Al-Rafidain Journal of Computer Sciences and Mathematics (RJCSM)

www.csmj.uomosul.edu.iq

A Computer System for Measuring the Relationship of Smell and Pain

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Article information

Article history:
Received 10 March ,2025
Revised 10 April ,2025
Accepted 28 April ,2025
Published 26 June ,2025

Keywords:
Smell vs Pain,
Olfactomete,
Pain tolerance.

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Abstract

Smell is popularly believed to influence pain, even though several of these claims currently lack significant scientific or engineering support. This paper proposes a computing system for conducting smell vs pain experiments using a laboratory－built olfactometer together with cold pressor test（CPT）and pressure pain threshold（PPT）measurements. We conducted CPT and PPT experiments for three different types of smells：pleasant, sweet, and unpleasant. Pain threshold and pain tolerance of the participants were recorded and analyzed. Results showed that inhalation of sweet and pleasant smells during CPT increased tolerance for pain for all groups（$p < 0.01$）. Likewise, inhalation of sweet and pleasant smells increased pain threshold during PPT in all groups where $F(3,28) = 94.517, p = 0.002$ for sweet smell, $F(3,28) = 51.362$, and $p = 0.004$ for pleasant smell. Further, we observed $F(3,28) = 16.430, p = 0.020$ for the unpleasant smell）. These results concluded that sweet and pleasant smells can increase pain tolerance while unpleasant smells can decrease pain tolerance. In conclusion, applications of sweet and pleasant smells may be a beneficial addition to the management of pain symptoms. The results are relevant for workplaces where many people suffer from musculoskeletal pain, as well as in clinical settings where pain patients are treated. The key novelties of this paper are as follows：Firstly, we proposed a computer－controlled hardware system that can be used for smell vs pain experiments；secondly, we proposed a PPT and CPT combined testing method for smell vs pain experiments；and thirdly, we validated the effects reported for CPT in previous research using different odorants.

Index terms Smell vs Pain, Olfactometer, Pain tolerance, Cold Pressor Test, Pressure Pain Threshold, Algometer

DOI: 10.33899/csmj.2025.158108.1179,

1. Introduction

PAIN is a complex sensation and cannot be directly measured. It is shaped by the intensity of noxious stim－ulation and by psychological variables, such as emotional state and mood［1］［2］. It can only be described properly by the person feeling the pain because it is an individual expe－rience［3］. People often think of pain as a purely physical sensation. However, pain also has biological, psychological, social, and emotional factors ［4］. Emotional thoughts and attitudes of patients affect pain perception［5］. Nevertheless, pleasant stimuli such as music or humorous films improve mood and reduce pain［6］while manipulations that affect mood negatively in turn increase pain perception［7］.

Recent research suggests a significant relationship be－ tween pain and olfaction. Stress and pain share common

physiological aspects and neurobiological origins,

with stress influencing both acute pain manifestation and chronic pain maintenance［8］. Olfactory substances have been shown to affect pain intensity and unpleasantness , while gustatory substances influence pain threshold and tolerance［9］.

Smell is highly related with chemistry and memory［10］. Some consider it as the most emotionally expressive of the senses because the sense of smell is somewhat primal［10］ and exceptional. Because of these characteristics of smell, it is popularly believed that smells（odors）have the potential to influence human performance, behavior, and mood［11］, ［12］. Some believed that by smelling a pleasant odor such as aromatherapy treatment can reduce pain［13］, ［14］, ［15］. Using EEG brain activity for different types of smells can be identified and localized［16］, ［17］ and using a similar setup,

it was found that aroma can relieve discomfort, immersion, stress and dizziness in a virtual reality environment [1].

Previous studies [18], [19] have provided evidence that odors may modulate pain in both humans and animals. Another study has suggested that pain tolerance can be influenced by odors, and certain odors significantly increase cognitive and physical performance as well as physiological arousal in humans [6], [11], [20]. Furthermore, certain smells increased the pain tolerance in rats and mice [19], [21]. Similarly, [13], [22], [23] reported how smells of essential oils can be used to influence pain and possibly lead to relief of pain.

The main purpose of this study was to present a proper engineering method that can be used to conduct smell vs pain experiments and investigate the effect of smell on human pain threshold and tolerance. One of the key contribution for the engineering system was developing a computer controlled laboratory built olfactometer [24]. Olfactometers can help to obtain much accurate results for this kind of experiments. They can keep a particular odor in a personal space of a user for a defined period and able to switch to a different smell within seconds. In addition to that, we used an algometer (to take PPT measurements), a timer, and a temperature meter for the experiments. Fig. 1 and Fig. 2 show the system we proposed being used for CPT and PPT experiments.

Using the proposed system, we investigated the effects of smell in pain threshold and perception. Validating the effects of these smells on pain threshold and tolerance will help to better understand the relationship between perceived smells and pain perception. Furthermore, these results could help to investigate the rationale under the use of odorants as an analgesic method, especially for neck and shoulder pain as proposed by aromatherapy because both pain perception and smell have emotional hedonic attributes, and it has been reported that sweet smell increased pain tolerance, we investigated whether sweet (pleasant and sweet), and pleasant (but not sweet) smells will reduce pain and whether unpleasant smell will increase pain perception in two different conditions, cold pressor test (CPT) and pressure pain threshold (PPT). PPT can be used to stimulate different areas in the body such as muscles, joints, tendons and ligaments. Hence, we believed that using PPT should be an effective way of testing, especially for people who suffer from neck, shoulder, and back pain. Meanwhile, CPT was a well known method to obtain pain threshold or pain tolerance. Using both methods together allow us to re-validate the results obtained by the other experiment. Previous studies on smell vs pain conducted either using CPT or PPT. Hence we decided to combine both experimental methods because we would be able to validate and compare our results easily with the previous works.

The key contributions of this paper are as follows. First, we developed an engineering platform to conduct smell vs pain studies. Secondly, the combination of two experiments,

CPT and PPT enhanced the accuracy for testing the hypothesis. Thirdly, we used orange, lavender, and fart smells as the combination and this combination was not tested on PPT before. Moreover, we aim to bring this research to apply contexts such as the working environment where about a third suffer from musculoskeletal pain. Clinical settings where pain patients are treated may also benefit from such knowledge.

The next sections of this paper are organized as follows. Section II will discuss the system we developed for conducting smell vs pain studies. User study methods and experimental procedures would be discussed in section III. The results obtained from the experiments will be presented in section IV. Section V will discuss the findings of this research and potential applications.

2. Smell vs Pain Test Platform

The test platform proposed by the authors equipped with a laboratory olfactometer, algometer, temperature meter, laptop, and a stopwatch. For both CPT and PPT the laboratory olfactometer was used to produce and deliver different smells and it was controlled using the laptop. The algometer was used in the PPT experiment to apply pressure on the trapezius muscle. In the CPT experiment ice water at 7 ^∘ C was monitored using the temperature meter. The time taken to report pain threshold and tolerance were measured using the stopwatch app. Following two subsections will provide more information about the algometer and laboratory built olfactometer. Following sub sections will discuss the olfactometer and algometer in detail.

