Enhancing Workplace Well-being: Integrating Physiological Data into Aromatherapy through Calm Technology

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ABSTRACT

This study aims to develop an intelligent aromatherapy device that harnesses the principles of calm technology to enhance workplace well-being. The device automatically initiates aromatherapy based on physiological data from a wearable wristband to relieve anxiety and enhance office vitality, thereby increasing productivity. The study recruited 90 participants, divided into three groups of 30 people. Anxiety was induced by the Kraepelin test(arithmetic task) and the efficacy of aromatherapy using lavender essential oil, coconut oil and blank group served as control groups. Our experimental findings highlight the effectiveness of lavender essential oil in significantly reducing anxiety levels when compared to the control group. This case study underscores the potential of intelligent aromatherapy device as natural, non-pharmacological intervention for stress management and vitality enhancement in office settings, aligning with the principles of calm technology. It lays the foundation for the further development and improvement of intelligent aromatherapy equipment to improve the quality of work and life.

CCS CONCEPTS

• **Human-centered Computing**; • **Human Computer Interaction**; • **Interaction Devices**;

KEYWORDS

Stress, Aromatherapy, Calm technology, Physiological data

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1 INTRODUCTION

With the rapid development of technology, the increase of work tasks and the blurring of the line between work and life, the problem of stress and anxiety in the modern office environment has become more and more prominent [1]. Stress is often associated with tension, time pressure, and increased workload, while anxiety can be due to job demands, uncertainty, and a competitive environment. These problems may manifest as physical symptoms, emotional distress, and mental health issues. Stress and anxiety not only negatively impact an individual's health, but also their productivity and work performance [2]. Research shows that chronic exposure to high stress can lead to fatigue, insomnia, anxiety symptoms, and emotional exhaustion, which can ultimately affect productivity and creativity [3]. Additionally, they may also lead to cardiovascular problems, immune system disturbances, and other health risks [4].

In order to alleviate the problems caused by long-term stress, some employees may need to seek medical assistance, including psychological or medication treatment. Psychological therapy can help employees deal with emotional issues such as anxiety and depression, while medication may be necessary in certain situations to stabilize emotions and alleviate symptoms [5]. However, a better approach is to take proactive preventive measures to reduce and manage work stress before the stress problem becomes severe. This includes using stress relief techniques such as deep breathing, physical exercise, meditation, and aromatherapy, as well as establishing a healthy work life balance [6]. Aromatherapy is a promising option as it can be easily integrated into daily work, providing rapid emotional support, and helping employees cope with stress without relying on medication [7].

Aromatherapy is the use of volatile oils to act on the olfactory nerves of the human body, stimulating the brain to synthesize neurotransmitters of joyful emotions, thereby regulating the body and mind, eliminating negative emotions such as anxiety, depression, and anger, while also avoiding gastrointestinal reactions and other drawbacks. Currently, it is also widely used to regulate human emotions and alleviate stress [8]. Neurologists believe that the reason why fragrance can eliminate people's negative emotions is because the flowers or stem and leaf cells of plants can decompose into a volatile aromatic oil after being exposed to sunlight. If this fragrance comes into contact with olfactory cells in the human nasal cavity, it will produce beneficial physiological reactions [9]. For example, the smell of lavender can eliminate tense and melancholic emotions, thus effectively treating insomnia and depression.

In this work we devised a smart diffuser for office people called AromaMate, which revolutionizes the concept of stress management by tapping into the power of scent to alleviate anxiety and promote office vitality. Through harnessing calm technology [10], AromaMate introduces an innovative approach that leverages aromatherapy in an unobtrusive way to effectively reduce stress levels.

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Embracing this unique utilization of olfactory stimulation, AromaMate offers individuals a discreet and personalized solution to find calm in the midst of their work.

2 RELATED WORK

Aromatherapy is used to treat chronic pain, depression, and anxiety. Essential oils recommended for aromatherapy include tea tree oil, cinnamon oil, clove oil, eucalyptus oil, thyme oil, rosemary oil, lavender oil, and more [11]. Recommended methods of using these essential oils are bathing, inhalation, and massage. Hosseini et al. found that sniffing lavender volatile oil can effectively reduce anxiety levels in patients who are about to undergo cardiopulmonary bypass heart surgery [12], Kasper et al. found that oral lavender volatile oil preparations can effectively reduce anxiety levels in patients with sleep disorders [13], Kianpour et al. found that continuous sniffing of lavender odor for 4 weeks can effectively prevent postpartum women from developing stress, anxiety, and depression [14]. One clinical study investigating anxiety during childbirth [15] reported no psychological benefits and undesirable physiological effects of orange aroma administration. A study that considered changes to the perceived fragrance of essential oils after mental and physical work reported an unfavorable impression of orange aroma [16].

