response to wildfire smoke. Through semi-structured interviews of forty-five individuals in Northern California, we explore perceptions of threat and efficacy, social processes, and protective behaviors in response to wildfire smoke events between 2018 and 2020. We found that for many participants sensory experiences and engagement with wildfire smoke information were instrumental in forming perceptions of threat and efficacy. Three themes related to social processes emerged: interpreting information together, protecting vulnerable others, and questioning protective actions. Through these themes we show how social norms and social support interact in complex, non-linear ways to influence threat and efficacy perceptions, and directly affect protective health behavior. Finally, we propose a conceptual framework of wildfire smoke protective behavior. This study contributes to a growing body of knowledge within the disaster risk and protective health literatures related to wildfire smoke response. Our findings demonstrate how the study of psychological factors and social processes during natural hazards, like wildfire smoke events, is essential to understanding individual protective health decision-making pathways and ultimately, to developing a more comprehensive view of how individual actions affect exposure.

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1. Introduction

Extreme wildfire events, like those that have recently devastated regions of the western United States (U.S.), southeastern Australia, and Brazilian Amazon, pose a growing and significant health threat to people around the globe. Exposure to wildfire smoke has been linked to negative short and long-term health impacts (Reid et al., 2016; Xu et al., 2020). Wildfire smoke contains fine particulate matter ($PM_{2.5}$), with more oxidative and proinflammatory components (from burned vehicles and structures) than urban air $PM_{2.5}$ (Balmes, 2018; Dong et al., 2017; Makkonen et al., 2010; Verma et al., 2008; Xu et al., 2020). In the short-term, exposure to wildfire pollutants (Larsen et al., 2018; Stone et al., 2019), is associated with coughing, shortness of breath, and headaches (Balmes, 2018). There are also reported associations between exposure to wildfire smoke and long-term adverse respiratory health (Liu et al., 2015; Reid et al., 2016), reproductive health (Abdo et al., 2019; Holstius et al., 2012), and cardiovascular health outcomes (Cascio, 2018), as well as higher risk of mortality (Xu et al., 2020). Finally, recent studies have found that exposure to $PM_{2.5}$ is associated with increased risk of COVID-19 infection and mortality (Wu et al., 2020; Zoran et al., 2020).

As climate change advances, wildfires and wildfire smoke events are expected to become more frequent and intense (Wu et al., 2018). Models show that climate change accounted for approximately 55% of fire aridity in the western U.S. from 1979 to 2015 (Abatzoglou and Williams, 2016). Liu et al. (2016) estimated that over 82 million people in the western U.S. will likely experience increasing intensity and frequency of wildfire smoke events by mid-century. Across the western U.S., housing growth in the wildland-urban interface has also increased wildfire risk, as more people live in and interact with flammable landscapes (Radeloff et al., 2018). However, because smoke can travel hundreds of kilometers from wildfires, even populations far away are likely to be affected. By the end of the century, fire-related pollution is predicted to account for more than 50% of the annual average $PM_{2.5}$ concentration in the U.S., leading to 17,000 to 44,000 additional wildfire smoke-related deaths each year (Wu et al., 2018).

To improve our understanding of how wildfire smoke exposure affects population health, we investigate individual protective health decision-making during wildfire smoke events, and the social processes that interact with and influence individual decisions. The role of behavioral and social processes in producing negative population health outcomes remains understudied (O'Lenick et al., 2019), but there is a growing acknowledgement that individual risk perceptions contribute to overall natural hazard risk by affecting how communities respond to and successfully mitigate environmental threats (Aerts et al., 2018; Eiser et al., 2012; Hayden et al., 2017). Behaviors such as staying indoors, wearing a particle-filtering mask when outdoors, and using indoor air filters, can mitigate exposure to wildfire smoke (Glik, 2007; Johnson, 2012; Xu et al., 2020). Yet, whether and how individuals engage with these behaviors may be related to features of social vulnerability, such as low access to information or resources (Cutter et al., 2003; O'Lenick et al., 2019) or the way threat perceptions are shaped by social interactions and information (Kasperson et al., 1988).

In this paper we provide empirical evidence of how social processes influence individual responses to wildfire smoke. Drawing from this evidence, we also advance a conceptual framework which describes how processes of social norms and social support influence perceptions of threat, efficacy, and behavior in the wildfire context. Catastrophic wildfires in California in recent years have exposed millions of people to wildfire pollution across the state and beyond. The 2018 Camp Fire, the most deadly and destructive wildfire in state history, burned 153,336 acres, killed 85 people, and destroyed 18,804 structures (CALFIRE, 2020a, 2020b). In 2020, five of the six largest wildfires in California history occurred, burning more than 4 million acres, approximately 4% of the entire state (CALFIRE, 2020c). By investigating the experiences, perceptions, behaviors, and reflections of individuals who lived through the wildfire smoke produced by the Camp Fire and recent extreme smoke events in Northern California, this paper provides insight into how social processes affect the pathways that lead to individual protective health actions. The findings also contribute to a conceptual framework of wildfire smoke protective behavior outlining these pathways, while acknowledging the complexity of the social, political, and cultural contexts where an individual is situated.

2. Relevant models and empirical literature

2.1. Behavioral models

Several theoretical models from social psychology and decision-science inform our investigation of protective health decision-making during wildfire smoke events. Particularly relevant are three behavioral models: the Health Belief Model (HBM), designed to understand health behaviors (Janz and Becker, 1984; Rosenstock, 1974); the Theory of Planned Behavior (TPB), used in both health and environmental psychology (Ajzen, 1998; Ajzen and Fishbein, 1980; Mccaul et al., 1993); and the Protective Action Decision Model (PADM), applied in natural hazard contexts (Lindell and Perry, 2012; McEachan et al., 2011). Although these models may differ by design, they all acknowledge the role of social processes and interactions in protective health decision-making. Both the HBM and PADM include social cues as signaling information that lead to threat evaluation and action (a construct akin to descriptive social norms), while the TPB suggests subjective norms (the behavioral expectations of important others) are predictive of behavioral intentions. However, the reflexivity of social interactions with behaviors is not deeply examined in these models. Causal paths between threat perceptions, social experiences, and behaviors may be non-linear, suggesting that further study is needed into the complexity of social processes during natural hazards and public health threats (Rimal and Lapinski, 2015). For more description of these behavioral models see Appendix A.