The relationship between pain and cardiovascular changes is complex and multifaceted, with mixed findings reported in the literature. Some studiesexamined the association between self-reported pain scores and vital

signs like heart rate and blood pressure in emergency department settings [25] [26], others suggest that acute pain can trigger a stress response, leading to increased blood pressure and heart rate [27]. This physiological response is thought to be mediated by the sympathetic nervous system, which is activated in response to pain. As such, we justify the use of heart rate and blood pressure as measures of pain response in our study, acknowledging that the relationship between pain and cardiovascular changes is not yet fully understood.

A. Detailed Measurement Setup

As shown in the pictures of **Figures** 1 and 2, the measurement setup used in this study combines a computer-controlled laboratory olfactometer, a digital algometer, and auxiliary devices for cold pressor and pressure pain threshold tests. The detailed setup consists of the following components:

Laboratory Olfactometer: Custom-built with seven odor delivery channels and one continuous airflow channel. It releases specific odors such as sweet, pleasant, unpleasant, and a control (no smell) through a 3D-

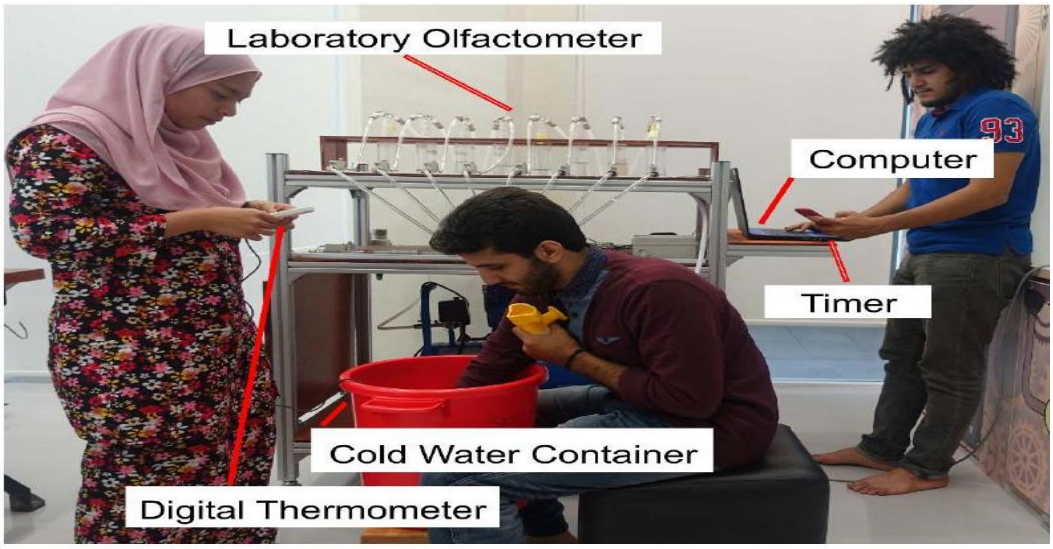

Figure 1. Experimental setup for cold pressor test (CPT). The participant dipping his hand inside the ice water with temperature kept at 7°C, and constantly monitored with digital thermometer

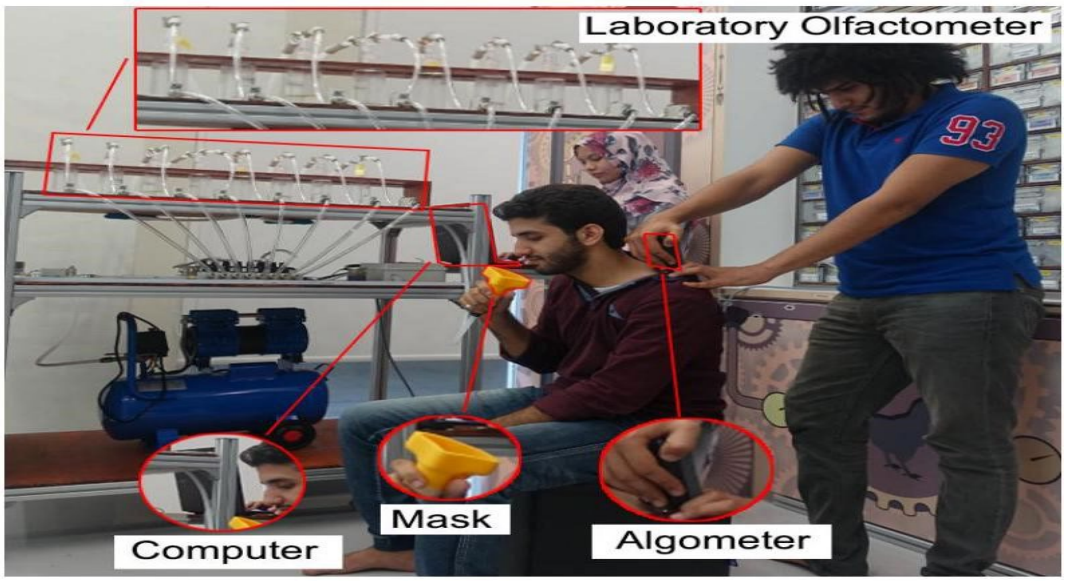

Figure 2. Experimental setup for pressure pain threshold (PPT) measurement. Readings were taken with digital hand held algometer at the upper trapezius muscle (left and right) while the participant inhaled the smell through the mask.

printed mask connected to the device. Odor delivery is precisely controlled using an Arduino microcontroller and pneumatic systems.

- Cold Pressor Test (CPT) Setup: The participant immerses their hand in ice water maintained at a constant temperature of 7°C, monitored with a digital thermometer. A stopwatch app records the pain threshold and tolerance times.
- Pressure Pain Threshold (PPT) Measurement: A digital hand-held algometer applies increasing pressure to the upper trapezius muscle until the participant reports pain. Measurements are repeated for the left and right shoulders under controlled conditions.

The block diagram in **Figure** 3 provides an overview of the experimental workflow.

