

Article

The Role of Suppression Performance Information in Judging When to Use a Fire Extinguisher

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Abstract: The ability of a fire extinguisher to suppress fires varies by the rated performance of the unit. Safety guidance in the United States indicates that the occupant should consider the performance rating of the extinguisher when deciding to use it with a fire. The present study investigated whether individuals are aware of the connection between the suppression performance of fire extinguishers and the intensity of fires the unit can extinguish. Across five experiments, participants were presented with fire extinguishers that varied in suppression performance (smaller, medium, and larger) and judged whether the extinguisher could extinguish a developing room fire that increased in intensity. The fire intensity at which they stopped attempting to use the extinguisher (threshold) was calculated. No significant differences in threshold were observed by suppression performance condition when suppression information about the single extinguisher at hand was presented. This included when information was provided about the amount of agent, the distance and duration of discharge, and with the water equivalent the extinguisher was rated. However, when trained on the differences in suppression performance between extinguishers and provided with corresponding containers of water, thresholds did vary by performance rating. We discuss how providing information about variations in suppression performance may be necessary to highlight differences in extinguisher ratings.

Keywords: decision making; human behavior in fire; perception-action; information processing; mental representation



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1. Introduction

Fire extinguishers are portable devices used to suppress a fire [1]. Several types of extinguishers are commercially available, categorized by which combustible materials they should be used with as well as different performance ratings. The performance rating of an extinguisher refers to how large of a fire it is capable of suppressing [2]. To effectively use a fire extinguisher, individuals need to know what actions to take and when to attempt to extinguish the fire. Despite multiple ratings being available for commercial and residential use, it is unknown whether individuals connect the suppression performance of extinguishers with the highest intensity fire they can extinguish. Research provides evidence of significant variations in layperson fire extinguisher knowledge including the use actions required and which classes can be used with categories of combustibles [3]. In the present study, we focused on layperson judgments of extinguisher suppression performance. Specifically, we examined whether individuals incorporated the suppression performance of the extinguisher when judging if they should use it to put out a developing fire. In doing so, we assessed whether individuals were aware of the connection between fire extinguisher suppression performance and fire intensity.

1.1. Sources of Fire Extinguisher Knowledge

Knowing how to use a fire extinguisher is typically learned from employers and publicly available information. Most training focuses on how to use an extinguisher and the types of combustibles they can be used with. The recommended action sequence that is the focus of training materials is the pull (remove the pin), aim (the nozzle), squeeze (the trigger to discharge agent), and sweep (motion to apply agent across fire), or PASS, technique [1]. Fires are categorized by the combustibles involved (e.g., class A: wood; class B: oil; and class C: electrical), and extinguishers are labeled based on which class they can extinguish [1]. Awareness of these aspects of fire extinguishers is crucial to effective use with fires without posing an increased risk of harm to the occupant. In the United States, workplace organizations that provide fire extinguishers are required to train employees who are permitted to use them [4]. In residential homes, training is typically not required of occupants even though many jurisdictions require that property managers provide tenants access to fire extinguishers [5]. In the absence of formal training, instructional materials are available from fire extinguisher manufacturers and government organizations. However, awareness of this information can vary. Indeed, the general population varies in fire extinguisher action technique and knowledge about combustibles, with those lower in knowledge reporting less ability in being able to effectively use extinguishers [6]. As such, the fire safety benefits of having an extinguisher placed within a business or home could be diminished when occupants have little knowledge about performance and usage.

The perceived suppression performance of extinguishers has been the focus of less research when compared to that of performed actions and combustible information. In the United States, commercially available fire extinguishers receive a rating that indicates the fire suppression performance of the unit. These ratings correspond to the fire intensity that can be suppressed by the extinguisher. For example, Underwriter Laboratories (UL) assigns a rating for use with class A fires based on performance when extinguishing fires with increasing amounts of wood and fuel (e.g., a 1-A rating is based on performance with 72 wood members whereas a 10-A rating is based on performance with 324 wood members) [7]. For class A extinguishers, these ratings correspond to an equivalent amount of water (e.g., a 1-A rating is equivalent to 4.5 L; a 10-A rating is equivalent to 64 L) [7]. However, the amount of information available to building occupants about the suppression performance of an extinguisher varies. In the United States, the canister labels indicate several performance factors: the class of fires the extinguisher can be used with, the UL ratings, and in many cases, the total weight of the suppression agent contained within the unit. Notably, the water volume that corresponds to class A ratings is not typically provided on extinguisher labels. Additional information about performance is provided in user manuals for extinguishers, typically including the distance and duration at which the unit can discharge the agent. Although perceptual characteristics of the units are also available, specifically the physical dimensions and weight of the canister, these may not provide accurate estimates of suppression performance due to the type of canister material (e.g., lighter aluminum versus heavier steel) as well as the pressurization of the contained agent. Whether the general public connects extinguisher suppression performance with fire intensity remains to be examined.

