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Light my fire but don't choke on the smoke: Wellbeing and pollution from fireplace use in Sweden

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ABSTRACT

Fireplaces are popular in Northern Europe. However, particle emissions from fireplaces have been identified as an environmental problem and a health problem. User behaviors affect particle emissions and the success of particle reducing technologies to a large extent. This interdisciplinary study aims to investigate why and how people use their fireplaces, including what emotions people associate with fire, and their interest in learning more about fire making and changing behavior related to fire making. It does so by applying an emotion regulation model in a novel way. In total, 146 Swedish individuals owning a fireplace (the majority had wood stoves, a few had tiled stoves, boilers or other types of fireplaces) participated in an online questionnaire about motives, behaviors, knowledge, and interest in learning and changing behavior. The most common motives for using a fireplace in this sample were complementary heating and "cozy fire making". Our results suggest that watching a fire can aid in regulating emotions from unpleasant stress towards joy and provide a pleasant atmosphere for socialization, and that wood fuel may be a preferred complementary energy choice because it provides beautiful light, comfortable warmth, beautiful design and safety. People reporting emotional motives for using a fireplace also reported an interest in changing behavior.

1. Introduction

The aim of this study is to acquire an increased understanding of motives and behaviors related to fireplace usage, especially emotional motives. In the introduction below, we first provide a brief background on domestic fire making and the related problems with particle emissions. Second, we briefly review research on restoration and emotion regulation relevant to fire making. We then summarize research indicating the importance and lack of knowledge about the user when trying to reduce particle emissions from fireplaces. Last in the introduction, we describe the scope of the present study.

1.1. Fire making

In Northern Europe and many other temperate regions, the use of domestic fireplaces is popular. In Sweden, small-scale biomass combustion covers approximately 34% of the heat demand of small houses [1]. There is a total of roughly 1.85 million small-scale combustion devices in the country, of which wood-fueled fireplaces, tiled stoves, masonry heaters, wood stoves and fireplace inserts make up approximately 80% [1]. In Norway, more than 40% of the biomass use for energy purposes come from wood log combustion, and there is a national strategy to increase the bioenergy use in wood stoves and fireplaces [2]. Similar trends can be found elsewhere in Europe, for example in Germany (where approximately 50% of the household heat is provided by wood fuel in furnaces and biomass boilers, and the number of single-room fireplaces has increased significantly [3]) and in Austria (where several thousands of new wood log heating systems are installed annually, and almost half a million primary residences are heated with biomass-fueled individual stoves and central home-heating systems [4]). Other biomass-rich countries where wood log combustion is common include Canada, where there are approximately 3.6 million wood-burning appliances and residential wood combustion constitutes the second largest national source of black carbon emissions [5]. In Sweden, where this study was conducted, there is a strong trend in using wood stoves – in particular modern ones with glass sections where the fire is visible – for creating a cozy atmosphere, to perform "trivseleldning" ("cozy fire making"), which loosely translates to making a fire for comfort, well-being and coziness. For example, this can mean lighting a fire in the afternoon when returning home from

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Fig. 1. Sometimes the main reason for making a fire may be to create a cozy atmosphere.

work to create a relaxing setting as illustrated in Fig. 1.

Similarly, the Nordic concept of "hygge" [6] often involves candles or fireplaces to create a cozy, comforting home [7]. Recreational and aesthetic reasons are shown to play a role in fireplace use in other regions as well, for example in rural Greece [8], where economic reasons are otherwise strong.

In this study, we included individuals who have a range of wood burning appliances (see Fig. 2 for visual examples), such as modern wood stoves with visible fire, "open" fireplaces and ceramic stoves. For simplicity, however, we will continue to use the term *fireplace* in the text to denote all kinds of wood burning appliances and refer to special types, such as *wood stove*, if it is important for the context.

1.2. Burning wood is associated with health problems and climate change

Well-established research across disciplines show that burning wood – which emits particles from wood smoke – is problematic for both personal health [9–12] and the environment [11,13]. For example, emissions of black carbon aerosols from wood smoke contribute to climate change and increased global warming [13]. Recent research further suggests that particle emissions may contribute to mental illness such as anxiety symptoms [14] and potentially impact the development of Alzheimer's disease [15]. Burning wood for heating and cooking is a well-known problem in developing countries, where household air pollution (HAP) leads to millions of deaths each year, particularly affecting women and girls [16]. End users' awareness of the negative aspects of wood smoke may be limited, as shown in previous research [17,18], but even so, there are socio-cultural factors that are valued more strongly than health, for example using the wood smoke to preserve food and keep mosquitos away. Research and technical development across disciplines are addressing problematic wood-burning practices in developing countries [17–22], ultimately working for clean energy for all. As argued by Akintan et al. [17], socio-cultural factors involved in fuel choices and fire making practices in developing countries have been largely overlooked in the past but play an important role in understanding how to support behavior change. The complex challenges related to the lack of affordable sources of clean energy in developing countries are however outside the scope of this study. Instead, this study explores why people in developed countries like Sweden are increasingly using wood stoves for residential heating, interior design and recreational activities and restorative experiences, despite health and environmental cautions.

1.3. Restoration from nature and from fire

When people look at or interact with nature, they seem to feel better (e.g., [23]). Negative emotions such as anger and stress may disappear [24] and depleted cognitive resources can be restored [25–27]. The processes explaining the restorative effects from nature are likely to consist of many different subprocesses that are not yet fully understood. Attention restoration theory [28,29], and processing fluency theories (e.g., [30–32]) suggest that restoration from looking at natural beauty has to do with processing ease of the stimuli and fascination for the natural surroundings, while Ulrich et al. [33] propose that some natural surroundings have a fast stress-reducing effect. Mayer et al. [27] further add the role of feeling connected to nature and part of nature as a component contributing to the restoration experience elicited by natural elements.