2.2. Social processes

Extensive research within the social sciences has examined how social processes influence individual decision-making in response

to public health and environmental threats (Bruch and Feinberg, 2017). In the health psychology and natural hazards literatures, *social norms*–shared belief systems that provide information on how to behave and manage relationships (Cialdini et al., 1991; Lapinski and Rimal, 2005)–and *social support*–the interactions that provide help during difficult events or crises (Kaniasty and Norris, 2004)–are two concepts that provide insight into the pathways of individual protective behavior during an extreme wildfire smoke event (Cialdini et al., 1991; Kaniasty and Norris, 2004; Lapinski and Rimal, 2005). Behavioral scientists have identified social norms as powerful motivators of protective action or inaction (Cialdini et al., 1991; Lapinski and Rimal, 2005; Schultz et al., 2007; for reviews on norms as social influence and empirical studies of normative interventions see Chung and Rimal, 2016; Farrow et al., 2017; Miller and Prentice, 2016).

Three types of social norms have been widely studied: *descriptive*, *injunctive*, and *subjective* (see Table 1). Descriptive norms give evidence of what most people are doing, providing information about effective or sensible actions. For example, people may be more likely to take a protective health action, like wearing a face mask, if they observe others doing the same thing (Lapinski et al., 2013). Alternatively, injunctive norms enforce prosocial behaviors like helpfulness through approval or sanctions (Berkowitz, 1972). Finally, subjective norms are perceived behavioral expectations that work through intimate social groups like a family unit (Ajzen, 1991; Lapinski and Rimal, 2005). During a wildfire smoke event, an adult child might expect their elderly parent to avoid outdoor activities. In the pro-environmental and natural hazards literatures, studies have found that perceptions of subjective norms are associated with individual mitigation actions, such as controlling invasive species (Niemiec et al., 2016) and maintaining flood insurance (Lo, 2013). A recent study on air pollution in China found that descriptive and injunctive social norms significantly predicted intended mask use (Yang and Wu, 2019).

During natural hazards or novel health events, when information is scarce or uncertain, behavioral norms often evolve (Lapinski and Rimal, 2005). During the 2013 Ebola crisis in West Africa, norms related to touch and burial rituals changed rapidly when these activities suddenly became vectors of disease (Rimal and Lapinski, 2015). However few studies have investigated the reflexive relationship between social norms and perceptions of threat and efficacy during hazards or health threats (Lo, 2013). Recent reviews suggest that more research is needed to understand the causal relationship between norms and behaviors (Rimal and Lapinski, 2015) and recommend qualitative research to provide a foundational understanding of how norms evolve and move within a community (Chung and Rimal, 2016).

In addition to social norms, research on individual and community responses to natural hazards has shown that social support can influence behavior (Kaniasty and Norris, 2004). Early work conceptualized social support as actions that reduce the psychological stress experienced by others before, during, or after an extreme event (Barrera and Ainlay, 1983). More recent scholarship has subdivided social support into three types: *informational*, *emotional*, and *tangible* (see Table 1) (Kaniasty and Norris, 2000). Under this framework, social support may be reciprocal, embodying behaviors that can be given or received. Health scholars have found that reciprocal social support may promote well-being (Maton, 1988; Schwartz and Sendor, 1999) and prevent negative impacts on self-efficacy after a crisis (Hogan et al., 2002). There is also evidence of a positive relationship between social support and health outcomes (Cohen, 1989; House, 2002), however the relationship between social support and protective behavior is less definitive. Some studies have found that individuals who experience greater social support are more likely to take protective actions before a traumatic event (Riad et al., 1999) or after (Kaniasty, 2012). Others suggest social support may moderate threat perceptions and efficacy perceptions by promoting self-efficacy (Lara et al., 2010) or by suppressing perceived risk (Babcicky and Seebauer, 2017; Wolf et al., 2010; Wong-Parodi et al., 2017). These conflicting findings demonstrate the need to further study the role of social support during natural hazards. In the context of wildfire smoke, reciprocal social support and its impact on protective behaviors has yet to be examined.

2.3. Air pollution and wildfire smoke empirical literature

While there is a rich literature on air pollution perceptions and risk communication (Bickerstaff, 2004; Bickerstaff and Walker, 2001; Cisneros et al., 2017; de Groot, 2012; Ramírez et al., 2019; Swan, 1970), only a few studies focus on individual responses to wildfire smoke. Of these, some seek to understand public tolerance to smoke events caused by prescribed burns (a preventative fire management strategy), finding that households with a higher number of health issues are more likely to be concerned with and less likely to tolerate smoke (Macey, 2008; McCaffrey and Olsen, 2012). With respect to wildfires, studies have shown that people recognize smoke as a health hazard and will take actions to protect their health (Hano et al., 2020; Macey, 2008; Rappold et al., 2019). For example, in a recent study by the U.S. Environmental Protection Agency (EPA), researchers used data from a smartphone application ("Smoke Sense") to document a positive association between individuals' perceptions of the benefits of protective actions and severity of short-term health impacts and mitigation behavior, such as avoiding outdoor recreation and staying indoors (Rappold

Table 1
Definitions of social processes.

Social process	Definition
Descriptive norms	Standards of behavior based on observations of what others do
Injunctive norms	Perceptions of what behaviors most people in a social group approve or disapprove of
Subjective norms	Perceptions of expected behaviors by valued others (e.g., close friends and family)
Informational social support	Information about how to understand a situation and suggestions on how to behave or what to do in response
Emotional social support	Reassuring or affectionate behaviors
Tangible social support	Giving or receiving material items (e.g., food, money, temporary shelter)

et al., 2019).