1.2. Perceptions of Extinguisher Suppression Performance and Fire Intensity

Despite the information about extinguisher performance that is available, ambiguity may be present when an occupant is deciding whether to use an extinguisher with a fire due to several factors. First, there is variation in how fires grow in intensity based on combustibles and building characteristics as well as the resulting hazards posed via byproducts (e.g., smoke) [8]. This entails that the hazards posed by a fire in one incident may

differ from another, including whether it is appropriate to attempt to use a fire extinguisher. Second, fire safety guidance emphasizes that extinguishers should be used with incipient fires that are small enough to be extinguished [1]. This may also contribute to ambiguity as guidance lacks specific information about how to determine whether the intensity of the fire is indeed small enough in comparison to the suppression performance of the extinguisher at hand.

Each of these factors may contribute to ambiguity in how intense a fire an extinguisher can suppress. In such cases, occupants may be less likely to attempt to use an extinguisher or expose themselves to increased risk of injury if used improperly. This includes use with a fire that exceeds the suppression performance of the extinguisher. Indeed, a report in 2010 reviewing incidents involving the use of fire extinguishers observed that the majority of non-extinguishment events were due to using an extinguisher with a fire that was too large for the extinguisher to suppress [9]. This highlights the need for additional research to investigate how individuals perceive the suppression performance of fire extinguishers.

1.3. A Cognitive Model of Fire Intensity and Extinguisher Suppression Performance

We hypothesize that another source of ambiguity is the mental representation of fire extinguisher suppression performance. Drawing on cognitive models of number judgments, the occupant must compare a symbolic representation of suppression, the rating and performance information within the extinguisher label and manual, to an analog quantity, the physical fire. In the triple-code number model, comparisons of numbers in symbolic form (e.g., spoken words or printed digits) are performed using corresponding analog mental representations [10]. These analog representations are non-symbolic Gaussian distributions arranged on a mental more-versus-less continuum and allow for ordinal judgments to be made, such as which digit is greater in value (i.e., the representation farther along the more-versus-less continuum). For example, when an individual compares the values of “7” and “9”, they first need to recognize these symbols as visual forms of numbers using learned knowledge; these visual forms are transcoded to corresponding analog magnitudes which provide numerical meaning, allowing for the judgment that “9” is greater than “7” in value. In this manner, the triple-code model provides a framework for processing symbols into quantitative meaning.

When applying the triple-code model to fire extinguishers, we suggest that fire intensity and suppression performance are similarly represented in the mind as analog representations. A prior study by Bonny and Milke (2023) observed evidence that the perception of fire intensity is supported by analog mental representations [11]. In the study, participants completed a comparison task where they were asked to judge which of two simulated fires was more intense. The participants were more likely to correctly select the more intense fire the greater the difference in the intensities between the two fires. This suggested that analog mental representations of fire intensity are similar to those in the triple-code model of number: they are imprecise, with representations of intensities close in value overlapping, contributing to difficulty perceiving the differences between them. We propose that similarly, people use analog representations to mentally represent extinguisher suppression performance. When an occupant judges whether an extinguisher can suppress a presented fire, we hypothesize that the occupant is comparing the corresponding mental representations to determine if the fire representation is larger than that of the extinguisher. Thus, those with more precise mental representations would be better able to judge whether a fire could be suppressed by an extinguisher.

In addition to the analog representation, comprehension of the symbolic description presented on labels and manuals is crucial to perceiving the suppression performance of fire extinguishers. In the triple-code model, individuals must learn to read and comprehend

visual number symbols (e.g., digits and number words) to transcribe them to analog representations. Whereas prior research has extensively examined the development of numerical language comprehension [12], we are not aware of prior research that has investigated the comprehension of fire extinguisher suppression performance descriptions. Without sufficient comprehension, individuals are likely to be inaccurate in transcoding symbolic descriptions of suppression performance into analog magnitudes. This indicates that the comprehension of extinguisher suppression performance contributes to judgments of whether a fire can be suppressed.