1.3.1 Restorative experiences from fire

Recent research suggests several psychological benefits from watching a fire. Watching a controlled fire is associated with relaxation in terms of lowered blood pressure [34], a relaxing effect on the brain [35] and some mental patients even report tension release in association with fire-setting [36]. Furthermore, socializing around an evening bonfire seems to promote more friendly and creative discussions (e.g., storytelling, "big picture" and theory of mind) compared to socialization during daytime (e.g., complaints, economic matters and jokes) [37]. Taken together this research suggests that when a human makes a fire this may not only be a combustion process but also an emotional process and a restorative process.

1.4. Emotion regulation and fire

Describing emotions scientifically is not trivial and scientists have different viewpoints on how this could be done [38]. Emotions have for example been described in terms of basic categories (e.g., [39]) and dimensional state models (e.g., [40–43]). Emotions can also be considered *a constructive process* that describes *"streams of concurrent and interacting ongoing processes: appraisals that last and change"* [44]. Barrett [45] further suggests that the *"psychological events called 'anger', 'sadness' and 'fear' are not the elemental building blocks of emotions, but instead are mental events that result from the interplay of more basic psychological systems"* [45]. The process approach suggests that humans, at least partly, actively *create and generate* their emotions, rather than passively experience them [46].

1.4.1 Emotion regulation and emotion generation

Emotion regulation refers to *"attempts to influence emotions in ourselves or others"* [47]. It can be discussed if *emotion regulation* and

Fig. 2. Different kinds of wood burning appliances. From left to right: a modern wood stove with visible fire, an "open" fireplace, and a ceramic/tiled stove/masonry heater (image credit: Kakelugn med jugendkrön från Rörstrand, ca 1900, by Svante Tirén, CC BY-SA 3.0 license).

emotion generation can, or should, be distinguished from each other, and it may depend on one's point of view [48]. When making a fire for coziness people bring the natural element of fire into their homes in order to feel better. Cozy fire making can thus be considered an active step in order to influence emotions in ourselves or others in line with McRae and Gross's [47] definition of emotion regulation. However, positive feelings associated with cozy fire making can also be regarded as created cognitive appraisals of ongoing psychological, biological and social processes during the fire-making event, in line with Feldman-Barrett's approach [46].

1.5. Zhan's emotion regulation model

Zhan's model [49] claims to be a model of emotion regulation describing how emotions interact and regulate each other, and the model elegantly integrates seemingly conflicting perspectives on emotion. The model describes how one emotion is likely to turn into another in a promoting cycle (like the seasons of the year, autumn will come after summer) and a counteracting cycle (e.g., when there is an unexpected snowfall in the summer, this will counteract summer for a while). According to the model there are five emotions ("seasons") and the event of a specific emotion makes three other emotions less likely to happen at the same time and one more likely to happen soon. For example, if joy is happening, sadness, fear and anger are less likely to happen at the same time and worry/thinking is likely to happen soon (if summer happens, winter and spring are less likely to occur at the same time, and autumn is likely to come soon). The promoting circle is described as follows: joy promotes worry/thinking, worry/thinking promotes sadness, sadness promotes fear, fear promotes anger and anger promotes joy. The counteracting circle is described as follows: joy counteracts sadness, sadness counteracts anger, anger counteracts worry/thinking, worry/thinking counteracts fear and fear counteracts joy. Even though the parable of seasons can illustrate how the model works, emotion regulation according to the model can happen rapidly within seconds or minutes [49,50]. Zhan further suggest that the model also can be helpful to understand more slowly developing processes over time, such as diminished wellbeing caused by anger [49]. Thus, the time frame considered by the model is suitable for emotion regulation in relation to fire-use, since fire can be considered an instant process but also can go on for hours and be repeated over time.

In this study, there are three main reasons why Zhan's model [49] is interesting to apply in exploring emotional benefits from fire making: Firstly, the model integrates seemingly conflicting theoretical views on emotion, and therefore adds a new relatively unexplored, but potentially promising perspective to emotion research. Secondly, given that Zhan's model may be regarded a process-oriented model of emotion regulation where one emotional event develops into another, seemingly without too much conscious, cognitive efforts, it fits well with how restoration from nature is described to happen (e.g., [29]). Furthermore, the transition from anger to joy and from joy to thinking is similar to nature's ability to reduce unpleasant stress and restore cognitive capacity as described within restoration research [24–27,33]. These similarities to restoration response make the model interesting to apply when researching restoration from fire. Thirdly, the model is based on traditional Chinese beliefs that emotions promote and counteract each other in a natural cyclic flow just like other cyclic transitions in nature. For example, fire will turn a wood log into vibrant air and dust, just like joy will turn anger and unpleasant stress into pleasant thoughtfulness. The similarities between the flow of emotional events happening inside a human as described in Zhan's model, and watching the flow of natural transitions e.g., burning wood in the fireplace, may create a feeling of connectedness with nature as described by Mayer et al. [27].

1.6. Recreation and pleasant emotions versus particle emissions

Given the negative effects from wood smoke, is it possible to enjoy the restorative psychological benefits from watching a fire without suffering too much from or causing emissions? When trying to answer that question, it is important to keep in mind that wood smoke can be of very different character and particle emissions depend largely on *how* users behave when they make a fire [51,52]. For example, burning small dry logs or using non-wooden material increase particle emissions considerably [51,53].