Traditional fragrance mainly use the volatilization of the fragrance itself, or through heating, natural placement, and atomization of essential oils with water. Smart fragrance device produced by combining traditional products with smart hardware. Cyrano odor diffuser [17] and Moodo smart home fragrance diffuser [18] and other products appear, and users can modulate and broadcast fragrance through mobile phone applications. Smell Kingdom [19] realizes the "coding" and "decoding" of smells in real life, and applies them to consumers watching movies, bringing users a new movie watching and smell experience.

There could be adverse effects on both work and personal life if people fail to recognize their state of anxiety and not take preventive measures. The failure to intervene in a timely manner can lead to a decline in productivity. Research conducted by Lohmann-Haislah et al. [20] has demonstrated that anxious employees tend to exhibit relatively lower job performance. Prolonged anxiety is associated with various health issues. These health concerns may translate into increased healthcare expenses and days lost at work [21]. It is well known that aroma inhalation can cause physiological and psychological changes in human [22], and the effects of aroma are believed to be caused by pharmacological and psychological mechanisms. This underscores the importance of developing intervention tools like smart aromatherapy devices, aimed at helping employees manage their emotional states and enhance both their productivity and overall well-being. AromaMate provides a solution by offering smart aromatherapy devices that facilitate the use of aromatherapy as a preventive measure on a regular basis. By incorporating intelligent features and portability, AromaMate ensures individuals can experience the benefits of aromatherapy continuously. With its intelligent, personalized, and portable features, AromaMate can become a valuable tool for emotional management in individuals' everyday lives.

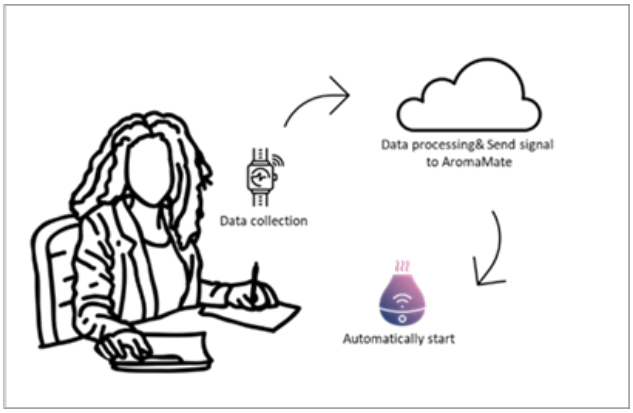

Figure 1: Design Concept of AromaMate

3 CONCEPT DESIGN AND METHODS

3.1 Concept Design

AromaMate leverages calm technology to provide personalized aromatherapy, aiding in mood enhancement and anxiety management. AromaMate aims at discreetly improving emotional well-being without interfering with the user's daily life. This smart approach ensures users get the right support when they need it. By harnessing the power of calm technology and aromatherapy, AromaMate is a new way to find stress management and emotional balance in today's fast-paced world.

The smart device relies on real-time data from wearable sensors that seamlessly connect to the user's wristband to monitor their physiological state. By continuously assessing variables such as heart rate and skin behavior, AromaMate can detect signs of increased anxiety or stress levels. Once these indicators are identified, the device automatically initiates aromatherapy, releasing carefully selected scents known for their calming and mood-enhancing properties, such as lavender. What sets AromaMate apart is its ability to adjust the intensity and duration of aromatherapy based on the user's current emotional state. If the system detects heightened anxiety, it can release a stronger scent over a longer period of time, effectively relieving anxiety. Figure 1 shows the design concept of AromaMate.

The AromaMate is equipped with three fragrance modules, which can accommodate up to three fragrance capsules at the same time. Users can mix different fragrance capsules to create personalized fragrance, and adjust the proportion of corresponding fragrance capsules through mobile applications on their phones. They can save and share the fragrance they have prepared with others, with personal customization and social attributes. We use aromatherapy methods to maintain a moderate concentration for 30 minutes and automatically stop, ensuring that users receive professional stress relief without worrying about adverse reactions caused by excessive or prolonged aromatherapy.