1.4. The Present Study

We investigated whether individuals could recognize differences in fire extinguisher suppression performance in relation to fires of increasing intensity. We hypothesized that if participants were aware of this connection, their judgments would be affected by extinguisher suppression performance. To manipulate suppression performance, three common extinguisher ratings (UL ratings: 1A, 2A, 4A) were selected and presented to different participants. Second, we hypothesized that providing descriptions of extinguisher suppression performance with increasing amounts of information would enhance differences in judgments. Across experiments, the extinguisher performance description was manipulated. Descriptions were varied by presenting the specific agent weight of the extinguishers (21.13 kg, 1.81 kg, and 4.54 kg) with a scaled-model diagram of an adult human (Experiment 1) with the addition of manufacturer specifications of discharge distance and duration (Experiment 2), and equivalent water volume (Experiment 3). Participants were provided with information about a single extinguisher performance rating during the experiment.

We further hypothesized that enhancing the comprehension of suppression performance would improve participant judgments. In Experiment 4, we examined whether training on variations in suppression performance magnified differences. To do so, participants were provided with instructional materials about all three extinguisher performance rating conditions; afterward they were asked to respond using only one of the presented extinguisher ratings, similar to the prior experiments. In Experiment 5, we addressed whether removing the context of an extinguisher when describing fire suppression affected comprehension. To do so, participants were presented with containers filled with water volumes that corresponded to the selected fire extinguisher ratings.

Simulations of a developing room fire were used to depict different intensities. Similar to prior research [13], simulations were used instead of real fires due to the level of experimenter control over the simulation parameters, including combustion, room layout, and numerical estimates of intensity (heat release rate). These simulations were rendered as video clips and presented to participants. Prior research has observed differences in the protective actions individuals report as the intensity of a fire increases using simulated and real videos [14–16].

To measure the perceived suppression performance of a unit, the highest fire intensity at which participants judged the extinguisher should not be used was calculated as the extinguisher threshold. We hypothesized that the extinguisher threshold would be higher for extinguishers of greater suppression performance and this effect would be stronger with more information about suppression performance and with training.

2. Method

2.1. Open Practices Statement

All data, analysis codes, and research materials are available via an online repository (<https://doi.org/10.17605/OSF.IO/C2FQW> [17]). All the analyses were conducted using

R and the following packages: “effectsize” [18], “emmeans” [19], and “lme4” [20]. The figures were generated using the “ggplot2” R package [21]. All the tests were two-tailed ($\alpha = 0.05$). The study design and data analyses were not pre-registered.

2.2. Participants

A total of 411 participants were recruited from an online participant panel (Prolific.co) and retained for data analysis across all the experiments (age: $M = 36.56$ years, $Min = 18$, $Max = 72$; N biological male = 203; race: N Asian = 34, N Black or African American = 36, N multiple = 25, N White = 316). A total of 187 participants from Experiments 1 through 4 reported at least some prior experience with fire extinguishers (data not collected for Experiment 5). The recruitment requirements included normal or corrected-to-normal vision, United States residency, English fluency, and the use of a modern browser (Google Chrome or Mozilla Firefox) running on a laptop or desktop computer.

A sensitivity power analysis was run to determine the minimum effect size that could be detected for an analysis of variance interaction effect. With a sample size of 400, a set of five experiment conditions, and numerator degrees of freedom of four, the minimum effect size that could be detected with statistical power of 0.80 was Cohen’s $f = 0.174$. This indicated that the present study was sufficiently powered to detect whether a small to medium effect size [22] was present, but may not have been sensitive to very small effects.