1.6.1 Lab tests versus actual user behavior

There are known user behaviors that impact particle emissions negatively, e.g., [51], and most likely unknown behaviors that may increase particle emissions as well. Furthermore, it is well established that emissions measured in real-life operation in peoples' homes are substantially higher than in controlled lab tests [54,55], which emphasizes the need to understand the impact of user behavior [56]. In one study, particles from a badly operated wood stove exhibited more than 10 times higher toxicity, leading to the onset of chromosome defects at particle concentrations more than one order of magnitude lower than for well-operated wood stoves [57]. Taken together, what knowledge a person has about fire making, and *how* a person makes a fire – for example what kind of fireplace the person is using, the type of wood used, the conditions of the wood logs, if the person observes the color of the smoke and can act accordingly, and how the fire is started and put out – impact considerably the amount of emitted particles. User behavior must therefore be understood in order to identify ways to support people to change behavior to less harmful ways of making fires.

1.6.2 Smoke as an indicator of user misbehavior

The color of the smoke is one indicator of the combustion conditions, albeit a complex and non-trivial one to decode. The vapor phase of wood smoke is typically transparent, implying that the color of the smoke, if visible, originates from the presence of dispersed droplets and particles [58]. Under hot-burning conditions, the flue gas is 500–700 °C and transparent, and the particulates consist of black carbon (typically dominated by elemental carbon) and trace elements [59]. During cold- or smoldering-burning conditions, the flue gas is 200–300 °C and clearly colored (blue-gray), and particulates are dominated by organic carbon [59]. Although it is definitely clear that the user significantly influences the total particulate emissions via the burning conditions in the stove, there are contradicting observations as to whether hot temperatures/high burn rates are worse than low temperatures/low burn rates [52,59]. One possible explanation lies in the fact that different burning and ignition conditions not only affect the total number (and mass) of particulates emitted, but also the relative amounts of different types of particles [60]. In general, colored (blue-gray/brown) smoke is interpreted as a sign of particulate emissions with more adverse health effects.

1.6.3 Wood cleaning technologies and user behavior

Besides user behavior, there are technical solutions for cleaning wood smoke that can help reducing harmful particles (e.g., electrostatic precipitators, catalytically active honeycomb reactors). However, such technical solutions will still be sensitive to how the user behaves, as the operation of a stove largely determines the properties and characteristics of the particulate matter generated. For example, using pine wood produces stickier waste products (the so-called "tars") than birch wood. Tars are combustion gases rich in particles formed from the condensation of heavy, reactive organic hydrocarbon-based species and may cause fouling and blocking of the stove, chimney or secondary gas cleaning devices. Gases rich in particulate-forming species of lower condensation temperature may pass through technical devices intended for gas cleaning in the gas phase and form particles first after having exited the chimney. Consequently, how the user behaves also plays a

central role for the possibilities to successfully design and implement technical solutions helping to reduce particle emissions. This further points to a need to identify and understand different types of user behavior to assess their implications for future technological development of wood burning appliances.

1.6.4 Interdisciplinary approaches are important in order to reduce emissions

In order to increase the acceptance among fireplace owners to consider changing (aspects of) their behavior to making fire in a more environmentally- and health-friendly way, and to develop successful particle reducing technologies, it is important to understand user motives and behaviors when using a fireplace, since motives affect how people understand and accept new solutions [61]. There is limited research that looks at the use of fireplaces in *developed* countries, including how users behave when they make a fire in the home, and their potential willingness to change behavior. By combining and drawing on research on psychology and combustion/exhaust gas aftertreatment, this interdisciplinary study aims to start filling the research gap described above.

1.7. The present study

1.7.1 Purpose

The purpose of this study was to acquire a better understanding of user motives and behaviors when using a fireplace. This purpose was divided into three sub-purposes: 1) explore motives for using a fireplace, 2) explore emotions related to the use of a fireplace, and 3) if possible, identify ***user profiles*** with respect to behaviors likely to cause or decrease particle emissions, motives, knowledge about good/bad behaviors and willingness to learn and change behavior. That is, is there a way to categorize the study participants into any kinds of groups, according to behaviors, motives, knowledge, and willingness to learn and change behavior? The long-term agenda with this work is to explore ways to support a change in behavior to more environmentally- and health-friendly ways to use wood stoves or other types of fireplaces in modern homes. Steg & Vlek [62] suggest a four-step process for interventions in order to promote environmental-friendly behavior: 1) identify relevant behaviors, 2) examine the main factors behind the behavior, 3) design a suitable intervention, and 4) evaluate the effectiveness of the intervention. In this study we focus on steps 1 and 2, identifying behaviors and underlying motives for these behaviors.

1.7.2 Hypothesis about emotion regulation

The emotional event of watching a fire could be seen as a short clip from a longer movie consisting of a continuously ongoing flow of emotional events. We hypothesized that a majority of survey respondents would associate watching a fire with joy in Zhan's model [49] in line with the research reviewed above [e.g., 23,24].

2. Method

2.1. Participants

Data was collected through an online questionnaire between December 6, 2018 and January 17, 2019. As mentioned, the study took place in Sweden, and a total of 146 individuals from several different parts of Sweden filled in the questionnaire. Of the total 146 participants, 24 were men, 90 were women, 1 "other gender", and 31 chose not to state gender. Participants were between 24 and 74 years (M = 39, SD = 10). The majority of the participants (n = 96) had a wood stove (Swedish = braskamin), 15 participants had an open fireplace, 12 participants had a ceramic stove, and 11 participants reported having other types (e.g., wood boiler) and 12 participants did not specify. Participants who answered the question about living area (n = 117) lived in city areas (23%), municipalities (28%), and in the countryside (28%). The participants were recruited from social media (Facebook), through snowball sampling where individuals forwarded the link to the survey to friends and acquaintances and groups.