3.2 nk Experiment Design

3.2.1 Participant. A total of 90 participants were selected as participants for the study, aged from 20 to 50 years old(M=35.42, SD=15.98).

The snowball sampling [23] technique was employed for participant recruitment, whereby initial participants were identified and then additional participants. All participants were healthy with normal olfactory function. This study was approved by the local Ethical Review Board (ERB). To avoid causing unwanted feelings, users are informed in the consent form that they can stop participating at any time. They can revoke their permission to use their data under any circumstances.

3.2.2 Experiment Preparation. The laboratory temperature is 23±1°C, humidity is 60±5%, the environment is quiet, and the light is soft, which meets the research requirements. On the day of the experiment, the diet of the participants should not contain alcohol, caffeine, and other ingredients. Smoking, taking any drugs, and cosmetics and essential oils with aromatic smells are strictly prohibited, and sleep time at night is guaranteed to be 7 hours or above.

As a laboratory stress method that can induce anxiety emotions in the human body and cause changes in physiological indicators, mental arithmetic tasks are widely used in research. The mental arithmetic task of "continuously subtracting 17 from three digits" as a stressor, which is so-called Kraepelin test, this task is frequently used to induce acute stress in various studies [24].

By measuring the changes in various physiological indicators, the degree of anxiety in the human body under stress can be objectively reflected, and the low-frequency to high-frequency ratio (LF/HF) of heart rate variability is a sensitive indicator that reflects the balance of sympathetic and parasympathetic nerves [25]. The increase in this value indicates that the subject has successfully induced anxiety under laboratory stress conditions. We use the Empatica E4 wristband to collect the data.

Lavender Essential Oil stands out as a highly researched and popular aromatherapy oil, often considered the most extensively studied within the field. According to aromatherapists, lavender is a cell rejuvenator, antiseptic, and immunostimulant. It is known for its calming effects, and it is said to enhance well-being. Additionally, it offers the advantage of being cost-effective [26]. We opted for a commercially available capsule-based aromatherapy diffuser, with lavender essential oil chosen for its pharmacological properties, coconut oil as a placebo with a pleasant aroma, and a blank group for control. We selected a medium concentration and set the duration to 30 minutes.

In light of AromaMate's current conceptual design stage, which lacked a physical prototype, our experiments necessitated human assistance. This involved continuous monitoring of both the wristband and the aromatherapy machine using the applications. This approach allowed us to simulate the device's intended functionality and gauge its potential efficacy in stress management, even though a physical prototype had not yet been developed.

3.2.3 Experiment Procedure. The experimental process is divided into four stages, each of which records the total number of heartbeats and heart rate variability LF/HF of the participants. The participants are required to fill out the visual analysis scale, and at the end, the participants are required to fill out the Likert scale for the AromaMate design concept.

- Baseline period: After briefly explaining the test requirements and process, the experimenter assisted the participants in adjusting their comfortable sitting posture, and recorded the pre-stress baseline period for 10 minutes. The experimenter dictated the instructions: "Thank you for participating in today's experiment. During the experiment, you will wear equipment that does not cause any harm to your body to test your heart rate under different conditions. At each stage, you will hear my instructions, just focus and follow them."
- Stress period: Each group took the same task by listening to the recording, continuously subtracting 17 from the 3-digit mental calculation program (presenting 1500ms/question), and prompted for the correct answer after an interval of 3 seconds. Participants were required to report their mental calculation results orally as soon as possible within 3 seconds. Regardless of whether the reported results were correct or not, the correct answer was subtracted by 17 from the recorded sound. If the report was made after the next digit sound, it would be counted as an error, and the mental arithmetic task continued for 30 minutes.
- Intervention period: The lavender group and coconut oil group continued to undergo mental arithmetic tasks and essential oil intervention for 30 minutes. The blank group continued to take the arithmetic task for 30 minutes.
- Recovery period: Rest for 10 minutes.

3.2.4 Statistics. We are using IBM SPSS 28 for statistical analysis. The data does not conform to a normal distribution, it is denoted as M (Min, Max), Bonferroni corrections were applied. Kruskal-Wallis test is used for inter-group comparison. Wilcoxon signed-rank test is used for intragroup comparison. The level of statistical significance (p) was set at 0.05.