2.3. Materials

The online experiment was hosted via a JATOS server [23] and coded using jsPsych [24]. Fire simulations were run using the FDS software (version 6.7.9) [25] and rendered as videos via the PyroSim software (version 2022.2.0803) [26]. The simulated room was a residential living room and the adjacent hallway. The room contained a sofa with two adjacent side tables opposite of the room entrance, a coffee table in front of the sofa, a chair next to the room entrance, and a trashcan. The dimensions of the furniture were based on specifications typically observed in the United States. The fire for this simulation was rendered on the surface of the coffee table (1 m width and depth, centered in middle of table). As the focus of the present study was on fire intensity (measured as heat release rate, HRR), smoke opacity was rendered as near-transparent. A set of nine videos of the simulation were rendered (8 s duration) depicting the fire at increasing intensities (mean video HRRs: 1.13, 21.80, 68.38, 140.89, 239.34, 363.71, 514.03, 690.26, and 892.43 kW; Figure 1). For Experiments 1 through 4, color images of fire extinguishers from commercial websites were scaled in width and height in a diagram where each was presented with a silhouette of an adult male (height = 1.77 m). For Experiment 5, containers filled with different volumes of water corresponding to extinguisher ratings were scaled and presented with the same silhouette.



Figure 1. Image captures from each video stimulus across experiment tasks (numbers correspond to the increasing fire intensities displayed in each video).

To estimate prior experience with fire extinguishers, participants in Experiments 1 through 4 reported the frequency at which they had engaged in extinguisher-related activities and events in the past (0 = “Never”, 1 = “Once”, 2 = “Several times”, and 3 = “Regularly”). This included extinguisher training (“Have you ever been taught or trained in the use of a fire extinguisher?” and “Have you ever used fire extinguishers

during training courses?”) and during fire incidents (“Have you ever used an extinguisher on a ‘real’ fire, outside of training?”). Due to the low frequency of responses for items, participants who responded “0” to all the items were characterized as having no prior experience; those who responded as “1” or higher to any item were characterized as having at least some prior experience with extinguishers. Note that fire experience was used as a descriptive variable and not included in any inferential statistical analyses due to the low frequency of experience.

2.4. Design

Participants were presented with each fire video in a fixed sequence from lower to higher intensity (within-subject, 9 levels). For Experiments 1 through 3, participants were assigned to a description condition that varied in the amount of information presented about the performance of an individual fire extinguisher (between-subject; Table 1). Each subsequent condition added additional information to the previous condition: weight (the weight of the agent in the extinguisher), weight + discharge (addition of discharge duration and distance based on manufacturer specifications, [27]), and weight + discharge + water (addition of water equivalent of extinguisher, per Underwriter Laboratories, UL, specifications, [7]). For Experiment 4, participants were trained with information about the performance specifications of differently rated extinguishers. For Experiment 5, instead of a fire extinguisher, participants were presented with a container that contained a specific volume of water that corresponded to UL ratings; at no point during the task were fire extinguishers described.

Table 1. Suppression performance information included in each experiment.

Experiment	Unit Type	Agent Weight	Discharge Duration	Discharge Distance	Water Volume	Training
1	Extinguisher	Yes	---	---	---	---
2	Extinguisher	Yes	Yes	Yes	---	---
3	Extinguisher	Yes	Yes	Yes	Yes	
4	Extinguisher	Yes	Yes	Yes	Yes	Yes
5	Container	---	---	---	Yes	---

For each experiment, participants were randomly assigned to different suppression performance conditions (between-subject, 3 levels: smaller, medium, and larger). These conditions corresponded to the performance specifications presented during the experiment (the specifications were presented in both imperial and metric units; Table 2).

Table 2. Suppression performance specifications for each extinguisher condition.

Suppression Performance	UL Rating	Agent Weight	Discharge Duration	Discharge Distance	Water Volume
Smaller	1A	1.13 kg	8–12 s	1.83–2.44 m	4.5 L
Medium	2A	1.81 kg	13–15 s	3.66–5.49 m	9.0 L
Larger	4A	4.54 kg	19–21 s	6.10–7.62 m	18.0 L

2.5. Procedure

After clicking on the online study ad, the participants were presented with a consent form. This research complied with the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board at Morgan State University (protocol number

22/12-0209). Informed consent was obtained from each participant. Those who provided consent were presented with the task.

The participants in Experiment 4 were presented with training that contained informational materials about the performance specifications for each of the three differently rated extinguishers used in the present study. For each performance rating, each type of information (Table 2) was presented with a post-test administered before continuing to the next extinguisher. Afterward, participants were informed which extinguisher rating they would use for the remainder of the experiment. The participants in all the other specification conditions did not complete the training.

All participants were asked to assume the perspective of a person in a scenario where they were visiting a neighbor's home to drop off an item. The house was unoccupied and when the person entered, they smelled smoke. Upon investigation into the living room, the participant noticed that a candle had started a fire on the coffee table.