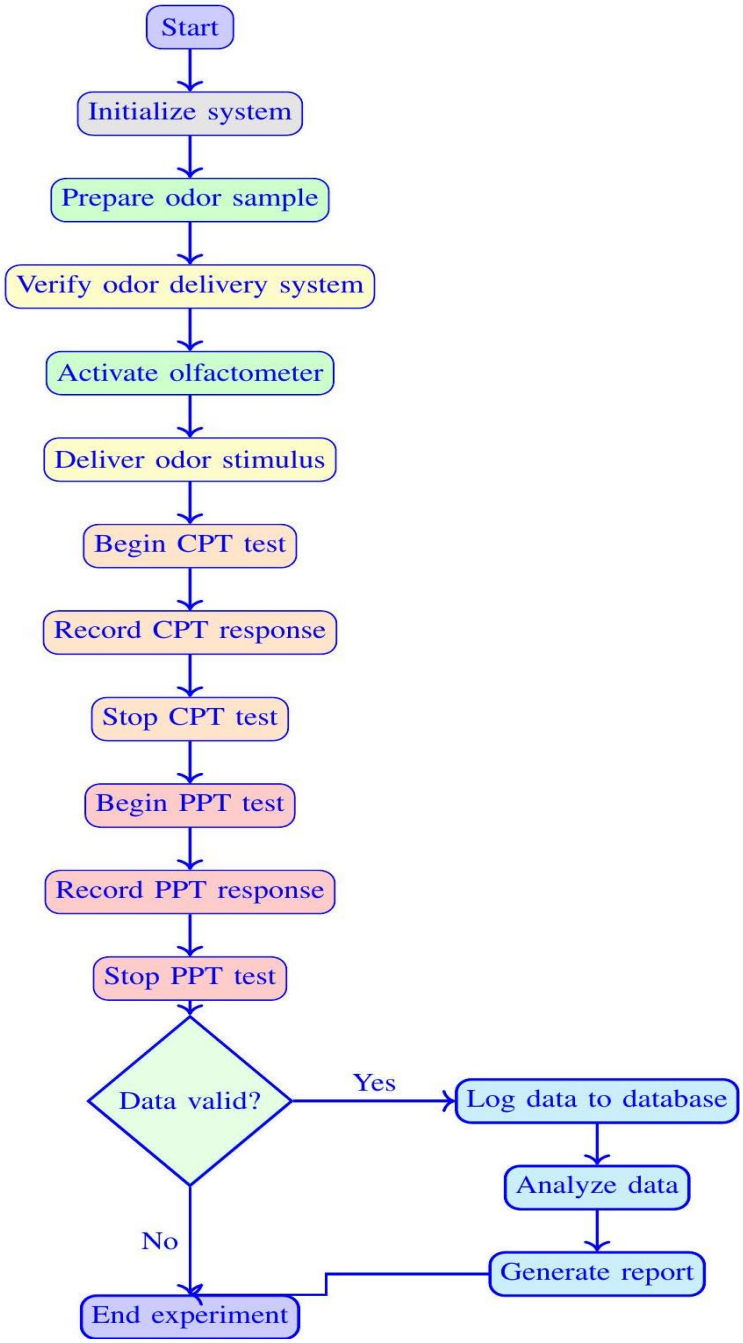

Figure 3. Detailed block diagram of the experimental measurement setup with added micro-steps. Adjusted for IEEE half-column format.

B. Laboratory Olfactometer

Olfactometer is a device which is used to generate and deliver different kinds of odorants based on a time-based protocol. To stimulate subjects with different smells, we built

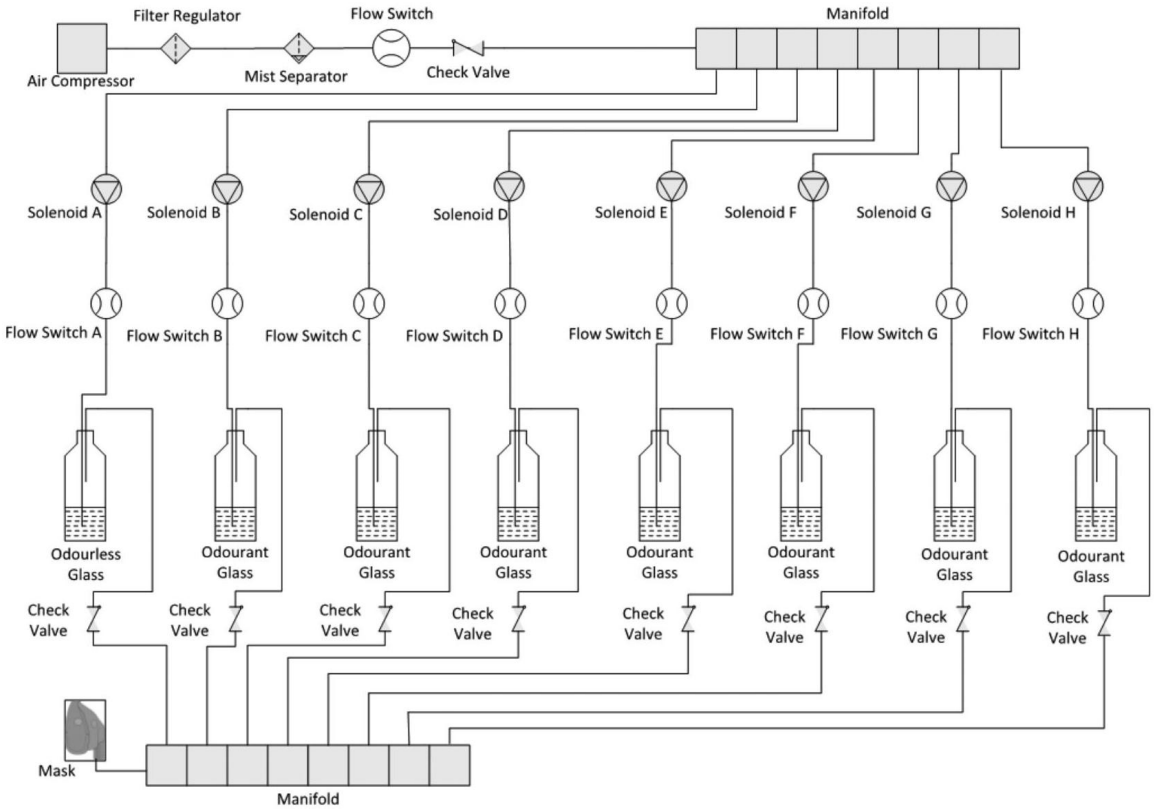

Figure 4. Pneumatic drawing of the olfactometer.

our own olfactometer. This laboratory olfactometer was designed with seven odor delivery channels and one continuous air flow channel. The device was controlled using a computer and released specific smells to a participant through the mask. For both PPT and CPT experiments, the olfactometer was configured to use three odor delivery channels (with lavender, orange, and fart) and a single continuous air flow channel (for no smell condition).

C. Detailed Measurement Setup

The measurement setup used in this study combines a computer-controlled laboratory olfactometer, a digital algometer, and auxiliary devices for cold pressor and pressure pain threshold tests. The detailed setup consists of the following components:

- Laboratory Olfactometer: Custom-built with seven odor delivery channels and one continuous airflow channel. It releases specific odors such as sweet, pleasant, unpleasant, and a control (no smell) through a 3Dprinted mask connected to the device. Odor delivery is precisely controlled using an Arduino microcontroller and pneumatic systems.
- Cold Pressor Test (CPT) Setup: The participant immerses their hand in ice water maintained at a constant temperature of 7°C, monitored with a digital thermometer. A stopwatch app records the pain threshold and tolerance times.
- Pressure Pain Threshold (PPT) Measurement: A digital hand-held algometer applies increasing pressure to the upper trapezius muscle until the participant reports pain. Measurements are repeated for the left and right shoulders under controlled conditions.

The temperature of the ice water was kept at 7°C, which is slightly warmer than the traditional 'ice water' temperature. This modification was made based on previous research, which has shown that water temperatures above 1°C up to 10°C can still effectively activate nociceptors and elicit pain perception [9] [28] [29] [30]. The temperature was constantly monitored using a digital thermometer.