3.3 Result

3.3.1 Comparison of Baseline Heart Rate Variability LF/HF.. Table 1 shows that there were no intergroup differences in baseline heart rate variability LF/HF among the three groups (P>0.05), indicating comparability between the groups.

3.3.2 Comparison of Heart Rate Variability LF/HF between Stress and Baseline Period. Intragroup comparison (see Table 2): The LF/HF of heart rate variability during stress period in all three groups of subjects was significantly higher than that of the baseline period. There was a statistical difference (P<0.01), indicating that all three groups of subjects successfully induced anxiety under laboratory stress conditions.

Inter-group comparison(see Table 2): There was no inter-group difference in LF/HF during the stress period among the three groups of subjects (P>0.05), with comparability.

3.3.3 Comparison of Heart Rate Variability LF/HF in Different Stages of the Experiment. Intragroup comparison (see Table 3):

The LF/HF of heart rate variability in the lavender group during stress period was significantly higher than that in the baseline period, intervention period and recovery period (z=4.78, P<0.01; z=4.34, P<0.01; z=3.57, P<0.01); There was no significant difference

Table 1: The comparison of heart rate variability LF/HF among participants in the baseline period

Group	No. of Participants	LF/HF(Min, Max)
Lavender	30	1.28 (0.46, 3.90)
Coconut	30	1.65 (0.41, 3.56)
Control	30	1.40 (0.24, 4.82)

Table 2: Heart rate variability LF/HF among participants in the baseline and stress period

Group	No. of Participants	Baseline Period	Stress Period
Lavender	30	1.28 (0.46, 3.90) **	2.16 (1.00, 5.65)
Coconut	30	1.65 (0.41, 3.56) **	2.41 (1.06, 5.63)
Control	30	1.40 (0.24, 4.82) **	2.45 (0.81, 6.14)

Table 3: Heart rate variability LF/HF among participants in different periods

Group	No. of Participants	Baseline Period	Stress Period	Intervention Period	Recovery Period
Lavender	30	1.28 (0.46, 3.90)	2.16 (1.00, 5.65)	1.63 (0.70, 2.98)	1.36 (0.24, 4.66)
Coconut	30	1.65 (0.41, 3.56)	2.41 (1.06, 5.63)	2.01 (1.02, 3.96)	1.74 (0.35, 3.38)
Control	30	1.40 (0.24, 4.82)	2.45 (0.81, 6.14)	2.43 (0.67, 4.66)	1.74 (0.46, 5.21)

in heart rate variability LF/HF between baseline period, intervention period and recovery period (P>0.05).

The LF/HF of heart rate variability during stress period in the coconut oil group were significantly higher than those in the baseline period, intervention period and recovery period (z=4.78, P<0.01; z=2.97, P=0.003; z=4.10, P<0.01); There was no significant difference in heart rate variability LF/HF between baseline and recovery period (P>0.05); The heart rate variability LF/HF of intervention was higher than the baseline and recovery period (z=2.86, P=0.004; z=3.10, P=0.002).

The LF/HF of heart rate variability during the stress period in the control group was significantly higher than that during the baseline and recovery periods (z=4.86, P<0.01; z=3.44, P=0.001); There was no difference between stress period and intervention period (P>0.05).

Inter group comparison (see Table 3): There was no difference in LF/HF of heart rate variability between the baseline and stress periods among the three groups (P>0.05). The expected LF/HF of heart rate variability in the lavender group was significantly lower than that of the coconut oil group and the control group (z=-2.02, P=0.04; z=-2.86, P=0.004).

4 DISCUSSION AND FUTURE WORK

The results of all three groups of subjects showed a significant increase in LF/HF heart rate variability during stress, highlighting the effectiveness of arithmetic tasks in inducing stress in subjects. This significant increase indicates the ability of arithmetic tasks to trigger physiological responses typically associated with stress. LF/HF heart rate variability is a reliable marker for assessing the balance of the autonomic nervous system, reflecting the interaction between sympathetic and parasympathetic nervous activities. A high LF/HF ratio usually indicates enhanced sympathetic innervation, which is a typical physiological response in stressful situations. In this study, a significant increase indicates that arithmetic tasks trigger a sympathetic 'fight or escape' response, leading to a tilt in the balance of the autonomic nervous system towards sympathetic activation. This enhanced sympathetic activity may be due to the complexity of the task itself and the nature of induced stress, which often leads to an increase in alertness and arousal levels.