In Experiments 1 through 4, the scenario stated that the person saw a common residential ABC class fire extinguisher within reach. Participants were provided with a description of the extinguisher. The description included the weight, distance, duration, and water equivalent information depending on the specification condition they were assigned. The description was provided with a diagram that depicted the width and height with respect to an outline of an average-height adult. Prior to the judgment task, participants completed a manipulation check which included questions specific to the experiment about the performance of the fire extinguisher they were presented. Afterward, the participant was reminded of the scenario and of the performance information of the extinguisher.

In Experiment 5, the scenario stated that a container with a specific volume of water was within reach. A diagram that depicted the width and height of the cylindrical container (only height was varied to represent the different volumes) with respect to an outline of an average-height adult was presented. Prior to the judgment task, participants completed a manipulation check. Afterward, the participant was reminded of the scenario and of the water container information.

For the judgment task, the participants were informed that they would view videos of the fire as it grew in intensity. The instructions emphasized that participants should be consistent in their responses. At the beginning of the trial, participants were informed the fire had grown in intensity. After pressing the "start" button, the video automatically played. Next, they decided whether the fire extinguisher or container could suppress the fire with response options of "yes" or "no". The specific prompt for Experiments 1 through 3 was, "Can the extinguisher put out the fire?"; the prompt for Experiment 4 was adjusted to include the weight of the specific capacity they were assigned, "Can the [weight] extinguisher put out the fire?" and the prompt for Experiment 5 was, "Can the water put out the fire?".

3. Results

3.1. Data Processing

The fire intensities were coded in order from one through nine, corresponding to the presented videos. Post hoc tests were adjusted using Sidak corrections for family-wise errors. Continuous factors in models were centered and scaled.

The participants who were inconsistent in their responses (using an extinguisher with larger but not smaller intensity fires) were dropped from further analysis (13 dropped and 411 retained). The number of participants for each suppression performance condition and experiment is presented in Table 3.

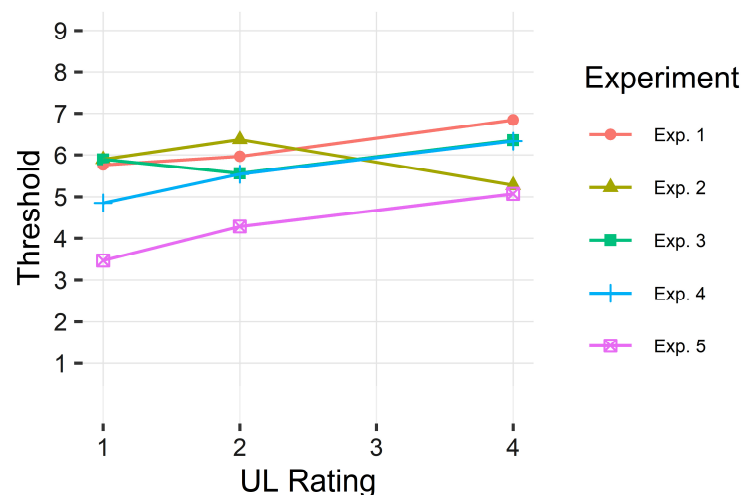
Table 3. Number of participants retained for data analysis by each experiment and suppression performance condition.

Experiment	Smaller	Medium	Larger
1	29	27	26
2	28	27	29
3	28	27	28
4	27	26	27
5	26	28	28

Some participants (78) did not respond correctly to all of the manipulation check questions. Across the experiments, the mean percent of correct responses to the manipulation check questions about suppression performance was 89% (SD = 31.12). The performance varied by manipulation check question (from highest to lowest mean percent correct): discharge distance (92.72%), weight (92.40%), water equivalent (84.66%), discharge duration (84.21%). Since participants were reminded of the relevant information after responding to the manipulation check, all participants were retained for data analysis with a control variable included to indicate whether the participant had passed the manipulation check.

3.2. Extinguisher Threshold

For each participant, the extinguisher threshold was calculated as the largest intensity fire (coded 1 through 9) that participants attempted to extinguish (the highest amount was assigned to those who indicated that the extinguisher could be attempted to be used with all intensities and the lowest amount for those who reported that they should not attempt to use the extinguisher at all; Figure 2). In this manner, a higher threshold indicated that the participant judged that the extinguisher could suppress a more intense fire (see Supplementary Material Figure S1 for responses at each intensity for each experiment).