Another body of work focuses on how individuals interact with health communications and information about wildfire smoke. Although a recent review found mixed evidence of public health messages eliciting behavior change (Fish et al., 2017), studies have found that information can influence threat perceptions (Kolbe and Gilchrist, 2009; Marfori et al., 2020). A study in Australia suggests that public health communications promoted behaviors that reduced smoke exposure during a bush fire (Kolbe and Gilchrist, 2009). Another case study found that during a bushfire some individuals were given conflicting behavioral guidance; they were advised to remove fuels around their home to mitigate fire risk and also avoid outdoor physical activity to mitigate smoke exposure (Marfori et al., 2020). These competing messages may have led to diminished threat perceptions of wildfire smoke (Marfori et al., 2020).

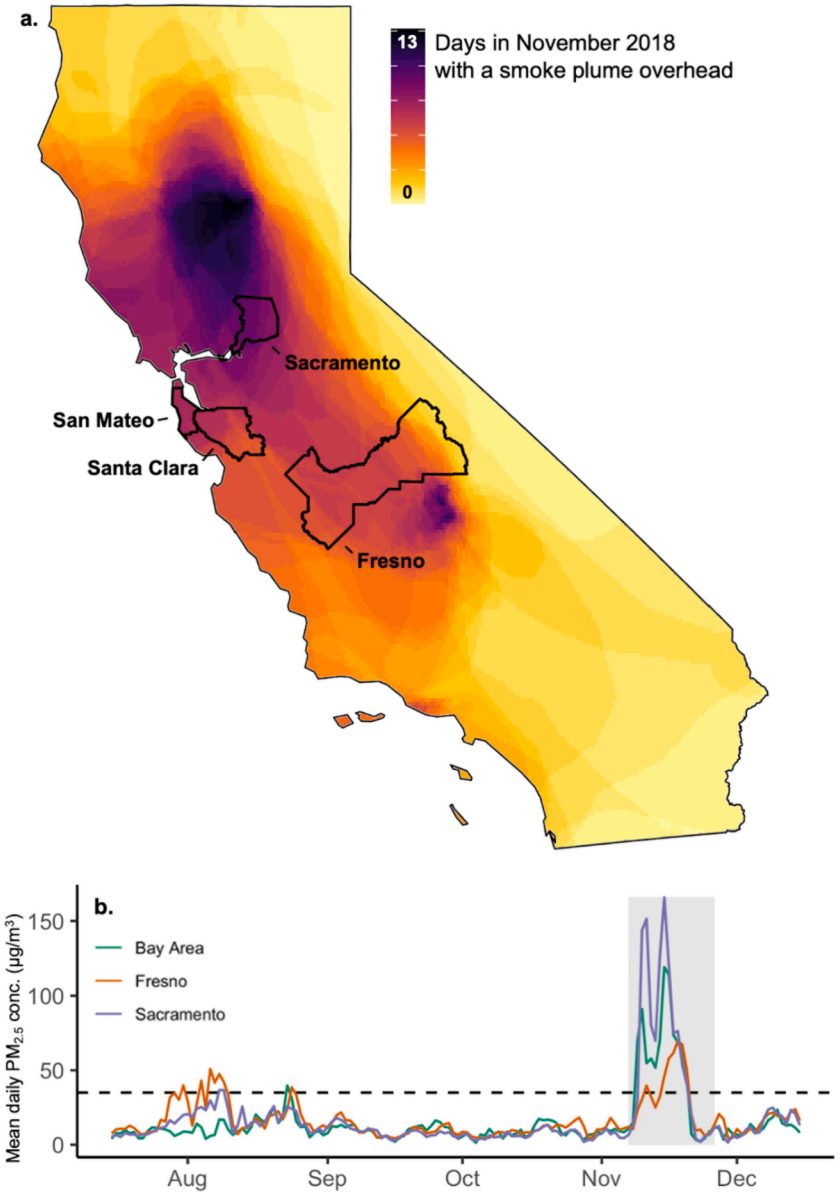

Fig. 1. (a) Map of California showing study counties and number of days with smoke plume overhead during the Camp Fire in November 2018; data on daily observations of smoke plumes was obtained from the NOAA Hazard Mapping System (NOAA, 2020). (b) Daily mean concentrations from measurements at EPA Air Quality System monitors located in each county during the 2018 fire season. Bay Area includes data from monitors in San Mateo and Santa Clara counties. The shaded area shows duration of the Camp Fire (the same period represented in panel (a), and dashed line is the NAAQS 24-hour standard for $PM_{2.5}$ of 35 µg/m^3. The methods we used to generate this figure are described in Appendix C.

3. Research design and methods

3.1. Research questions and objectives

Despite increased interest in wildfire smoke risk, relationships between threat perceptions, efficacy perceptions, and the social processes involved in protective health decision-making have not been examined holistically using a qualitative case study approach, as we do in this paper. Through a case study, we examine the lived experiences of individuals exposed to extreme wildfire smoke events in context, observing and validating relationships between psychological constructs, generating new theories and models of behavior, and posing hypotheses that can be further tested through quantitative methods, like surveys (Creswell and Clark, 2017). This study thus contributes to a growing body of knowledge that seeks to better understand public perceptions of wildfire smoke as a health hazard and the social processes that may motivate or hinder protective health actions.

We investigate the protective health decision-making processes of individuals exposed to wildfire smoke from the 2018 Camp Fire and other major wildfires in California during the 2019 and 2020 fire seasons. These extreme wildfire events and the experiences of individuals who were exposed to the associated smoke provide a critical case of wildfire smoke exposure, allowing us to identify and describe the psychological factors and social processes that influence protective health decisions. Regarding individuals' lived experiences of these major wildfire events, we explore the following three research questions:

1. How do individuals perceive the threat of wildfire smoke?
2. How do individuals perceive the efficacy of their actions in response to wildfire smoke?
3. How do social processes, such as social norms and social support, interact with wildfire smoke threat perceptions and efficacy perceptions to influence protective health behavior?