2.2. Ethics

The present study follows ethical guidelines in Sweden for survey data. Before participating in the study, the participants were informed about the purpose of the study, their rights to end at any time and that participation was voluntary. Participants gave their consent by clicking on "next" for the questionnaire to start.

2.3. Questionnaire

An online questionnaire with questions about motives, emotions, behaviors and knowledge was created. All questions are displayed in Appendix 1, and we describe the content below.

2.3.1. Questions about motives for using a fireplace

We asked three questions about motives for using a fireplace: one where participants had to define the most important reason for using their fireplace, and two questions where participants could agree with several statements about what the fireplace represented to them.

2.3.2. Questions about emotional association

For each of the five basic emotions in Zhan's model [49], three words/sentences were created to describe the basic emotion (Table 1). Participants could then judge if they associated this item with using a fire. We also asked if they did *not* associate the same items with fire in order to avoid leniency effects.

Table 1
Items created to measure Zhan's model.

Basic emotion Zhan [49]	Words describing the emotion
Joy	"Happiness", "Calmness", "Harmony"
Worry/thinking	"Worry", "Creativity", "Thoughtfulness"
Sadness	"Sorrow", "Sadness", "Melancholy"
Fear	"Desire to escape", "Feeling of danger", "Fear"
Anger	"Anger", "Inconvenient stress", "Irritation"

2.3.3. Questions about emotional motives

We also asked directly about emotional change in association with fire making based on Zhan's model [49]: "transition from anger to joy" (e.g., "If I am annoyed, I get happier when I make a fire") and "sadness counteracts joy" (e.g., "If I feel a little sad, I often get happier by making a fire) and "joy promotes worry/thinking" ("I often get good thoughts when I have been sitting in front of the fireplace for a while"). We also added a social dimension to the use of fire ("It is cozy to spend time together in front of the fireplace").

2.3.4. Questions for identifying user profiles

In order to explore whether it would be possible to group participants and identify user profiles, we asked a number of questions about behavior, knowledge, and usage. These questions were grouped into index variables. The index variables and the calculation method are reported in Appendix 2. In addition to the index variables, we also asked two general questions about whether the participants like or dislike the fire making process.

2.3.5. Other questions

For exploratory purposes, other general questions concerning fireplace usage were also asked. Descriptive statistics for some of the remaining questions are reported in Appendix 3.

Table 2
Main reasons for using a fireplace. The two columns to the left show answers where participants could select one or more options. The two columns to the right show proportions of participants selecting the option when only one option could be selected.

Main reason (select one or more options)	Number of participants selecting the option	Main reason (select one option)	Percent and number of participants selecting the option
"Cozy fire making"	115	Complementary heating	44.7% (n = 59)
Complementary heating	96	"Cozy fire making"	43.2% (n = 57)
Keep down cost for heating	55	Main heating	9.8% (n = 13)
Preparedness in case something happens	49	Did not answer	9.6% (n = 14)
Increase value of the property	33	Other reason	2.3% (n = 3)
Main heating source	13	Total	(N = 132)
Hot water	5		
Baking/cooking	2		

As can be seen in Fig. 3, beautiful light and more comfortable heat were the most common answers concerning other functions that participants valued with their fireplace.

3. Results

In the section below, we present the results from the study. First, we report motives for using a fireplace. Thereafter, we describe emotional associations with fire and finally we report results related to possible user profiles. We then discuss the results in the following section.

3.1. Motives

When participants were asked in the questionnaire to select only one reason for having a fireplace, the most common reason in this sample was *complementary heating* closely followed by "cozy fire making" (i.e., creating a cozy atmosphere). When participants were allowed to select more options, almost all participants stated more than one reason to use a fireplace (Table 2), and one respondent explicitly wrote that it is not possible to provide only one main reason. When being able to select several options, the most common answer was "cozy fire making".

3.2. Emotional associations with fire

Fig. 4a shows the number of times each emotional item was associated or not associated with watching a fire. Since our hypothesis was that the majority would associate fire with joy, a binomial test was carried out to test the null hypothesis that the majority of respondents did not associate watching a fire with joy. The association with joy was defined as having reported happiness, calmness and/or harmony in relation to watching a fire (i.e. positive replies to questions Q18_2, Q18_7 and/or Q18_12). The proportion of participants ticking at least one of the joy items (0.82) was larger than the expected (0.50), $p < .001$. As can be seen from Fig. 4b many participants also *dissociated* watching a fire with anger and fear.