1) Operation of the Olfactometer

There are three subsystems in this laboratory Olfactometer; pneumatics system, controller circuit, and controller program. The schematic diagram of the olfactometer is shown in Fig. 4 To supply pressurized air, an ' Oil－Free

Air compressor □ was used. When the tank of the compressor is full, it is sufficient for the olfactometer to operate for about 30 minutes. The compressor switched on automatically and pump air when the air pressure of the storage tank turns low. A ' pressure regulator unit ' ^{b} with an air filter and a mist separator was installed to make sure that the air released by the compressor has the correct air pressure and free from dust and water particles. Then the air is flowed through a ' digital flow switch ' which measured the air flow rate. Digital flow switch contained a knob that can adjust the air flow rate. We set the overall flow rate in the system to $5\mathrm{l/min}$ and this value was chosen to prevent any discomfort to the subjects.

Next, there was a ' manifold that divides the incoming airflow into eight channels. Eight solenoid valves were connected at end of manifold ' s outputs to control the air flow. Based on the stimulation protocol, the 7 valves related to smell delivery channels were opened or closed. Flow rate of the channels were set using the eight digital flow switches. Eight check valves were placed after the flow switches to prevent the backward flow.

Then there were eight odor gas washing bottles [One of these gas washing bottles contained distilled water and the rest of the 7 bottles contained liquid odor solutions. The active airflow was bubbled through the solutions and generate odorized air. The air left from the gas washing bottles directed through check valves to prevent the back flow. Then, a manifold was used to combine eight channels into a single output channel. Finally, the output airflow was connected to a 3D printed mask, that presented the produced odors to the user. This 3D printed mask can be fixed into a chin rest if necessary. All the tubing for the olfactometer were made using polyurethane. Four different sizes of fittings 组明 were used to connect these tubes with manifolds , check valves, solenoids, and other components.
Each solenoid valve was driven by a separate circuit which connected to an Arduino microcontroller. Microcontroller output pins were connected to eight MOSFETs that switch on and off the solenoids. The zero voltage at the MOSFET would closed the solenoid while 5 V would open it. We implemented optocouplers in between the microcontroller and MOSFETs to disconnect the logic and power and en— hance the safety of the system. Arduino microcontroller was operated on 5 V USB power and solenoids were operated at 12 V . This olfactometer can be easily interfaced with user study software such as E—Prime ^{jj} . OpenSesame ^{k} , and PsychoPy ^{11} However, for both CPT and PPT experiments , there was no activity to be perform on the computer for the participants, therefore, we controlled the olfactometer using the MTputty ^{m} serial port client.

2） Odor Switching ability of the olfactometer

We roughly measured how fast the olfactometer could switch between different smells by performing a simple experiment . The odors used in this experiment were lavender, tea tree oil, and distilled water（as the control flow）. First, the olfactometer was set to operate without any smell（using the control flow which bubbles through distilled water）for five seconds. Then, olfactometer released the lavender smell for $21s$ and after that it released the tea tree oil smell for 21 s . For a total duration of $67s$ we recorded the following : i） number of seconds taken for the subject to feel the lavender smell, ii）number of seconds taken for the subject to feel tea tree oil smell, and iii）number of seconds taken for the subject to stop feeling lavender smell completely. Ten user ' s（four trials per person）responses were aggregated and analyzed.

The average time taken for the users to detect the lavender smell was $6.19 \pm 2.61s$ after releasing. After the olfactome — ter stop producing the lavender smell, the time taken to flush out the lavender smell from the olfactometer was 10.54 ± 6.17 s . Users started to sense the tea tree oil smell after 5.29 $\pm 1.15s$ after releasing. In conclusion, this olfactometer was able to deliver a new odor to a user approximately in $6s$ and it took about $11s$ to flush out the previous odor completely from the system. This test results provided a rough idea about the time it takes for the olfactometer to produce and deliver a smell as well as the time taken to switch between different odorants. During the smell vs pain experiment, we only needed to change the smells in between the trials. Since the olfactometer takes a short time to both flush out one smell and deliver the new smell, we were satisfied with using this olfactometer for both PPT and CPT experiments.

D. Algometer

The algometer is a device that can be used to measure the pressure and identify force eliciting pressure-pain threshold (PPT) [31], which is the minimum force applied where the sensation of pressure changes to pain. It can be used to measure the PPT on muscles, joints, tendons, and ligaments. PPT can be defined as the total number of force needed to evoke a sensation of pain different from discomfort or pressure [32]. Algometer used in this experiment is shown in Fig. 5 and it was a Wagner FPIX ^{TM} Digital Algometer [33]. The contact area of the circular probe was $1\ \mathrm{cm}^2$. The pressure from the device was applied perpendicular to the mid portion of the upper trapezius muscle at a rate of approximately $3N \cdot s^{-1}$ until the participant experience that pressure becomes pain.

Figure 5. Hand held Digital Algometer (Wagner Pain TestTM - Model FPIX): a Digital device that give accurate pressure/force readings.

3. Smell vs Pain User Study

After developing the technical platform, we conducted two experiments to study the effects of smell on pain threshold and pain tolerance for CPT and PPT. This section will provide a detailed overview of our experimental methods and procedures.

A. Subjects

Total of 32 subjects comprising 14 males and 18 females, (mean age $= 26.3$ years, standard deviation $(SD) = 7.8$ years, range $= 20 - 45$ years), participated for the two studies. An ethics approval for this study was obtained from the Institutional Review Board, and each subject signed a consent form. Participants were paid for the time they spent based on hourly rate. Subjects were physically examined for good physical well-being and female subjects were excluded if they are pregnant or breastfeeding. Generally, any subject with either of the following conditions: bronchopulmonary or neurological disease, chronic pain, cold or allergy symptoms, smoking, allergy to perfume, current use of analgesic medication including non-prescription drugs were excluded. Subjects with any kind of heart problem was
also excluded [34]. Subjects were likewise advised not to use alcohol within 12 hours of the experimental procedure. Because of the role expectation and emotion plays on pain perception [35], participants were blind regarding the type of smell presented to them. The subjects were majorly university students and office workers.

B. Experimental Procedure

Our experiment was designed to understand if olfactory stimuli influence pain. The odorants we used were orange (sweet), lavender (pleasant), fart (unpleasant), and no smell as the control condition. This experiment was spread within four days per participant, each smell per day, and one day for no smell condition. The order of smells was randomized for

each participant. The experiment was divided into two sub experiments: (i) cold pressor test (CPT) and (ii) pressure pain threshold (PPT) test. The ambient temperature was kept at 20°C throughout the experiment. Subjects were familiarized with the procedure before the main experiment. The two experiments lasted for about one hour.

1) Experiment 1. Cold Pressor Test (CPT)

The aim of this study was to investigate how different type of odors affect pain perception, and to extend the findings reported by [11] using different smells and a different approach. The experiment took place for four days for each participant. In the first day, participant sits quietly in a comfortable chair for 5 minutes and the procedure was started with no smell (CPT-) condition (control). The temperature of the ice water was kept at 7°C and constantly monitored using a digital thermometer. The participant will immerse his/her hand and the experimenter was making sure the height and angle of hand that went down in water are same for every subject. The time of hand immersion was recorded. Then, participant was told to leave his/her hand in the ice water for as long as the subject can tolerate or endure the pain and withdraw when the subject can no longer tolerate the pain. The time at which the subject withdraws his/her hand, when he/she felt some pain was also recorded. Using these data we calculated the duration of the pain tolerance.