3.2. Interview protocol

To answer these questions, we developed an interview protocol informed by existing behavioral models and empirical literature on social processes. Interview topics included: (1) tenure of residency and sense of place; (2) knowledge and perceptions of fire seasons, causes, and baseline air quality; (3) previous experiences with wildfires, wildfire smoke, and air pollution; (4) perceptions and experiences during the Camp Fire and other major wildfire smoke events in 2019 and 2020; (5) use of and trust in information about wildfire smoke; (6) protective actions taken to mitigate risk from wildfire smoke exposure and perceptions of response efficacy (effectiveness of specific actions); (7) protective actions that participants wished they had taken or plan to take in the future; and (8) reflections on emotions related to wildfire smoke experiences and the interview process. Not all interview topics or emotional social support, due to few mentions, are discussed in this paper. To review the full content of the protocol please see Appendix B.

3.3. Study area

We conducted interviews in four counties in northern California: Fresno, Sacramento, Santa Clara, and San Mateo (Santa Clara and San Mateo will be referred to as "Bay Area" counties). We selected these counties because residents were severely impacted by wildfire smoke from the Camp Fire in 2018 and by major wildfire events in the 2019 and 2020 fire seasons (see Fig. 1). We also selected and stratified counties based on baseline exposure to $PM_{2.5}$ using data from the EPA, which sets National Ambient Air Quality Standards (NAAQS) and annually assesses whether counties are in attainment (areas that meet air quality standards) or nonattainment (areas that fail to meet air quality standards) (US EPA, 2016). Fresno County was in severe nonattainment for $PM_{2.5}$ from 2018 to 2019, whereas Sacramento and Bay Area counties have been in moderate nonattainment for $PM_{2.5}$ during those same years (US EPA, 2016). This sampling strategy ensured that we interviewed individuals with varying levels of previous experience with poor air quality.

3.4. Data collection

This study draws from 45 semi-structured interviews with individuals who lived or worked in the study area. We interviewed 18 individuals from Fresno County, 13 from Sacramento County, and 14 from Bay Area counties. The interviews were conducted between June 2019 and September 2020. Interview participants were selected through purposive and snowball sampling, using key informants from regional advocacy groups and community organizations (Creswell and Poth, 2016; Patton, 2015). Our interview sample was not intended to be strictly representative of northern Californians, but instead capture a diversity of lived experiences, baseline air quality, and wildfire smoke exposure across demographic characteristics such as age, race, ethnicity, occupation, and gender; for participant demographics see Appendix D. We were particularly interested in understanding the decision-making processes of individuals vulnerable to the effects of smoke due to their susceptibility (e.g., people who are over 65 years old or with chronic respiratory illness) or exposure (e.g., outdoor workers).

All interviews were conducted by an interviewing team member (DJXG, FNS, JZM, or SLF) and were audio recorded and later transcribed verbatim. Interviews lasted between forty-five minutes and two hours and were conducted in the language preferred by participants: forty-three interviews were conducted in English and two in Spanish. During 2019 and January 2020, we met interview participants in their homes, cafes, or office spaces facilitated by community organizations. These locations ensured privacy for the participants and allowed the interviewer to establish rapport. After February 2020, all interviews were conducted virtually as a precaution for COVID-19. Steps were taken to ensure privacy and comfort for participants considering the challenges of virtual formats

(Santana et al., 2021). For example, during in-person interviews, participants were asked questions using a printed image of the Air Quality Index (AQI) (see Appendix E). During virtual interviews, the same visual tool was used, but it was either sent to the participant by text message or presented through the "share screen" tool in Zoom. All interviewees were given $25 (USD) gift card incentives in gratitude for their study participation. The interview protocol was semi-structured, allowing the interviewer to pursue new lines of questioning when fruitful and the participants the space to describe experiences in their own words (Creswell and Clark, 2017; see Appendix B for the full interview protocol). After each interview, analytical memos were written by the interviewer to record additional contextual information about the interview setting and participants.

3.5. Data analysis

Interview data were coded and analyzed through a combination of deductive and inductive techniques by the coding team (FNS, MOJ, and SLF). Interviews were coded deductively into topics corresponding with the interview protocol, such as environmental cues, threat perceptions, self-efficacy, response efficacy, and protective health behaviors. Interviews were also coded inductively using thematic analysis to identify emergent patterns and connections between participants. Thematic analysis identifies patterns in the data without predetermining topics and constructs (Braun and Clarke, 2006; Charmaz, 2014). The inter-rater reliability score of the coding team was 0.8, widely accepted as a valid level of inter-rater agreement representing mutual understanding of the codebook (McHugh, 2012). After coding was complete, lead author FNS organized existing codes into three broader themes: interpreting information together, protecting vulnerable others, and questioning protective actions. These themes were developed such that the associated codes demonstrated internal homogeneity (within themes) and external heterogeneity (between themes) (Braun and Clarke, 2006), and are discussed in detail in section 4.4. Analytical memos developed by interviewers were also used to validate thematic findings. For more detail on codebook development see Appendix F.

4. Results and discussion

4.1. Conceptual framework

Informed by our interview analyses as well as existing empirical research and behavioral models, we propose a conceptual framework of wildfire smoke protective behavior (see Fig. 2). The framework outlines the decision-making pathways and interactions between psychological factors and social processes reflected in the experiences of our interview participants. It also acknowledges that decision processes occur in complex cultural, social, and political contexts, where factors like demographic characteristics, health