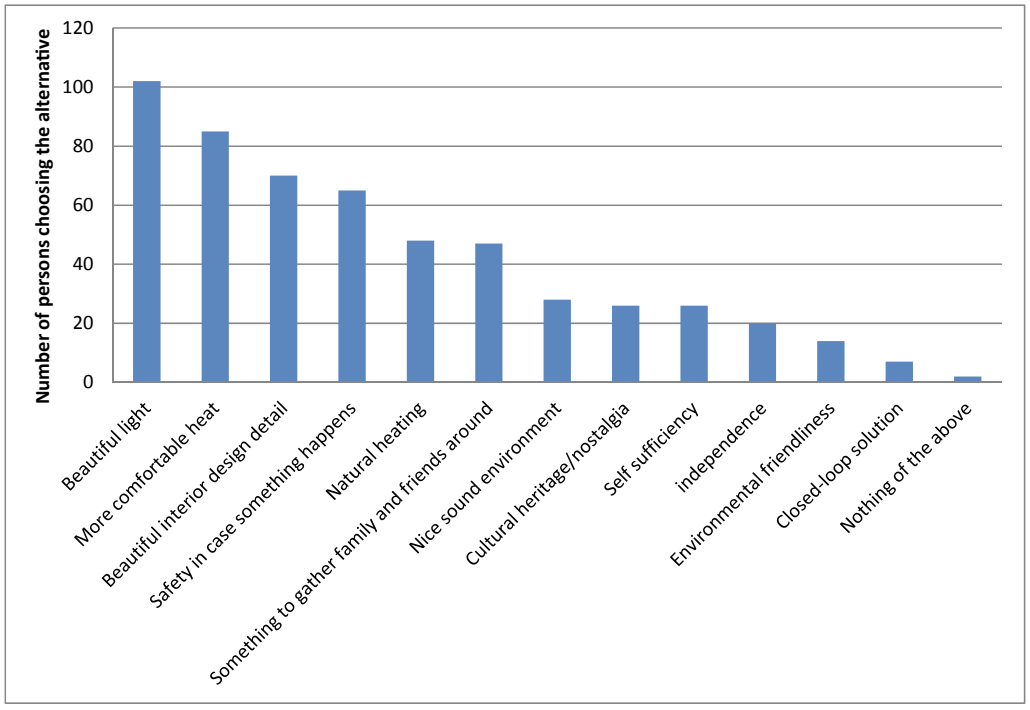
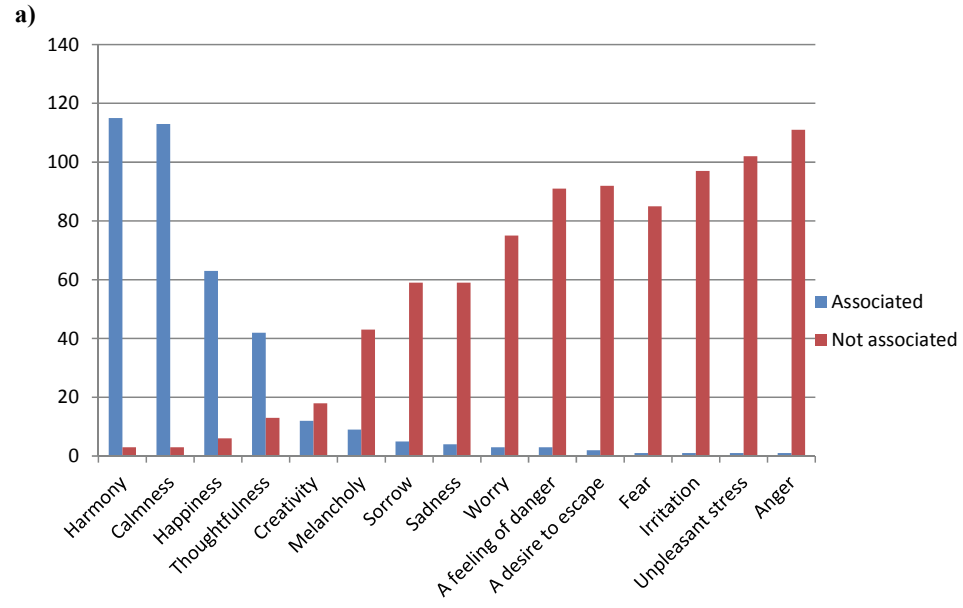


Fig. 3. Characteristics people value with a fireplace.



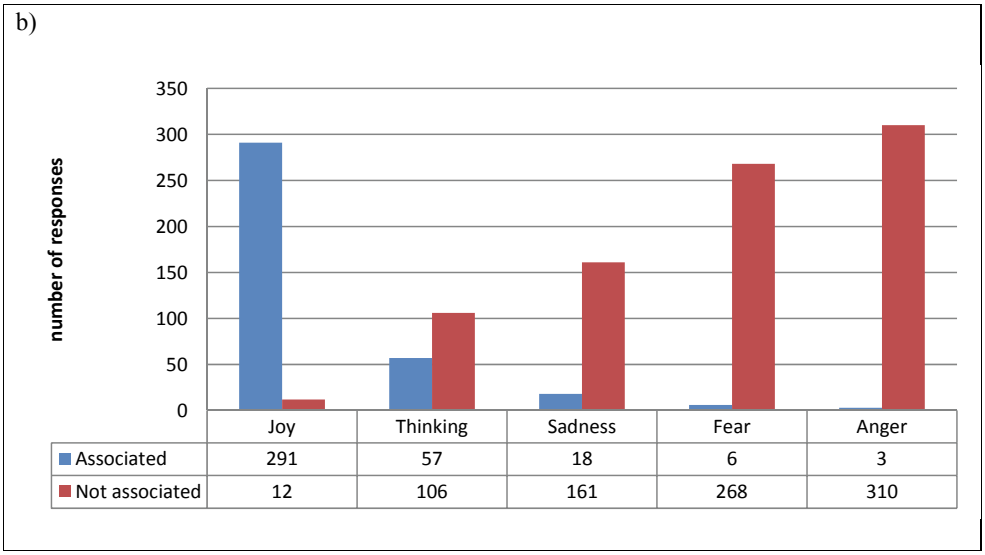


Fig. 4. Emotions associated and not associated with spending time watching a fireplace indoors. The upper picture, Fig. 4a, consists of the items used in the questionnaire. The lower picture, Fig. 4b, shows the summarized scores of the item words within each factor of Zhan's model. Words within the factor Joy (including the items Happiness", "Calmness" and "Harmony") were most frequently associated with fire. Second and third most associated emotions were Thinking ("Worry", "Creativity", "Thoughtfulness") and Sadness ("Sorrow", "Sadness", "Melancholy"). Fear ("Desire to escape", "Feeling of danger", "Fear), and Anger ("Anger", "Inconvenient stress", "Irritation") were the least associated.