Participants had to wait for 30 minutes to switch between left and right hand without smell (CPT-) and the procedure was repeated. This interval was kept enabling the participant to adjust to normal body temperature. The second day, participants were exposed to a smell (CPT+) at approximately 5 minutes. The selected smell was released using olfactometer while dipping the hand (right or left) inside a cold ice water at temperature 7°C as shown in Fig. 1 and 30 minutes interval between switching of hands. This was repeated for all the smells and the duration was recorded and compared between the different smells.

2）Experiment 2.Pressure Pain Threshold measurement

In the second experiment，the pressure pain threshold（PPT） was measured. We used an algometer to apply pressure on the upper trapezius muscle（upper shoulder muscle）.

The participants were same as in the first experiment，that is university students and office staff，because most often these group of people have neck and shoulder pains. About one third of working age adults are estimated to experience neck and shoulder pain［36］，［37］.

First，each participant sits quietly and comfortably on a chair and waits for 5 minutes without smel. Then，the upper shoulder area（upper trapezius muscle）was exposed . Using the algometer，pressure was exerted on the upper trapez－ ius（upper shoulder muscle）. Five measurements of pain threshold were taken from each upper shoulder at different points. Interval of approximately 30 seconds separated each measurement，and 5 minutes to switch from left to right. In all instances，the right trapezius was tested first followed by the left. Total of 10 PPT readings were recorded for each of the participants.

Participants were instructed to state when the sensation of pressure changes to slightly unpleasant pain［38］. Slightly unpleasant，as suggested by［39］repre－ sents an approximate intensity of 5 on a 21 －point numeric pain rating scale，and this agrees with the definition of pain established by the International Association for the study of pain［40］. Because we want to measure pain tolerance and also capture pain threshold. This procedure was repeated for all the three smells and the smell was released using olfactometer as shown in Fig. 2.

C. Data Analysis

All statistical analyses were carried out using statistical package for social science（SPSS）for Windows. A sig－ nificance level of $p < 0.05$ was adopted for all analyses.

Data for both experiments were analyzed using One－Way Analysis of Variance，comparing the means within the groups and between the groups，to evaluate whether sweet and pleasant smell can increase pain threshold and tolerance . Effect size for One－way ANOVA was calculated to estimate the difference between the groups.

4. RESULTS

A. Study 1：Cold Pressor Test

In the analysis，data were removed if the subject could not complete all four trials because the experiment was divided into four groups，sweet smell，pleasant smell，no smell and unpleasant smell conditions. Also，data was excluded if subject removed his／her hand in CPT within 5 secs，because a substantial proportion of the subjects did not find the temperature noxious. Our hypothesis，was that sweet smell can increase pain tolerance while unpleasant smell can reduce pain tolerance. Thus，we measured the duration（time in secs）each participant can withstand the pain from cold pressor test. The total number of participants that completed the four trails were $32(n = 32)$.

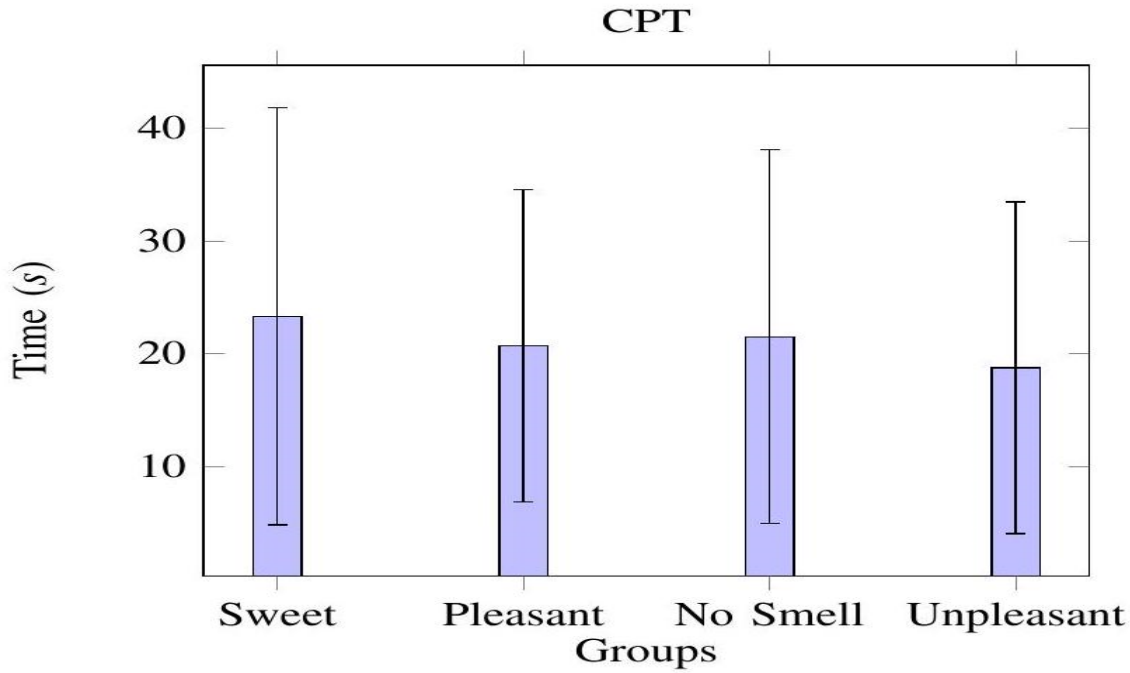

Figure 6. This graph visualize the means for the Cold Pressure Test（CPT）. Error bars shows standard deviations（Std）.

Comparing Mean Ratings for Genders

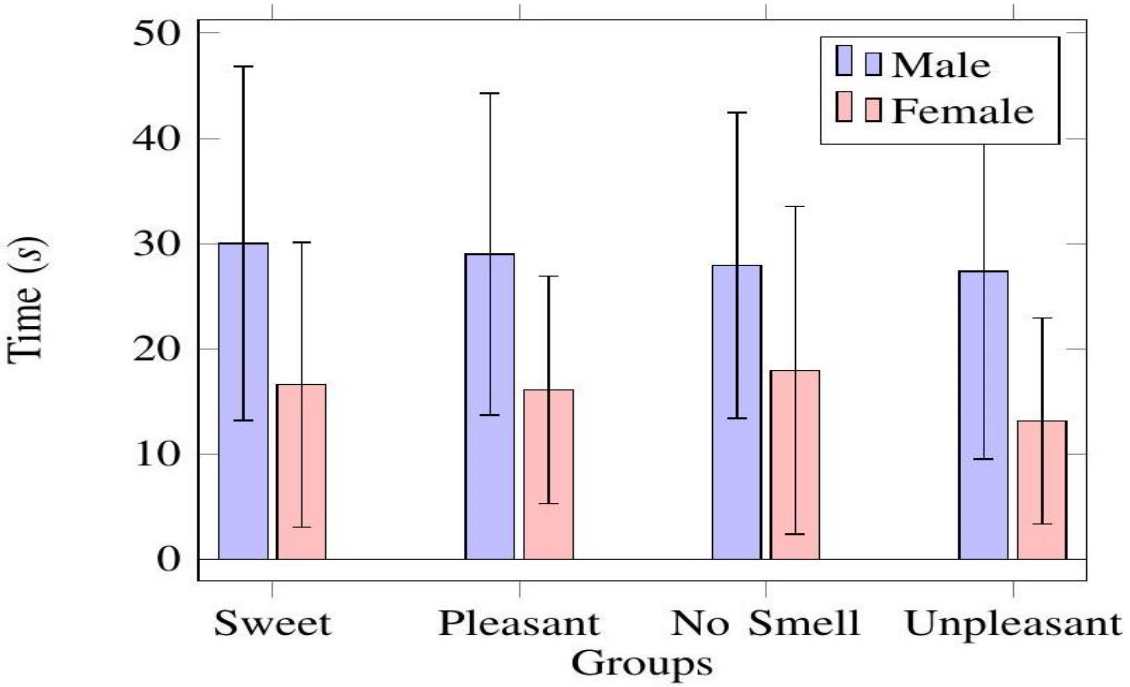

Figure 7. Comparing means between male and female participants for CPT. Error bars shows standard deviations（Std）.