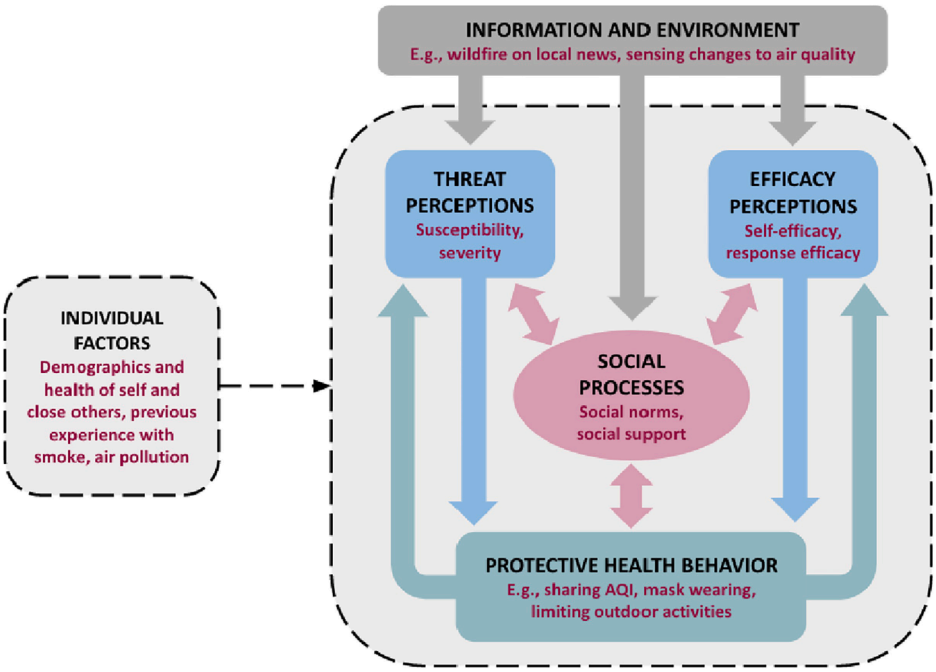

Fig. 2. Wildfire smoke protective behavior conceptual framework, based on analysis of semi-structured interviews and informed by the Health Belief Model (HBM) (Janz and Becker, 1984), Theory of Planned Behavior (TPB) (Ajzen, 1991), and the Protective Action Decision Model (PADM) (Lindell and Perry, 2012). For example, watching wildfire news coverage and smelling smoke may elevate health threat and protective behavior efficacy perceptions. These elevated perceptions may result in mask wearing, but social processes such as observing family not wearing masks may lead to individuals electing against mask wearing themselves.

status, and previous experiences with wildfire smoke and air pollution may also play a role in individual behaviors. Using this framework to address our first two research questions, we examine the role of information and environmental changes on participant threat perceptions (perceived severity and susceptibility) and efficacy perceptions (perceived self-efficacy and response efficacy). To address our third research question, we explain the novel ways that social norms and social support may heighten, or in some cases, diminish, threat and efficacy perceptions, ultimately altering pathways to individual protective health behaviors, as well as how social processes may directly influence protective health actions. We also discuss the reflexive nature of protective health actions, where the experience of enacting or avoiding certain behaviors may influence threat and efficacy perceptions, promoting or suppressing future protective actions.

4.2. Environmental changes on perceptions of threat and efficacy

The sensory experience of wildfire smoke increased many participants' perceptions of the severity of threat and for many participants, diminished their perceptions of self-efficacy and response efficacy. Most of our interviewees (n = 38) discussed how they perceived wildfire smoke to be a severe health threat, and many first learned about the wildfire smoke by sensing changes in the environment, describing both the olfactory (n = 24) and visual (n = 32) nature of encountering wildfire smoke (Appendix G). For example, one participant explained how the smoke smelled of "burnt-ness" that "wasn't quite like a barbeque" (P-24) and that "you could taste it [and] you could smell it. It was nasty" (P-25). Others reported what they saw, saying "[I]t was crazy! You couldn't see down the street. There was this gross color orange" (P-5). These environmental changes, related to the smell of the air and color of the light, were important cues for individuals as they first assessed the potential threat of the wildfire smoke. When talking about the air, a pattern emerged of how participants used language to evoke disgust; participants characterized the air as "heavy," "really thick," "dirty," "muggy," "dense," "grainy," "stuffy," "gross," "hellacious," and "stinging." One male participant, a landscaper, used a vivid metaphor, "I would have to describe it like a car…with a bad engine, just running, right on your face" (P-18). Another participant, a student, conjured the images of a dystopian film, saying it felt like "the middle of a Mad Max movie" (P-11). These descriptions exemplify the intensity of sensing wildfire smoke.

Although unusual, a few participants (n = 4) said they used their senses exclusively and did not search for information about wildfire smoke. One participant said he relied on visual cues to determine threat: "No, I didn't look at the rating system. I don't typically have to look at that. I just look at the sky and how dark it is" (P-44). A woman with two children knew the smoke was harmful "because you smell it in the air" (P-24). When her senses alerted her to the wildfire smoke threat, she took action by keeping her children indoors, bolstering her sense of self-efficacy. "I think I took all the steps necessary to make sure that we were in a healthy environment…. I kept my kids from the smoke as much as possible. So, I think I did okay" (P-24).

Sensing environmental changes led other participants to question their abilities or the effectiveness of protective actions. One retired physical therapist in Fresno said breathing in the smoke was "almost like an immune response, where my body is trying to fight something off, but it's an unknown entity and I don't think my body knows how to fight it" (P-33). A man who works in agriculture, said that "you can't sleep because of the smell. It stays on you and in your nose. I don't know if it's detrimental, but it felt like it burned" (P-45). Unsure of how their bodies would react to the smoke, these individuals connected smelling and breathing wildfire smoke to their health. Several interviewees (n = 5) noted uncertainty about mask effectiveness when they could still smell smoke through their masks. One participant complained that eventually "inside the mask you could smell the fire" and "it sort of [felt] better to just breathe outside the mask than [with] the mask on" (P-1), even though he knew that masks filtered the air. Another person said that even when wearing a mask, "it was hard to breathe. I could feel it in my lungs. It felt like I smelled it in my lungs" (P-3). These comments aligned with a broader theme among the majority of participants (n = 31) who engaged in "mask questioning": wondering either what type of mask to wear, how to manage mask discomfort, or when to replace a mask.