3.3. User profiles

3.3.1. Interest in change and knowledge

Generally, the reported interest in learning how to make fire in a better way and changing behavior was high. As can be seen from Table 4, more than 83% of the participants reported that they wanted to learn more, and 74% reported they are willing to change behavior in order to make fire in a better way.

3.3.2. "Don't know"-answers

We observed that the number of "don't know"-answers were relatively high for some of the behavioral questions compared to other

Table 4
Willingness to change and learn.

Willingness to change and learn	Total number of responses	Percentage very interested or interested
Learn more about how to make a fire in a good way	111	83%
Get in contact with a chimney sweep that can provide individual advice	108	51%
Change my habits in order to make fire in a better way	108	74%
Share my own knowledge about making fire with others	107	45%

Table 5
"Don't know"-answers to questions about good and less good behaviors, including the quality of the smoke.

Question	Percentage Don't know
How often does your smoke look like this?	
Translucent smoke	23.4%
Dark/Gray smoke	19.7%
Yellowish smoke	24.4%
Whitish smoke	19.2%
Is this kind of smoke good?	
Translucent smoke	25%
Dark gray/black smoke	14%
Yellowish smoke	25%
White smoke	24%
Are these behaviors good?	
Light the fire top down	33.3%
Use wood with a degree of moisture of 15–20%	21.4%
Flames are clear and yellow	15.5%
Prolong the time of fire by reducing air supply	15.5%
Use plastic packaging as fuel	14.5%

questions related to whether a behavior is considered good or not. As Table 5 shows, about 33% did not know if it is good to light a fire top down, and 25% of the participants did not know if translucent smoke is good or harmful.

3.3.3. Motives, interest, and don't know answers

We calculated index variables for 'Emotional motives for using a fireplace', 'Frequency of using the fireplace', 'Self-rated fire making skills', 'Interest in learning and change', and Summary score for "don't know"-answers of the qualities of a fire/wood smoke. A more detailed description of the index variables and the included items are listed in Appendix 2. We then correlated the index variables with Pearson correlations (cf. Table 6). 'Interest to learn and change' were significantly correlated with 'Emotional motives', and negatively with the Number of "don't know"-answers. 'Self-rated fire making skills' and 'Frequency of use' did not correlate significantly with 'Interest to learn and change behavior'.

We also performed a regression analysis with the dependent variable 'Interest in learning and changing behavior' and the independent variables 'Self-rated fire making skills', 'Frequency of use', 'Emotional motives', and number of "don't know", and the model was significant [$F(4,122) = 4.103$, $p < .01$]. As can be seen from Table 7, 'Frequency of use' and 'Self-rated fire making skills' were not significantly related to 'Interest in learning and changing behavior' when controlling for emotional motives and number of "don't know".

As can be seen from Table 8, most participants in this sample seemed to like the process of fire making, except for a few participants who were not as enthusiastic.

Table 7
Coefficients from regression analysis. Dependent variable was Interest in learning and changing behavior.

	t	*p*	*Beta*	*F*	*df*	*p*	*adj.* R^2
Overall model				4.10	4	0.004	0.1
Emotional motives	2.701	0.008	0.257				
Number of don't know about smoke	−2.485	0.014	-0.229				
Frequency of firing	-0.682	0.496	-0.065				
Self-rated skills	0.440	0.661	0.045				

Table 8
Overall judgment of like and dislike of making a fire.

I like making a fire			I'm not so keen on making a fire	
	Frequency	Percent	Frequency	Percent
Completely Disagree	1	0.0	117	95.1
–	3	2.4	5	4.1
–	19	15.3	1	0.8
Completely Agree	101	81.5	0	0.0
Total	124	100.0	123	100.0

3.3.4. Gender and living area

In order to investigate if gender and/or living in a rural or urban setting mattered for interest in changing behavior and learning more, a univariate ANOVA was made. The dependent variable was the index variable 'Interest in learning and changing behavior', and independent variables were gender and living area (Stockholm/Göteborg/Malmö, smaller municipality, countryside). The result was non-significant ($F(5,107) = 1.26$, $p = .29$).

4. Discussion

The purpose of this study was to acquire a better understanding of user motives and behaviors when using a fireplace. As described above, Steg & Vlek [62] propose that identifying relevant behaviors and understanding the drivers behind those behaviors should be done before attempting to change behavior in a pro-environmental way. Below, we first discuss how to describe fire making behavior in a relevant way, thereafter we discuss motives for fire making behavior in our sample, with special emphasis on emotional motives. After that, we report some appreciated functions with fireplaces that may contribute to the emotional experience. Last, we discuss user profiles, behavior, energy preference for wood as fuel, and limitations of our study.

4.1. What is a fire making behavior?

One of the challenges when it comes to identifying relevant fire

Table 6
Interest in learning and changing behavior, self-rated skills, frequency of use of the fireplace during different seasons, emotional motives for using a fireplace, and number of "don't know"-answers regarding the quality of the smoke.