A One－Way between groups analysis of variance was conducted to explore the impact of smell on pain tolerance. Participants were divided into 4 groups based on the number of smells used and their gender. Generally, CPT experiment showed a statistical significant result at $p < 0.05$ in all the groups using no smell condition as control. The mean and standard deviation（SD）of CPT are 23.30 ± 18.48（sweet）, 20.70 ± 13.80（pleasant）, $18.76 \pm$

14.70 unpleasant, and 21.50 ± 16.56 (no smell) respectively as shown in Fig. 6, which shows the time taken for the users to report unbearable pain for different smells. We also compared the groups between male and female, as well as the switch from left to right hand. Comparing between male and female, the sweet smell (orange) showed a statistically significant result $F(1,30) = 13.857, p = 0.001$, same applied for pleasant smell (lavender) and unpleasant smell, $F(1,30) = 5.853$, $p = 0.022, F(1,30) = 5.247, p = 0.029$. There was a statistically significant difference at $p < 0.05$ level in CPT for the groups. Fig. 7 represents the mean ratings for gender with sweet, pleasant, unpleasant and no smell, showing the time spent in water. However, between right and left hand, there was no statistical significant difference for the groups, $F(1,62) = 0.875, p = 0.353$. For all smells p was > 0.05.

In CPT experiment, the results clearly indicate that odor has a significant effect on pain. Notwithstanding reaching statistical significance, the definite difference in mean scores between groups were rather small. However, the Effect Size for One-Way ANOVA was calculated to estimate the difference between the groups. The results showed that there is a large meaningful difference between the groups. Sweet smell and unpleasant smell analysis showed that 98% of the total variance is accounted for by the smell effect, while 97% is accounted for pleasant smell. Between male and female the mean difference was higher in males as compared to females. Comparing means plots of sweet with unpleasant smell, the graph shows a significant mean difference between the male and female participants.

Calculated mean and SD for PPT as presented in **Figure** 6 when sweet and pleasant smells were presented are highest, while unpleasant smell is lowest. The observed variability in pressure pain threshold (PPT) values across participants can be attributed to several factors. Individual differences in pain perception are influenced by genetic predisposition, personality traits, and life experiences [41]. Also, genetic variation in olfactory receptor (OR) genes contributes to differences in odor detection, intensity perception, and pleasantness ratings [42] [43].

B. Study 2: Pressure Pain Threshold Measurement

Five PPT measures were performed approximately 5 to 10 seconds apart at five different points on the trapezius muscle on right shoulder and left shoulder, making it 10 PPT measures, total and average were calculated. Similar to CPT, PPT data also presented a significant result on all the groups, at $p < 0.05, F(3,28) = 94.517, p = 0.002$ (sweet smell), $F(3,28) = 51.362, p = 0.004$ (pleasant smell) and $F(3,28) = 16.430, p = 0.020$ (unpleasant smell). Calculated mean and SD for PPT as presented in Fig. 8 when sweet and pleasant smells were presented are highest while unpleasant smell is lowest.

There was a statistical significant different in comparison between gender, with $p < 0.05$ in all the groups while there was no significant difference in comparing left and right shoulder, $F(1,62) = 0.561, p = 0.457$. Fig. 9 compared the means amongst male and female, while Fig. 10 represents the graphs of the 4 groups comparing their means for right and left shoulder. Comparing Means for Genders for PPT

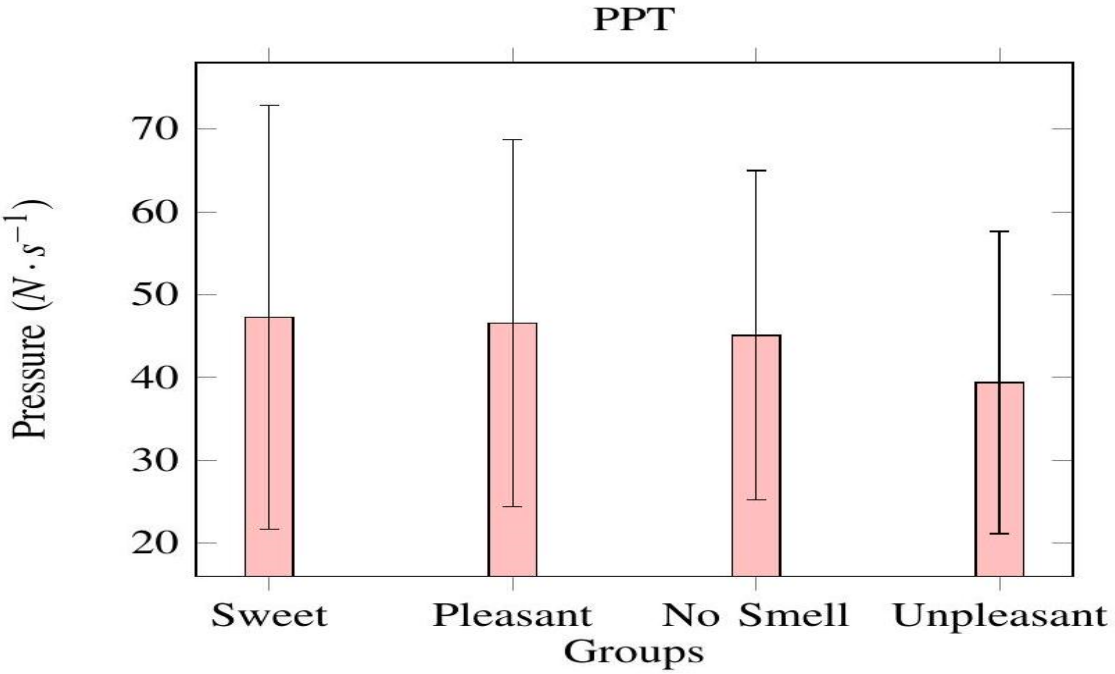

Figure 8. Means of the Pressure Pain Threshold (PPT) for each smell. Error bars show standard deviations (Std).