**Figure 2.** Mean participant thresholds for each Underwriter Laboratories (UL) suppression performance rating across experiments (higher thresholds indicated greater fire intensities could be extinguished).

To examine whether the threshold varied by extinguisher suppression performance, the corresponding UL ratings were used to code the smaller to larger conditions (smaller = 1, medium = 2, and larger = 4; see Supplementary Material Table S1 for threshold descriptive statistics). A linear regression model predicting threshold with the main and interaction effects of rating and experiment and a control variable of passing the manipulation check

was fitted. Significant main effects of rating, $F(1, 400) = 4.19, p = 0.041$, Cohen's $f = 0.15$; experiment, $F(4, 400) = 10.57, p < 0.001$, Cohen's $f = 0.33$; and interaction between rating and experiment, $F(4, 400) = 3.12, p < 0.001$, Cohen's $f = 0.18$ were observed (main effect of manipulation check passed, $p = 0.910$).

The post hoc tests comparing the rating coefficient to zero observed significant effects for Experiment 4 (coefficient = 0.74, SE = 0.28, adj. $p = 0.042$) and Experiment 5 (coefficient = 0.78, SE = 0.28, adj. $p = 0.024$; all other adj. $ps > 0.19$; Figure 3). The interaction was driven by a significantly stronger effect of rating for Experiment 5 compared to Experiment 2 (adj. $p = 0.025$) and Experiment 4 compared to Experiment 2 (adj. $p = 0.038$; all other adj. $ps > 0.12$). When comparing experiment thresholds at each rating, those for Experiment 5 were significantly lower for all but Experiment 4 for the smaller rating (1A; adj. $ps < 0.001$) and than all the other experiments for the medium rating (2A; adj. $ps < 0.01$; all other adj. $ps > 0.05$; Figure 2).

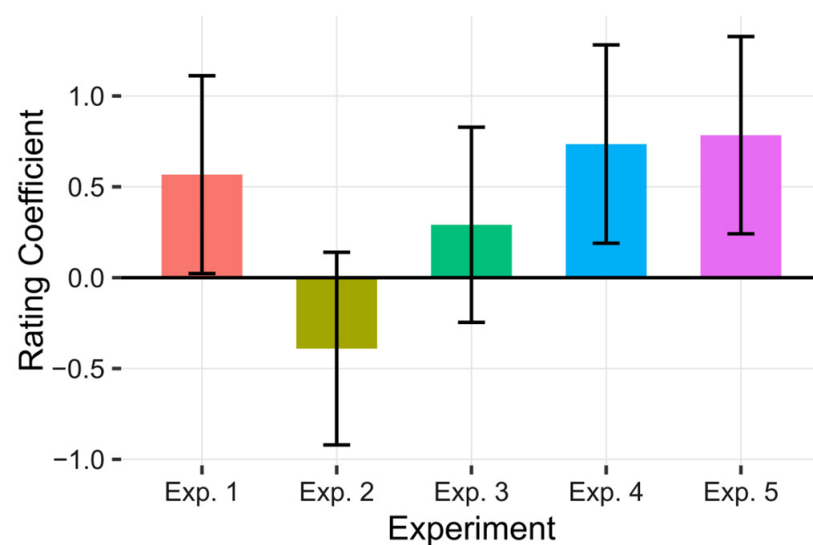


Figure 3. Fitted regression coefficients for suppression performance rating when predicting thresholds across experiments (larger values indicate stronger effect of rating on thresholds; error bars indicate 95% confidence intervals).

4. Discussion

The present study investigated whether individuals incorporated the suppression performance of a fire extinguisher when judging the ability of the unit to extinguish a fire. Participants were presented with videos displaying a developing fire at increasing intensities and the point at which they judged the extinguisher could no longer be used (threshold) was recorded. When presented with performance information about a single extinguisher, no significant differences in threshold by suppression performance rating were observed (Experiments 1 through 3). After being trained on the performance differences between extinguishers of different ratings, the thresholds significantly varied by suppression performance (Experiment 4). Furthermore, when presented as a container of water, without mention of fire extinguishers, the thresholds significantly varied by suppression performance (Experiment 5). This suggests that individuals needed additional information to comprehend extinguisher suppression performance to be aware of the connection with fire intensity.