	Interest in learning and changing behavior	Self-rated skills	Frequency of use	Emotional motives	Number of don't know answers
Interest in learning and changing behavior	1	0.158	-0.008	0.273**	−0.290**
Self-Rated skills		1	0.351**	0.388**	−0.257**
Frequency of use			1	0.131	−0.062
EmotionalMotives				1	−0.112
Number of don't know					1

making behavior is that it may not be clear if a behavior is environmentally friendly or not. On a general level, we identified the behavior *of making a fire in a domestic fireplace in a sample of Swedish users* (e.g., as opposed to making a bonfire outside as researched by Wiessner [37]). We also asked about details, for example if the fire was lit top down, since this is a well-established official guideline in Sweden aimed at reducing emissions. However, recent research [53] puts the correctness of this guideline in question. Interestingly, in the present study when asked if lighting a fire top-down was a good behavior, many respondents answered that they did not know. This answer may thus actually be quite knowledgeable since it could be a consequence of the belief that *nobody knows the answer,* e.g., because it is context dependent or because the question is not yet fully understood within science [63–65]. However, "don't know"-answers in surveys can mean several things [53]. For example, a "don't know"-response can be considered a consequence of *personal ignorance*, that is, if the respondent does not know the correct answer but think someone else does.

4.2. Motives for making a fire

The two most common reasons for using a fireplace were complementary heating and cozy fire making, suggesting that our sample represented a group of users oriented towards more comfort motives of fire making rather than heating for survival or cooking as described by others (e.g., [18,66]). Regarding emotions associated with the fire making process, our results suggest that fire making can be considered an emotional regulation process with a transition from unpleasant stress and anger to joy when watching a fire. This is line with previous research on psychological benefits of fire [34–36]. These results are also compatible with the idea that stress reduction from nature [33] corresponds to an emotional transition from anger to joy in Zhan's model and that cognitive restoration from nature [29] corresponds to the emotional transition when joy turns into thinking in Zhan's model.

4.3. Appreciated functions with wood stoves and their restorative potential

The three most appreciated functions of the fireplace are beautiful light, more comfortable heat, and adding a beautiful interior design detail. These three factors suggest that comfort derived from fire is a multisensory experience in line with Lynn [34]. One especially interesting observation is that "*beautiful light*" was the most commonly appreciated function in our sample, and more commonly chosen than "*more comfortable heat*".

4.3.1 Beautiful light

The warm golden glow from a fire is likely to contribute to the joyful experience in different ways. First, the color yellow is more often and more strongly associated with joy in colder and rainier countries around the world, possibly because it reminds people of the absent sun [67]. Furthermore, Kombeiz & Dielt [68] found that satisfaction with light made people rate other people's faces warmer and more competent, thus facilitating pleasant and joyful social bonding. Thirdly, light can affect the brain and the hormone system in a direct way [69]. Blue light that is common in led-light, TVs, computers and tablets can increase alertness and affect sleep hormones [70]. For example, playing games on blue light emitting screens in the evening negatively affected sleep and was associated with commission errors, that is when a person is doing something when they should not [71]. Our research shows that sitting in front of a fireplace may have the opposite effect of these modern habits, bringing calmness and relaxation. In general, people also seem to prefer natural light compared to artificial light [72]. Interestingly, the trend in "energy rich" places like Sweden to make a fire for comfort and wellbeing has evolved roughly at the same time as more energy efficient, less natural LED-light sources have replaced the light bulb. LEDs often contain a high amount of blue light even if they appear white [70] and have discontinuous color spectra compared to natural light coming from the sun or a light bulb [73]. A topic for future research may therefore be to investigate whether "cozy fire making" reflects an unknown basic need or desire for a certain type of light that modern energy efficient environments do not provide.

4.4. User profiles

If possible, we aimed to identify profiles of persons reporting behaviors associated with risks for higher emissions (e.g., lighting a fire from the bottom, general unawareness about the color of the smoke, using prohibited fuel such as plastics), but our data set did not provide conclusive evidence to describe groups in terms of traditional user profiles (e.g., gender, age or geographical area). This could be due to sampling, but also to the aforementioned difficulty to identify with certainty what is good and bad behavior respectively. However, in places with more than 42% green area, the green areas take care of air pollution efficiently [74], which makes densely urban areas more vulnerable when it comes to dealing with e.g., wood smoke.

4.4.1 Emotional motives and interest

An important and positive finding of this study is that socio-emotional motives for using a fireplace were correlated with interest in learning and changing behavior. Bergquist [75] suggests that emotional reasons may have stronger impact on behavior than normative pressure, and given that an emotionally appealing fire is also environmentally sound, people with emotional motives can easily be motivated to change behavior [76], even if the interest in reducing particle emissions is low.

4.4.2 The uninterested

Since we found a correlation between the number of "don't know"-answers about the color of the smoke and the lack of interest in learning and changing behavior, we speculate that there could be a group of fireplace owners that is not interested in adapting behavior if needed, and is disengaged when it comes to considering smoke and emissions.

The fact that even experts struggle with identifying optimal fire making behavior for all possible circumstances and contexts, has been used in the past as a motivation for developing wood burning appliances that minimize users' influence. Such systems can contribute to more efficient combustion [77]. Therefore, the current results suggest that it is important to further investigate the perceived importance of user influence in this "uninterested" group. It is well known that freedom and control are significant in influencing energy choices [78], and that behavioral influences are very strong in this area [12]. However, it is not yet established how highly the "uninterested" user group, as identified here, value personal freedom to control the fire making process. Such information will be critical in outlining effective strategies to minimize particulate emissions from this group.