The power of sensory experiences to influence perceptions of threat and efficacy among participants is notable. Previous studies of air pollution have found that perceptual experiences are likely to influence interpretations of threat severity (Bickerstaff, 2004; Bickerstaff and Walker, 2001; Wakefield et al., 2001). Sensory experiences are particularly important at the beginning of a wildfire smoke event when uncertainty is high and before media or other information sources have reported on the wildfire. Our findings also point to the salience of initial perceptions of threat and efficacy. Many participants' first memories of smoke were based on sensory data, and they later recounted these experiences with clarity and detail. Literature on anchoring and adjustment suggests that these experiences could serve as a perceptual anchor (Epley and Gilovich, 2006; Tversky and Kahneman, 1974), providing a baseline for comparison that may bias future estimates of wildfire smoke threat as individuals live through changing smoke conditions. Research has found that physical anchors (e.g., a sound, a weight, or a smell) may influence how individuals estimate physical stimuli, leading to insufficient adjustment from the anchor (LeBoeuf and Shafir, 2006). Thus, with regards to wildfire smoke, an individual's physical experience of smoke could influence future smoke perceptions, causing overestimation of threat by those who first sense high smoke levels and underestimation by those who sense low smoke levels. Another path of study could investigate the ways that sensory evidence of wildfire smoke triggers memories of past events or comparisons to previous air quality threats, also impacting current assessments of threat.

4.3. Information and perceptions of threat and efficacy

Information also influenced participant perceptions of threat and efficacy. Our interviews revealed that participants received and searched for information from a diverse set of sources, including local TV news, government websites (e.g., Airnow.gov) and weather apps on their phone. Many sought information about both the wildfire itself (where it was burning, what percent was contained, which

areas were under evacuation orders) as well as the wildfire smoke (where the smoke plume was, the AQI, and smoke forecast). Many participants (n = 31) said that they frequently or "constantly" (P-5, P-9, P-26, P-42) checked for updated information specifically about the wildfire smoke. One participant looked for updated information about "six times a day," explaining that checking frequently was driven by "a curiosity and wanting to know what the hell is happening. If I'm going to go out, if I'm going to work in the yard, if I'm going to open windows…" (P-36). Another participant in Sacramento repeated this reasoning saying, "[I] was just trying to plan out our days… could I go to the grocery store? Do my daily walks with [my dogs]? Could we go outside?" (P-2). For many participants, checking for information was a pivotal part of their day; it helped them update perceptions of threat severity and influenced decisions to reduce wildfire smoke exposure (e.g., by staying inside or forgoing opportunities to meet up with friends and family).

This finding suggests that many individuals will frequently seek out updated information during a wildfire smoke event, echoing recent studies that demonstrate a demand for personalized data on wildfire conditions (Hano et al., 2020; Rappold et al., 2019). Future research could leverage these information seeking behaviors by providing real-time data from portable air quality sensors and monitoring subsequent protective health behaviors. More precise and frequent data from sensors could catalyze updated threat perceptions commensurate with actual risks and behaviors that mitigate those risks.

Information, or in some cases the lack of information, also interacted with participant perceptions of self-efficacy. Although participants knew that wildfire smoke was unlikely to change significantly between the times they checked for updates, several still felt compelled to check very often.

I just wanted to see change. I would look at it so often and even if I didn't see change it would make me feel better knowing exactly how bad the air was outside. [It] kind of gave me a sense of control even though I really didn't have any control. But it made me [feel] like I was doing something. (P-39)

This person's self-efficacy was challenged by the rapidly changing wildfire conditions. Frequently checking for information was partially motivated by the desire to regain "control." Another participant spoke to a related motivation,

I knew it wasn't going to change that day…. I would even look out the window [and think] 'Maybe it will change soon. Nope, not going to change soon.' So, I was checking constantly…I was trying to manifest a change in conditions. Also, you're just confirming what your eyes see. (P-5)

For this interviewee, checking for information was a coping strategy motivated by a feeling of helplessness and a wish to "manifest a change" in the smoke conditions.

Our findings suggest that relationships between information seeking, and perceptions of threat and efficacy are not straightforward. Although empirical research on smoke indicates that information insufficiency or inconsistency motivates information seeking (Rose et al., 2017), health communications scholars have found that people may seek information not just to decrease uncertainty, but also to increase or maintain it (Brashers, 2001; Carcioppolo et al., 2016). Thus, future work could investigate the drivers of information seeking during wildfire smoke through the lens of uncertainty management (Brashers, 2001). Additionally, some participants used the AQI to complement their senses, validating and contextualizing what they were already seeing, smelling, or tasting in the air. This finding adds a new dimension to previous research on air quality and natural hazards, which found the opposite: that individuals often validate information with environmental cues (Bickerstaff and Walker, 1999; Sorensen, 2000). However, these findings all suggest that individuals use information and environmental cues in an iterative manner, moving back and forth between the two, when perceiving threat. Bickerstaff and Walker (1999) have argued that for information to be deemed credible by the public, spatial scale and the local variation of air pollution experiences must be acknowledged. Applied to wildfire smoke, we might ask, how do individuals respond if they smell smoke near their home, but the AQI does not indicate unhealthy regional air quality? Also, much like information seeking in advance of hurricanes (Morss and Hayden, 2010), individuals are likely to use multiple sources of information to evaluate smoke risk at certain times and places. This may be driven by the desire to compare information sources, for example, comparing hourly pollutant concentrations reported on Airnow.gov to the more frequent data available from PurpleAir sensors, which provide information at a more granular spatial scale. Building on previous work examining how the public responds to tornado warnings (Ripberger et al., 2015; Trainor et al., 2015) and hurricane forecasts (Morss and Hayden, 2010), risk communications scholars could explore how individuals prioritize conflicting information during wildfire smoke events.

4.4. Social processes of protective health decision-making

Our analysis reveals three themes illustrating the role of social processes in individual protective health decision-making in response to wildfire smoke: *interpreting information together*, *protecting vulnerable others*, and *questioning protective actions*. Within these themes, we identified how different types of *social norms* and *social support* can affect individual perceptions of threat and efficacy in response to wildfire smoke.

4.4.1. Interpreting information together

By frequently checking for and then sharing information with loved ones, participants illustrated the ways that *informational social support* influences protective health decisions. A majority of participants exchanged information about wildfire smoke with others in their community (n = 35). Many of these individuals received social support, learning helpful information from people close to them. One participant contrasted the information she heard from friends with what was on the news. "Nobody [on the news] actually really told you how to survive if you were outside. So, I found [out] from people I knew, friends; I talked to them" (P-3). By talking with friends, this participant filled gaps in her her knowledge of face mask type and effectiveness, as well as other ways to mitigate her wildfire smoke exposure. Another female participant who engaged in mask questioning went to her "dad source."