4.1. Mapping Extinguisher Suppression to Fire Intensity

The explicit comparison of extinguisher performance may have assisted in differentiating how intense a fire could be suppressed. The participant responses did change with

fire intensity across all the experiments: participants were less likely to judge that the extinguisher could suppress the fire at larger intensities. This indicated that most participants indeed recognized that there was a point at which the fire exceeded extinguisher suppression performance. However, that point did not significantly vary with extinguisher performance rating without training. This suggests that providing detailed descriptions of suppression performance was not sufficient for mapping the rating to a specific fire intensity. With training, the thresholds significantly increased with extinguisher ratings. It is also notable that the training presented in Experiment 4 had an impact despite being brief and focused on knowledge rather than extinguisher usage. Prior research that has investigated fire extinguisher training has typically used longer sessions along with interactive and immersive training [1,6]. Future research can examine whether more intensive and interactive training can further enhance the connection between suppression performance and fire intensity.

Comprehension of extinguisher rating differences likely accounted for the training effects in Experiment 4. In line with the triple-code model of number, comprehending the quantitative value of a symbol is required for making ordinal comparisons between analog representations [10]. Training the participants on differently rated extinguishers likely enhanced their understanding that the descriptions of extinguishers were connected to variations in suppression performance. The evidence of a significant connection between suppression ratings and thresholds in Experiment 5 provides further support for this hypothesis. The presentation of suppression performance in Experiment 5 as a volume of water was likely more accessible to the participants, enhancing comprehension. Indeed, the effects of suppression ratings on thresholds were similar for Experiments 4 and 5 despite using different types of units (extinguisher versus water container) and providing explicit training on performance differences in Experiment 4. This suggests that the individuals were more aware of the fire suppression performance differences across amounts of water than extinguisher ratings.

A remaining question is how mental representations of fire extinguisher suppression influenced judgments. The present study focused on the threshold at which people judged they should stop attempting to use an extinguisher to put out a fire. In accordance with the triple-code model, after recognizing symbolic descriptions, transcoding the symbol into an analog representation is required to compare quantities. Prior numerical cognition research has discussed that the position along a mental more-versus-less continuum and the precision of analog representations can both influence performance. For the former, positioning the analog representation above or below the veridical location on the continuum will contribute to over- and under-estimation in performance, respectively. For the latter, noisier representations have a wider distribution, contributing to overlap with adjacent representations and poorer ability to make ordinal judgments. We suggest that providing training in Experiment 4 about the relative differences in suppression performance and water volumes in Experiment 5 may have affected the relative positioning of corresponding representations along the mental continuum. However, the null effect of suppression ratings in Experiments 1 through 3 may have been from noisy representations. Specifically, difficulty in comprehending the descriptions of suppression performance may have contributed to representations with a large distribution. In this manner, participants may have positioned representations of suppression appropriately, but the overlap in the wide distributions contributed to poorer performance. Further research is required to investigate how these perspectives can account for ambiguity in extinguisher suppression performance.

4.2. Implications for Fire Extinguisher Training

The results of the present study have implications for training the general public to be aware of the connection between extinguisher suppression performance and fire intensity. In Experiments 1 through 3, we did not observe a significant connection between the extinguisher rating and fire intensity, even with increasing descriptions of suppression performance. This is particularly relevant to residential settings where, typically, a single extinguisher is available for incipient fires. The results suggest that the occupant is likely to perceive that there is an intensity at which they should no longer attempt to use the extinguisher, but there is ambiguity as to what that point is for the extinguisher within visual sight. This would entail that said occupant would be unable to follow fire safety guidance to only use an extinguisher with a fire that is small enough to be extinguished [1]. This calls for additional research into how to best convey the suppression performance, and limitations, of extinguishers of different performance ratings.

When developing and administering safety training with fire extinguishers, considerations should be made for how presenting extinguisher suppression performance could impact occupant behavior during fire incidents. When presented as a volume of water in Experiment 5, participants were significantly less likely to attempt to suppress the fire for the smaller (apart from those that received training in Experiment 4) and medium ratings. This suggests that using water volume to train suppression performance could lead to occupants being less likely to attempt to use lower-rated extinguishers with fires (note that water can only be used to suppress class A fires). We also observed that focusing on specific types of information can weaken the connection between suppression performance and fire intensity. The effect of suppression ratings on fire intensity threshold was significantly weaker for Experiment 2 compared to Experiments 4 and 5. In Experiment 2, participants were provided with agent weight along with discharge distance and duration. Even though this information was also presented in Experiments 3 and 4, it seems that the lack of water equivalent information and training contributed to weakening the connection to fire suppression performance. How best to tailor extinguisher training materials to shift occupant behavior during fire incidents should be evaluated by life safety researchers and practitioners.