4.4.3 Habit formation

Solutions that do not interfere with socio-emotional needs are more likely to be successful since motives can affect how people understand and accept novel solutions [61]. In psychological research on car use [79], it has been established that the impact of socio-demographic and psychological variables varies with the purpose of the trip. Strong habit formation seems to hinder behavioral change due to motivational or normative aspects, whereas leisure trips have a low relationship with driving habits, thus representing a window of opportunity to try out new alternatives [79]. A strong tendency to use wood combustion for relaxation-related purposes could thus indicate a possibility for higher acceptance towards changing behavior in an environmentally friendly direction, whereas everyday use of a wood stove as a main heating source would imply lower openness to such changes.

4.5. Energy preference for firewood

Wood fuel is often researched in energy poor environments and described as a kind of energy source used when other more modern energy sources (e.g., electricity) are lacking [66,80]. The respondents in our sample also appreciated their fireplace because it would provide *"safety in case something happens"*. Safety was the fourth most appreciated function together with *"something to gather friends and family around"*. In the future, there is a risk that we will experience more performance gaps in electricity due to extreme weather and climate change [81] and fireplaces could help people and society to better tolerate these performance gaps. Wood stoves can also be equipped with combined-heat-and-power (CHP) technologies to enable small-scale electricity production [82]. However, our research shows that wood fuel also can be a *preferred choice* when energy supply is affluent, mainly due to pleasant sensory experiences contributing to emotional wellbeing. This observation further suggests that people sometimes make energy choices based on *sensory experiences* that can be likened with choices of food. Such perceived quality aspects may reflect luxury comfort excess, but can also illustrate forgotten basic needs, e.g., for quality light in a dark country like Sweden where many people suffer from sunlight deprivation.

As a final, overall note, we also think the results from our study raise interesting complex questions about standard of living in countries like Sweden, where modern wood stoves (often with visible fire) are used as "luxury" objects to create a cozy atmosphere, rather than a source of "necessary" heating. What is the "validity" of the emotional motives seen in this study considering the health and environmental harm caused from burning wood? Or, does the fire with its age-old quality to stimulate deep conversations, well-being, and social bonds provide other necessities, much needed in our modern society? As Groves et al [83] describe in their work on mundane energy use, people might be well aware of the "wasteful", negative effects of a practice – in this case, burning wood which impacts the environment and personal health – and still engage in it, because of *attachments* to practices and ideas that have strong emotional meaning. For example, creating a cozy atmosphere through lighting a fire might be part of practices around making a family home, or, as with Groves et al.'s participants, making a welcoming home for visiting friends. This may create non-trivial tensions between on the one hand caring about the environment and on the other hand wanting to create a warm, cozy setting for one's family and friends.

5. Further research

This study was conducted in Sweden, but we believe that it contributes insights that are applicable in other similar geographical regions with fireplace use. By highlighting and starting to explore emotional motives for fire making in the modern home, and the role they might play in promoting change, we hope to illustrate the importance of considering this dimension. Given how fireplaces often are a complementary source of heating in homes and thus co-exist with other heating solutions, such as heat pumps, this research also provides insights that are relevant to research on other energy-related practices in the home, e.g., [10,84]. Our results also call for more research on *how* the fireplace elicits positive emotion, and we believe more research is needed generally in the intersection between mental health and energy choices. The same fire that causes mental wellness and sensory pleasure may also create mental illness from the smoke [14]. Mental health problems in Europe e.g., concerning sleep disorders, mood disorders, and anxiety disorders are a huge problem and cost around €35.4, €113.4, and €74.4 billion respectively [85] and the possible contribution and appropriate use of different energy sources may possibly improve mental health.

6. Limitations

This study is limited in several ways and should be considered a first attempt to research the group of people making a fire for coziness. Our approach could possibly be denoted critical realism, trying to explore and explain reasons for why people make a fire [86]. We also begin to explore what e.g., cozy fire making means, but qualitative research methods such as interviews are needed for a more in-depth understanding [86]. Even though we provide new perspectives on fire making drivers, our results are based on a limited sample in one country and may not be representative of all fireplace owners who engage in similar practices of making a fire to create a cozy atmosphere. We have also explored the topic of cozy fire making from an individual perspective, assuming that individual characteristics may affect behavior. However, changes in macro-social, technical or political perspective may interact with individual behaviors and we can only speculate about how users will interact with future technologies based on interaction with current technologies.

7. Conclusion

Our study shows that firewood, in addition to being people's enforced first choice in energy-poor regions [18,65], can be *a preferred energy choice* for complementary heating and coziness when energy is affluent. Cozy fire making stimulates tension release and cognitive restoration, like restoration from natural scenes [29,33]. Pleasant sensory experiences from light, warmth and beauty, as well as feelings of safety in case something happens, and means for pleasant social interaction, were appreciated functions of fireplaces. Our data suggests that sensory pleasure and emotions may affect people's energy use and choices. In line with Sahakian & Bertho [87], we conclude that studying emotions can open "*windows of opportunities for either de-stabilizing or re-enforcing existing practices*". Emotional motives for using a fireplace were correlated with interest in learning and changing behavior, and previous research on car use [79] suggests that recreational fire makers may be more open to adapt to more environmentally friendly practices. We call for more research on the mechanisms *how* firewood energy elicits positive emotions, and the role of firewood and modern stoves in future energy systems.

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

Supplementary data (Appendices 1, 2 and 3) to this article can be found online at https://doi.org/10.1016/j.erss.2020.101696.

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