When the human body experiences anxiety induced by laboratory stressors, its subjective psychological experience, behavioral performance, and physiological reactions will undergo corresponding changes [27]. However, subjective emotions and behavioral reactions are to some extent difficult to objectively and truly reflect anxiety levels, and the autonomic nervous system must accompany changes in anxiety emotions. By monitoring changes in heart rate variability LF/HF, the level of anxiety can be quantitatively measured. After successfully inducing anxiety in the participants, the lavender group continued to perform mental arithmetic while inhaling lavender for intervention. The heart rate variability LF/HF was significantly lower than during the stress period, indicating that lavender essential oil may rapidly act on the autonomic nervous system while the participants were facing mental arithmetic stress tasks. There is no difference compared to the baseline and recovery periods, indicating that the effect may be more persistent and stable.

Another interesting finding is that people's expectation of strong aroma effects leading people to relieve stress or divert attention, no matter what aroma they experience, will increase their processing speed. Some aromatherapy effects come from people's expectations. The coconut oil group, as a placebo, showed a slight decrease in expected heart rate variability LF/HF during intervention. Although coconut oil has no pharmacological effect on relieving stress, its

friendly aroma may alleviate some anxiety to some extent due to its expected relieving effect. In future research, it would be interesting to test the effectiveness of other aromas in relieving stress. Different aromas have been known to have various effects on mood and cognition. Testing the efficacy of lavender aroma in comparison to other aromas, such as citrus or peppermint, could provide valuable insights into the potential therapeutic benefits of different scents.

In an interesting report, Martin reviewed the current evidence and clinical significance of the "role of olfactory stimulation in the alteration of cognition, mood, and social behavior," concluding there is "a common, if uneasy, relationship with the holistic practice of so-called aromatherapy [28]. The observed effects are the result of a mixture of mechanisms, including aroma-specific pharmacological profiles and user expectation. Thus, the overall outcome of aromatherapy exposure is influenced by different mechanisms, each of which can be tuned to have the most beneficial effect on function. Given that aromatherapy is a rapid intervention with minimal side effects, further research is warranted as it has the potential to enhance cognitive function in response to stress.

Traditional aromatherapy lacked the incorporation of physiological data as signals for applying treatment. The timing of the therapy was not optimal, as individuals had to proactively seek treatment. The design of smart diffuser offers better self-prevention measures for people with low level stress. We should conduct further research to precisely pinpoint the onset of stress and correlate it with the administration of aromatherapy interventions. This precision would enable experiments specifically designed to alleviate stress at the moment it emerges, potentially enhancing the effectiveness of such interventions. Moreover, investigations into optimal dosages and intervention durations for essential oils are crucial. Delving deeper into the relationship between the amount of essential oil used and the duration of exposure could reveal the minimum effective dose and the necessary timeframe for achieving significant stress reduction. Incorporating variables like cortisol levels, EEG scans, or heart rate variability can provide a more holistic understanding of the effects of aromatherapy.

Despite the valuable insights gained from this study, it is imperative to acknowledge its limitations. To bolster the representativeness of results, future research should aim for larger and more diverse participant pools, encompassing a broader spectrum of demographics. Other scents will also be considered to test the effectiveness of alleviating stress. The brief exposure to aromatherapy may not adequately capture the potential long-term effects of such interventions. Extending the duration of interventions would allow for a more comprehensive assessment of their sustained stress-relief potential. Lastly, additional research is imperative to enhance the synergy between the software and hardware components of AromaMate. This pivotal phase is critical in guaranteeing the device's pragmatic utility and effortless operation within authentic stress management contexts. These endeavors aimed at mitigating these constraints will undeniably facilitate the advancement of a more comprehensive comprehension of aromatherapy's viability in stress management.

5 CONCLUSION

In summary, AromaMate is a creative conceptual design that combines calm technology, and data-driven aromatherapy based on physiological markers. It could be a promising step towards customizing efficient stress management solutions for people in the workplace. Future research should strive to expand the participant population, extend experimental time, explore various essential oil concentrations and durations, and cover a wider range of physiological parameters. AromaMate helps stress management by providing customized, non-invasive, and timely intervention measures. In the dynamic landscape of stress management, AromaMate demonstrates the potential of calm technology to enhance our well-being.

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