I got into that black hole [wondering] 'What's a P95 or P100 filter? Should I pay more for one or the other?' … I talked to my dad,

who does machining and is around tiny particulates all day, and he was like "P95 is fine." … The dad source is my go-to, probably most reliable, more than the internet source. (P-5)

During uncertain conditions, this participant perceived her father's advice to be the "most reliable" (P-5). For many participants who trusted friends and family more than sources on the internet or news, the informational social support that they received was essential to how they interpreted the wildfire smoke threat and evaluated the effectiveness of protective actions.

Some participants provided informational social support to people in their social circle. One participant gave out "pretty general" information about the air quality by asking basic questions of her friends and neighbors. "[I] mostly just [asked], 'Are you aware that the air is really polluted right now?'…And 'Do you know about PurpleAir?'" (P-22). Other participants shared technical information: one individual used his skills with spatial data to provide fire maps, "I made some maps of the Camp Fire so that people in Paradise could see where the fire was, how it was growing, all of that, because government and firefighters were not. But I know how to find their data…" (P-1), while another shared knowledge about air filtration, "Some people [asked me], 'What kind of filtration would you buy?' So, I talked to a couple people about that, and told them what I used" (P-21). By creating maps about the scope of the wildfire and sharing air filtration tips, these participants provided informational social support that likely influenced others' perception of the severity of the threat from wildfire smoke as well as their behavior.

These findings demonstrate how informational social support helps individuals negotiate the uncertainty of the wildfire smoke threat and unfamiliarity with specific protective actions. To manage uncertainty in the face of information gaps or conflicts, participants used interpersonal sources of information to make protective health decisions. Information was then interpreted, shared, discussed, and reinterpreted through repeated social interactions. Our findings validate previous work suggesting that information can shape wildfire smoke threat perceptions (Kolbe and Gilchrist, 2009; Marfori et al., 2020), and also provide additional evidence that social support may lead to greater intentions to engage in actions to protect against wildfire smoke, as has been identified in other contexts (Kaniasty, 2012; Riad et al., 1999). An important extension of this work would be to examine the effects of reciprocal informational social support, as many participants indicated their perceptions of self-efficacy and response efficacy were bolstered by exchanging information. However, our understanding of self-efficacy perceptions in relation to informational social support is limited by our cross-sectional sampling strategy and the retrospective nature of most interviews. Future work using surveys could examine how perceptions of efficacy and threat change throughout an ongoing wildfire event, before and after informational social support is given or received. Also, information from government and media sources may become more sophisticated, locally relevant, and prescriptive as wildfires become more frequent. This will require individuals to reevaluate their trust in and perceptions of these information sources, which may influence the extent to which people engage in informational social support.

4.4.2. Protecting vulnerable others

By taking actions to protect more vulnerable others, interviewees illustrated how the social processes of *tangible social support* and the establishment of *subjective social norms* can influence protective health and mitigation decisions. Although the majority of our interviewees believed wildfire smoke posed a severe health threat and acknowledged personal short-term health impacts, many (n = 30) were concerned for the health and emotional well-being of others perceived to be more susceptible. Many participants (n = 16) reported giving or receiving tangible social support, for example by gifting face masks (n = 7), receiving face masks (n = 3), providing financial support to wildfire evacuees (n = 2), buying air filters (n = 4), or running errands (n = 3) (Appendix G). One participant gifted face masks, even though she did not personally feel susceptible to the wildfire smoke, "I didn't even need a mask. I don't work outside. I'm in a very privileged situation… so I bought thirty [masks] and brought them back [from a work trip] and was like 'Everyone, get a mask'" (P-5).

Several interviewees expressed concern for their elderly parents and reflected on actions taken to protect them. One participant experienced minor health impacts from the smoke like a "sore throat" and "raspiness," but was more concerned for her father. "I talked to my father the most…. He has been in the habit of walking outside, a mile and a half to two miles a day. Because of his COPD, I asked him not to do that" (P-33). This participant established a new subjective norm with her father: the expectation that he would refrain from going outside during the smoke. The enforcement of subjective norms between adult children and elderly parents was articulated across several interviews. Another participant caring for her mother explained, "I'm her main support person for everything… I'm in charge of her activities. I actually cancelled a couple appointments during that time because it I didn't want her out in it…. I got her a mask. It probably wasn't an adequate one, but I did the best I could" (P-6). By purchasing a mask for her mother, this interviewee advanced a subjective norm that one should wear a mask if it is provided by a trusted source.

Finally, participants cited concern for children and family members with respiratory health issues, translating concern into behavioral recommendations. One participant felt anxious about the smoke impacts on her "little cousin, who does have respiratory issues and lives in the Central Valley" (P-7), another his "brother-in-law who has asthma" (P-8), and another his "mom [who] has health problems" and "lung issues" (P-1). One mother highlighted the ineffectiveness of the air quality flag program in central California, where colored flags (green, yellow, orange, red or purple) corresponding to the AQI are posted outside of schools (Shendell et al., 2007). During the wildfire she knew the "air quality was bad [and] it was not good to go outside," but at school "the children were running during the fire. Red flags at the school meant 'no,' but the children were outside, like a normal day." She felt distressed about her son who was born prematurely and suffers from chronic allergies, "I was worried about the health of my children, [especially] my child who suffers from nosebleeds," so she told her son, "'Don't go out, even if the teachers let you out'" (P-23). To protect her son, she promoted a subjective social norm that her kids should stay indoors even if teachers gave different instructions. Another Fresno mother was worried "when my son was in school and he was in marching band, they wanted him to go out or run track" even when air quality was poor (P-30). She suggested that if other parents knew more about the AQI they would be "more vocal about" what school activities should be allowed during days with poor air quality. "I would tell people to go [look at the AQI], so they can get the

same kind of information…whether your kid can be outside" (P-30). By advocating for other parents' engagement with the AQI, this participant contributed to another developing subjective norm: parents should attend to air quality and encourage schools to be responsive to current conditions when determining safe outdoor activities.