4.3. Limitations and Future Directions

The focus of the present study was on the perception of fire extinguisher suppression performance. To do so, we used visual and text-based renderings of the situation and objects as opposed to interactive devices and substances. Future studies should investigate rendering situations within a virtual reality (VR) environment to create a more interactive and immersive space for the participant. Indeed, prior PASS training research has observed that including VR can enhance action and knowledge acquisition compared to video-based training [6]. Future research can take a similar approach to using VR to train individuals on extinguisher suppression performance. Specifically, an interactive and immersive VR environment in which individuals use differently rated fire extinguishers to suppress an interactive fire could be compared to the text and video approach used in Experiment 4. In addition to addressing the limited training provided in the present study, this would also test whether VR training more generally improves understanding of fire extinguisher usage and performance compared to text and video-based approaches. In addition, using multimodal information can extend the present research. The motivation for using visual stimuli was to simulate situations where occupants can see a fire extinguisher but have yet to retrieve and hold the device. Having participants hold and handle extinguishers that vary in weight and size, similar to real devices, could identify whether such approaches can enhance mental transformations from extinguisher suppression ratings to fire intensity.

These approaches could allow for a better understanding of what factors contribute to greater situational awareness with regard to fire extinguishers.

The extent to which the findings of the present study extend to real fires and the general public more broadly should be investigated in future research. The motivation for using simulated fires was to allow for experimental control over the combustion properties and rendering parameters when creating videos of the fire at different intensities. Although the room that housed the simulated fire was constructed to contain furnishings indicative of a residential home, it lacked photo-realism. In addition, varied groups of individuals need to be examined to create a larger sample that is representative of the general public. The sensitivity power analysis indicated that the sample size of participants was sufficient to detect small to medium effect sizes in the present study. Indeed, the achieved statistical power of the interaction effect observed in the regression model was 0.83, which indicated that it was sensitive to the small effect size. The regression model results suggested that the impact of the experiment condition on the effect of extinguisher ratings on the threshold was small. In terms of practical significance, this indicated that the changes in awareness of the connection between extinguisher ratings and suppression performance across experiments was statistically significant but limited. The extent to which this effect is observed with a broader range of individuals and enhanced using different training and information presentation methods should be investigated in future research. For example, to address the photo-realism of the fire and representativeness of the general public, future research can utilize video recordings of controlled fires during the judgment task. Prior research has used a similar approach to studying human behavior in fire [14,15]. This approach can provide a trade-off between the practical limitations of having participants exposed to a real fire with a functioning fire extinguisher and testing a large, representative sample of the general public.

Subsequent research can investigate real-time decision-making about whether to use a fire extinguisher in an emergency scenario. The scope of the present study was on the perception of fire extinguisher suppression performance as it related to fire intensity. The tasks were designed to assess the mapping of extinguisher ratings to fire intensity. Whether enhanced awareness of this mapping improves occupant decisions about whether to approach a realistic fire event that poses a personal risk with an extinguisher remains to be determined. We hypothesize that individuals with greater comprehension, more precise mental representations, of extinguisher ratings will be less likely to expose themselves to danger when deciding whether to attempt to put out an intense fire that exceeds the rating of an extinguisher.

Future research can examine how individuals who vary in fire extinguisher expertise compare when estimating the suppression performance of differently rated extinguishers. The present study was limited, with few participants reporting accumulated extinguisher experience. We hypothesize that experts who have received extensive training in how to use fire extinguishers are more likely to connect suppression performance with fire intensity than novices who have not received fire extinguisher training. Subsequent research can recruit fire extinguisher experts and novices to examine whether expertise predicts awareness of how suppression performance is related to extinguisher ratings. Addressing these predictions can further inform how training and experience impact the perception of fire extinguisher suppression performance.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/safety11020058/s1>, Figure S1: Mean judgments of whether the extinguisher could suppress the fire (1 = yes, 0 = no) as fire intensity amount increased, across experiments; Table S1: Descriptive statistics of extinguisher threshold across suppression performance conditions and experiments.

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