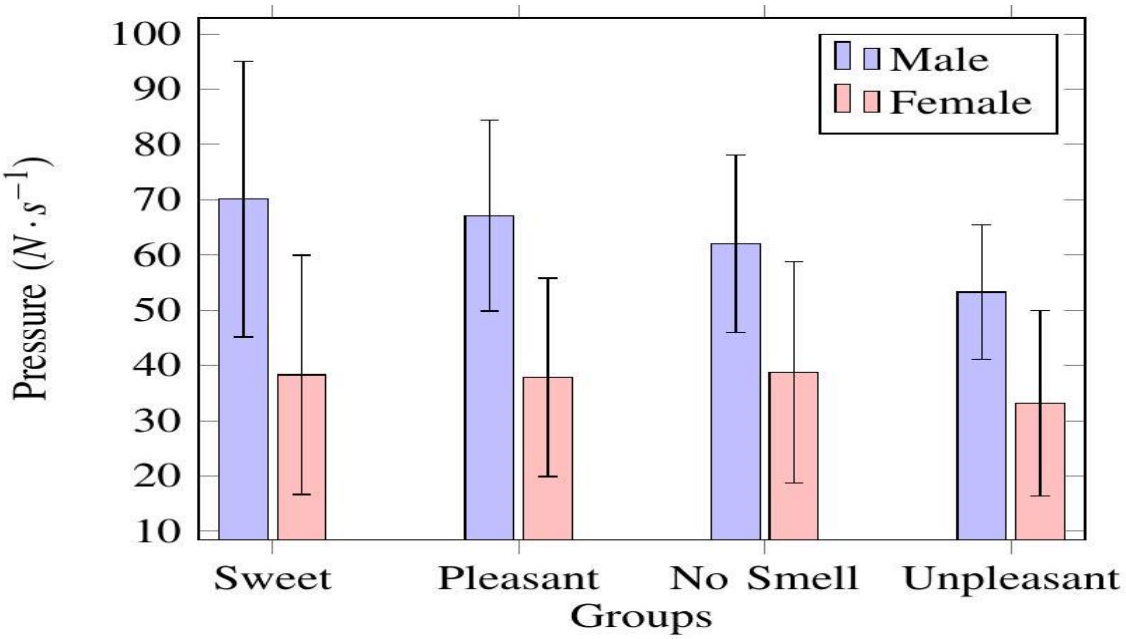

Figure 9. Comparing means between male and female participants for PPT. Error bars shows standard deviations (Std).

5. DISCUSSION

The main purpose of the user experiments was to study if sweet or pleasant smells increases the pain threshold and tolerance while unpleasant smells reduces the pain threshold and tolerance. CPT and PPT experiments clearly validated this claim. Sweet and pleasant smells increased the pain tolerance, the duration for the hand to be in the water significantly increased during CPT with sweet and pleasant smell contrasting to the no smell condition (CPT-) and unpleasant smell. These results evidently showed that sweet smell increased the duration that subjects kept their hand exposed to cold water. This result agreed with [44], whose studies reported that odor sweetness reduces pain where

Table 1. A comparison between the related works and Smell vs Pain research

Title of Work	Tools Used	Evaluation Methods	Results
Pain Tolerance Selectively Increased by a Sweet－Smelling Odor［5］	Nose mask impregnated with odor solution was worn by the partici－ pants.	Cold Pressor Test（ CPT）	Sweet smell increased pain tolerance.
Odors modulate pain perception A gender－ specific effect［6］	Cotton ball impregnated with odor placed in airtight bottle.	－Nociceptive thermal stimuli • Hot water trial	－Mood perception was significantly increased by pleasant odors. －Mood perception was significantly decreased by unpleasant odors. －No significant difference in mood perception was recorded in gender. －Pain perception was not influenced by odors. －Significant effect was obtained for gender on perception.
Effects of odors on pain perception： deciphering the roles of emotion and attention［3］	－TSA II Neuro－Sensory analyser －Computerized Knosys Olfac － tometer	Heat stimuli	－Pain experience can be modulated by odors. Pleasant and unpleasant odors can lead to changes in emotions.
Unpleasant odors increase pain process－ ing in a patient with neuropathic pain： Psychophysical and fMRI investigation [13]	Computerized Knosys Olfactome－ ter	Odor stimuli	Unpleasant odor increased pain intensity.

Electronic Instrument to Measure Ef－ fects of Smell on Pain Threshold and Tolerance（ this paper）	－Laboratory built olfactometer to present different smells accurately to the users －Algometer to take accurate PPT readings －Temperature meter to monitor the temperature of ice water during CPT －Stop watch app to record user response times	－Cold Pressor Test（CPT） －Pain Pressure Threshold（PPT）	－Sweet smell increased the pain tolerance and pain threshold －Pleasant smell increased the pain tolerance and pain threshold －UnPleasant smell decreased the pain tolerance and pain threshold －Significant effects obtained between male and female －No significant effects between to left and right shoulders

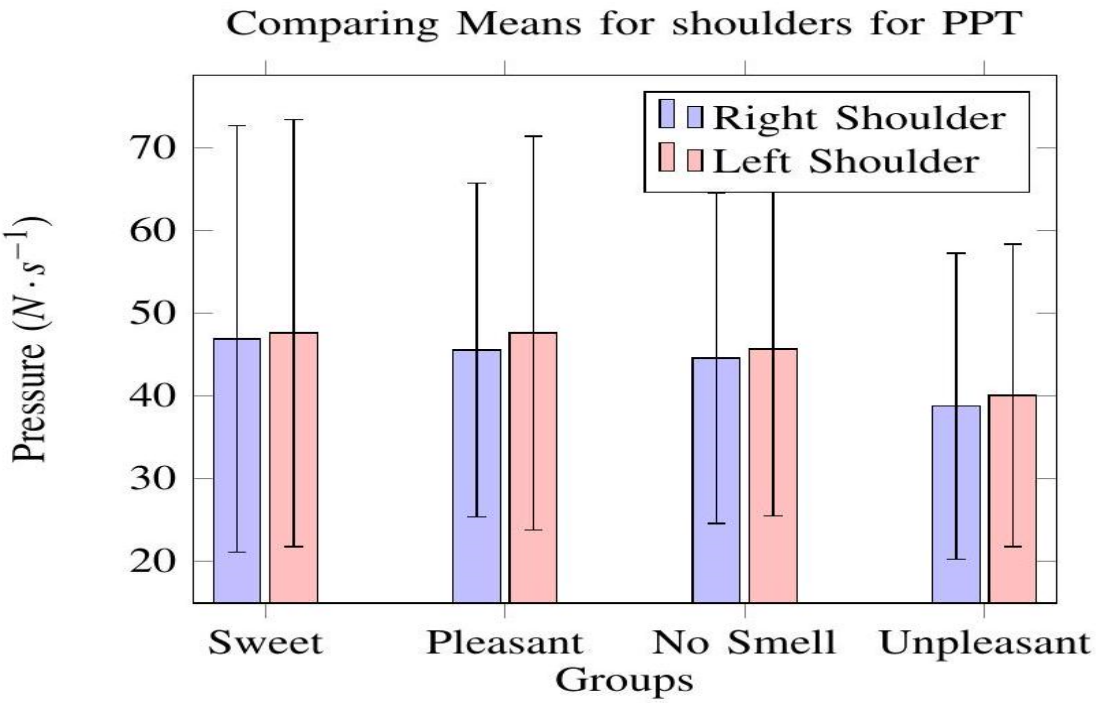

Figure 10. Comparing means of right and left shoulder of participants for PPT. Error bars shows standard deviations（Std).

pain tolerance was increased by sweet smell during CPT. Also［45］on their study on taste reported that sweetness increased pain tolerance. For us, both sweet smells and pleasant smells produced a positive result. Studies have shown people experience most of sweet－smelling odorants as pleasant［46］. Similarly, PPT increased significantly in both sweet and pleasant smell and reduced in unpleasant smell groups.