Our findings highlight a link between social support and emerging subjective social norms. For example, we identified the practice of gifting masks in these California communities–which did not exist–to our knowledge, before the 2018–2020 wildfires. Future work on wildfire smoke and social support could also engage with recent literature on how collective interest and pro-social motivations are related to protective actions during COVID-19 (Jordan et al., 2020; van der Linden and Savoie, 2020). To date much of this work has examined the effects of pro-social motivations on mask wearing intentions, but has yet to explore gifting tangible goods, and thus the possible associations between prosociality, social support, and subjective norms. Additionally, our findings related to parental concern about the lax implementation of the air quality flag program in Fresno schools suggest the need for research on wildfire smoke exposures, threat perceptions, and protective behaviors in socially vulnerable communities. Recent work exploring air pollution perceptions in central California identified significant gaps in information reach and information clarity to vulnerable populations (Ramírez et al., 2019). The disproportionate burden of air pollution impacts on racial and ethnic minority communities has been well-documented in the public health literature (Kinney, 2018; Mohai and Saha, 2015). It is imperative that population health scholars investigate how differential access and responses to wildfire smoke information influences protective behaviors and, in turn, exposure.

4.4.3. Questioning protective actions

We found that by questioning protective actions participants acknowledged the presence or absence of *descriptive social norms* in their community as well as *injunctive social norms* related to protective behaviors. Some participants identified descriptive norms by observing others' choices to mitigate exposure to wildfire smoke. Specific to mask use, one participant said "I don't even know what the rating is. It's [the mask] they had out that everybody was buying, so I was like, 'Oh, this is the one to wear" (P-8). This participant used a mask-type descriptive norm and acted directly on it. In other cases, participants commented on how their behavior diverged from the descriptive norms around them. A registered nurse, well-informed about mask type and efficacy, remarked, "I'd be out wearing a mask and nobody else was. So, I don't think most people take it very seriously" (P-22). By observing others not wearing masks, she inferred that smoke was not considered a serious threat by those around her.

Inconsistent or conflicting mask recommendations also resulted in participants questioning emerging *injunctive social norms*. An arborist said, "I remember that whole controversy about the different types of masks for the smoke. Some people were saying this type of mask, other people saying, 'No, that doesn't do anything'" (P-17). Another participant received conflicting advice from the news and her friends,

I cannot remember the exact name of the mask…but the ones that have a filter. The local news that was saying how you shouldn't wear those, or the elderly shouldn't be wearing them…Also friends or people in my immediate social circle [were saying], 'We don't need a mask. The news says the masks are bad for you.' But there's no way breathing in the air [was] good, so [I thought], 'I'm going to disagree with you and keep wearing my mask.' (P-11)

Additionally, participants mentioned uncertainty related to mask replacement (n = 5). "I heard that if you wore your mask too long, it would no longer be useful. That's why I only wore it when I was outside. Once my mask was done, I didn't know if I was going to get ahold of another one" (P-10). This participant's concern about mask scarcity and replacement limited when he would wear his mask to extend its usefulness.

These findings illuminate how individual responses to novel natural hazards may lead to the development of social norms that interact with protective health decision-making. Our interviewees described inconsistent and rapidly changing descriptive and injunctive norms and the confusion they produced, specifically highlighting mask questioning. For many participants, protective action decisions required an iterative approach of observing others, evaluating and questioning behavior, adjusting behavior, and so forth. Ultimately participants self-reported engaging in many different protective behaviors: staying indoors (n = 43), mask wearing (n = 42), using an air purifier (n = 16), evacuating the area (n = 11), replacing air filters in air-conditioning system (n = 9), using personal air sensors (n = 5), placing towels in door and window gaps (n = 5), and wearing long-sleeved clothes (n = 1) (Appendix G). Importantly, norms specific to face masks have continued to evolve during the ongoing COVID-19 global pandemic, leading researchers to identify how social norms may promote mask saving intentions (Si et al., 2021) and mask use (Nakayachi et al., 2020; van der Westhuizen et al., 2020). However, during COVID-19, social norms do not uniformly promote masks, with recent studies suggesting that within certain groups–young people (Andrews et al., 2020) or men (Palmer and Peterson, 2020)–norms may discourage both mask use and social distancing. Examining the diversity of social norms within different demographic or social groups may also yield insights into protective behaviors during wildfire smoke events.

5. Conclusion

The challenge of understanding and promoting protective health behaviors in response to natural hazards and health threats is of vital importance, as communities around the globe address the impacts of wildfire smoke. Wildfire smoke exposures may exacerbate disease burdens in areas already impacted by ambient air pollution (Liu et al., 2016), and may also substantially impact mortality and morbidity in areas that do not typically have high $PM_{2.5}$ concentrations (Vodonos et al., 2018). Despite evidence that individual protective behaviors can mitigate exposure to harmful wildfire smoke pollution (Xu et al., 2020), research on the factors that may motivate or moderate these actions is sparse. Theories of social vulnerability (Adger, 2006; Cutter et al., 2003; O'Lenick et al., 2019) and social amplification of risk (Brenkert-Smith et al., 2013; Kasperson et al., 1988) suggest that access to information and resources, as well as social interactions, are likely to impact protective behavior. This study's findings provide a novel perspective on the

psychological factors and social processes influencing protective health behaviors in response to the specific threat of wildfire smoke. These insights inform a conceptual framework suggesting complex, recursive relationships between information, the environment, perceptions of threat and efficacy, social processes, and protective behaviors that may be further modeled and examined through studies involving representative surveys. Additionally, our findings on social norms and social support can inform the effective design of public health communications and behavioral interventions and can contribute to the improvement of population health studies aiming to accurately estimate health effects of wildfire smoke exposures. When designing future studies and interventions, we recommend that researchers and public health officials consider how social processes in affected communities may influence exposure to wildfire smoke at the population level.

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CRediT authorship contribution statement

Francisca N. Santana: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing - review & editing, Visualization, Project administration. **David J.X. Gonzalez:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing - review & editing, Visualization. **Gabrielle Wong-Parodi:** Conceptualization, Methodology, Resources, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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