One possible explanation for the effect of odors on pain perception possibly is that odor influences mood, which in turn effects pain perception. And considering the mecha－ nism of smell pain reduction, the effect of smell on pain reduction may have several distinct mechanisms. This is because the sensory process of olfaction modify the brain activity through its ascension to numerous parts of the brain , including amygdala. The fact that the sense of smell directly links to the limbic region of the brain suggests that smell can quickly modify pain sensation and unpleasantness through its emotional modulation［47］, ［48］. Furthermore, smell could affect one ' s physiological and psychological state through two mechanisms ; the intrinsic pharmacological properties of the odor molecule itself and contextual association and memory［49］.

The results for both experiments were statistically sig－ nificant on gender differences. As also reported by［18］ , using hot water（ 46－48°C ）, odor pleasantness influenced the perception of pain more in woman than in men . But our results showed males mean CPT＋to be higher compared to the females CPT＋.

Table. 1 shows the comparison of contributions made in this paper with previous works. Our study was the first to investigated the effect of smell on pain combining two different approaches ; CPT and PPT using olfactometer to re － lease smell. No previous study has reported the

combination of the these odorants and measurements at this anatomical point. Other studies on PPT measurement did not employ the use of odorants. Some studies on PPT measurement are owing to pathology or done in relation to a therapeu－ tic intervention［50］－［52］and others on healthy humans reported on gender differences in experimental PPT［53］. The smells we have used（orange, lavender, and fart）were previously not tested as a combination for the smell vs
pain experiments. Apart from [3],13] this is the only study that was carried out using an olfactometer. Olfactometer can automatically create the necessary smell experiences in the environment near the participant. Other previous experiments used special wearables to make smell stimulation and these special wearables could distract the participant.

Our study provides evidence that sweet smell could increase pain tolerance and therefore reduce pain perception. Thus, we believe applying this method will be beneficial to companies, institutions, and can be applied in work environments generally. We can never ignore the cause of neck and shoulder pain especially among students and office workers, because they spend reasonable amount of time sitting and bending towards their computers. We suggest that the use of smell rather than pain relief medication could reduce drug over use and drug dependency rate among office workers. We believe using sweet smelling odorants could reduce pain and consequently will encourage and enhance work performance.

In this study we have used only healthy students and office participants. Future research will include testing with people with chronic neck-shoulder pain, e.g. during a standardized office work task. Repeated measures on different days with pleasant, sweet, unpleasant and control condition in a randomized order will be recorded. Perceived pain intensity on a scale of $0-10$, where 0 is no pain and 10 is maximal pain will also be measured.

The effect of smell on pain should also be seen in the light of cost-effectiveness. Pleasant and sweet smells could easily be dispersed in office work places at very low cost and thereby have the potential to benefit a large proportion of the workers. The results also have relevance for clinical settings where pain patients are treated, e.g. sweet and pleasant smells can easily be dispersed in physiotherapy settings to enhance the positive experience of the patient.

Conclusion

This study represents a groundbreaking investigation into the intricate relationship between odors and pain perception, advancing our understanding of how sensory stimuli influence human tolerance to discomfort. At the forefront of this research is the development of a novel computer-controlled platform specifically designed to facilitate precise and reproducible experiments on the interplay between smell and pain. This platform, coupled with the innovative methodologies employed, establishes a new benchmark for experimental design in this domain.

The results of this study are particularly compelling and carry profound implications for both theoretical and applied research. The findings unequivocally demonstrate that sweet and pleasant odors significantly enhance pain thresholds and tolerance levels, thereby acting as effective modulators of pain perception. In contrast, unpleasant odors were found to exert the opposite effect, reducing both pain thresholds and tolerance. This dichotomy underscores the powerful
influence of olfactory stimuli on sensory and emotional processing. Furthermore, the study reveals noteworthy gender differences in pain tolerance, with males exhibiting higher tolerance levels compared to females, an observation that warrants further exploration into gender-specific mechanisms in sensory perception and pain modulation.

The contributions of this research are both multifaceted and highly novel. First, the introduction of a robust and reliable computer-controlled experimental platform for investigating smell-pain interactions represents a significant technological advancement, providing researchers with a standardized tool to conduct experiments with unprecedented precision. Second, the combined testing methodology, integrating the Cold Pressor Test (CPT) and Pressure Pain Threshold (PPT), offers a comprehensive approach to examining the complex and multifactorial relationships between olfactory stimuli, pain perception, and sensory processing. By validating prior findings on CPT with a new array of odorants, this study not only corroborates existing knowledge but also enhances the generalizability and reliability of its conclusions across different sensory stimuli.

Beyond its scientific contributions, the implications of this research extend to the practical realm of environmental design. The findings offer valuable insights into how olfactory stimuli can be strategically harnessed to create multisensory environments that promote comfort, productivity, and overall well-being. In workplaces, study areas, and domestic settings, the judicious use of pleasant odors could serve as a non-invasive and cost-effective strategy to alleviate discomfort and enhance human performance.

In summary, this study not only bridges critical gaps in the understanding of smell-pain interactions but also sets a new standard for methodological rigor and innovation in sensory research. The dual contributions of a novel experimental platform and an integrated testing methodology underscore the transformative potential of this work. The findings presented here pave the way for future research and practical applications, offering a robust foundation for leveraging the influence of olfactory stimuli to improve quality of life and human experience in diverse settings. In this paper, we presented a computing platform to conduct smell vs pain experiments and then investigated whether sweet, and pleasant smells will reduce pain and whether unpleasant

smell will increase pain in two different conditions, cold pressor test (CPT) and pressure pain threshold (PPT). Both pain threshold and tolerance were significantly improved for sweet, and pleasant smells and reduced for the unpleasant smell. Furthermore, we found that gender played a role in pain tolerance where males have a higher pain tolerance than females. The key novelties of this research includes; introduced a technological platform that can facilitate for smell vs pain experiments, the first smell vs pain experiment done combining CPT and PPT, and validating previous experiments reported for CPT using different set of odorants. We believe these findings will be useful in the future for designing multisensory envirenments for work, studies, and living.

Acknowledgement

Authors would like to greatly appreciate valuable support made by our former Imagineering Institute ' s lab members including Halimahtuss Saadiah, Hamizah Shahroom, and Ha— nis Camelia. We further acknowledge the generous financial support from Nanjing University of Information Science &Technology and the University of Colombo School of Computing under the funding scheme, Research Allocation for Research and Development. This financial assistance greatly contributed to the success of our research endeavor by covering various research—related expenses.

Conflict of interest

The author declares the following potential conflict of interest: ***Adrian David Cheok*** is a member of the editorial board of this journal. However, this manuscript was handled using the journal's standard editorial procedures, independently of the author's role, to ensure an objective and unbiased review process. No other conflicts of interest are declared.

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