Investigating the Effects of Self-selected Pleasant Scents on Text Composition and Transcription Performance

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ABSTRACT

The extensive use of computers for text entry has been linked to increased stress, depression, and sleep disturbances, adversely affecting performance. Recent trends involve using scent diffusers to counter these effects. However, the impact of scents on text entry performance is not well-studied. Our empirical study investigated the effects of self-selected pleasant scents on text composition and transcription performance. Results showed that while composing, users were slower with a scent present, potentially due to heightened focus on text quality. Scent did not alter accuracy or text length. In transcription tasks, although scent did not alter typing speed, it adversely affected accuracy, likely due to its impact on concentration levels. Despite these mixed results, users felt more effective and enjoyed the scent, indicating a preference for its continued use. This study opens avenues for further research into scents' influence on computer-based tasks, potentially contributing to the evolving field of olfactory displays.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **User studies**; *Interaction paradigms*; *Text input*.

KEYWORDS

Olfaction, olfactory interfaces, smell, odor, odorant, scent, writing, composition, texting, text entry, data entry, workplace

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1 INTRODUCTION

The ubiquity of computers in daily life is evident, with U.S. office workers spending, on average, six hours a day on computers at work and an additional hour at home [74], while the global average reaches approximately 6.5 hours [71]. This data is complemented by another global survey indicating that even non-office workers spend about 3.5 hours daily on computers, with a significant portion of this time devoted to text entry-related activities [44]. Prolonged computer use has been associated with stress, depression, sleep disturbances, and a decline in performance [38]. To counteract these negative effects, there is a growing trend of using scent diffusers while working. This practice, often termed "aromatherapy", is widely promoted in lifestyle magazines and blogs for its purported benefits in reducing stress and anxiety and enhancing performance during computer use [52, 57, 64, 84]. These claims are seemingly supported by research suggesting that pleasant scents can improve mood and task performance [5, 15, 45, 47, 58, 77, 82]. However, there is a lack of consensus in the scientific literature regarding the efficacy of these practices.

Furthermore, existing research on the impact of scents on task performance has typically involved the use of a single, pre-selected scent, or has been limited to basic tasks like word, object, or sequence recall. In contrast, the task of text entry represents a more intricate and complex interaction of perceptual, cognitive, and motor processes [76]. It is a goal-directed process involving planning, retrieving information from long-term memory, and reviewing composed text [34]. Given this complexity, it remains uncertain whether the positive effects of scents observed in simpler tasks can be extrapolated to text entry.

This work aims to bridge this gap by examining the impact of user-selected pleasant scents on more complex text-related tasks, specifically text composition, like creative writing, and text transcription, similar to data entry tasks. To achieve this, we conducted two user studies. The initial two-week diary study evaluated the intensity, durability, quality, and density of fifteen commonly available essential oils and fragrances, to ensure uniformity in scent characteristics for the subsequent study. The second study focused on comparing performance in text entry tasks, measuring aspects such as speed, accuracy, and text quality, alongside user preferences regarding the presence of a chosen scent while typing. Unique in its approach, this study not only allowed users the freedom to select from a diverse range of scents but also provided a comparative analysis of text composition and transcription performance in the presence of these scents. This work adds to the text entry community's efforts to improve performance and user experience by exploring multi-modal interactions, such as speech, gestures, or olfactory elements [1, 32]. Additionally, insights from this study could inform future investigations of olfactory displays and interfaces to enhance mood and performance in various settings [36]. The integration of pleasant scents in work environments may also offer mental health and economic benefits, potentially leading to healthier, happier, and more effective workforces.

The contributions of our study are threefold. Firstly, it represents the first quantitative research to explore how self-selected scents affect both text composition and transcription performance, filling a notable gap in existing literature. Secondly, the study's protocol was meticulously developed through iterative processes to minimize subjectivity and bias, setting a precedent for future olfactory research. This approach enhances the external validity and replicability of the findings, facilitating more robust comparisons with other studies. Lastly, in response to the absence of suitable metrics in current research, our work introduces two novel performance metrics specifically designed for evaluating text composition. Additionally, we advocate for the adoption of the Dale-Chall readability formula as a standard tool for assessing the readability of composed text in future text composition studies.

2 RELATED WORK

This section provides an overview of the research on the impact of pleasant scents on mood and task performance. The adverse effects of unpleasant odors on human health and performance have been well documented in the literature [11, 47, 66, 78, 81, 91]. Additionally, studies have explored the use of scents in virtual and augmented reality systems (VR/AR) to enhance user experience and presence [39, 59, 63, 69]. A particularly innovative field involves the development of novel olfactory displays. These programmable devices either emit odorous molecules (chemostimulation) or directly activate odor receptors in the nose (electrostimulation) [16, 23, 33, 55, 60, 67, 68]. Advances in this area also include wearable solutions to increase the mobility of these displays [6, 24, 26, 30, 63, 83, 87]. While the outcomes of this research could guide the design of such devices by informing scent selection and emission balance, this falls outside the current work's scope. Yanagida [90] provides a comprehensive review of the techniques and technologies for scent production, manipulation, and direct delivery to the olfactory system.

2.1 Effects on Mood

Studies investigating the effects of scent on mood report conflicting results. Hulshof [45] found out that people are less aroused with relaxing scents (sandalwood) than with stimulating scents (peppermint). Knasko [47] argued that people are in a more pleasant mood with a pleasant scent (lavender). Similarly, Alaoui-Ismaïli et al. [5] reported that pleasant scents (vanilla, menthol) induce happiness and surprise in individuals. However, in an earlier study, Ludvigson and Rottman [50] did not find any effects of pleasant scents (lavender, cloves) on mood. In a different line of research, Holland et al. [43] showed that the scent of a typical all-purpose cleaner enhance *"the accessibility of the behavior concept of cleaning"* and influence actual performance of cleaning behavior. A study in a large shopping mall revealed that people are likely to help others more in locations with pleasant ambient scents, such as near bakeries and coffee shops [14]. Studies also identified pleasant scents to have a major impact on the purchase decisions [56]. Rimkute et al. [72] provide a comprehensive review of the effects of scent on consumer behavior.

2.2 Effects on Performance

There has also been no consensus on how pleasant scents affect human performance. Ludvigson and Rottman [50] reported that pleasant scents (lavender, cloves) improve arithmetic-inferential ability, but adversely affect analogical reasoning. They, however, did not find any effects of the examined scents on word recall performance. Schab [77], Smith et al. [82], on the other hand, reported significantly higher word recall rates in presence of pleasant scents (jasmine, Lauren perfume by Ralph Lauren). Morgan [58] found out that when people learn new words in presence of a pleasant scent (cinnamon), their recall rates after five days are significantly higher in presence of the same scent. Based on this, they argued that scent acts as a "retrieval cue" when recalling words. Herz [40] reported similar results with a different odorant (violet leaf), and Herz et al. [41] with a different task (word puzzles). Baron and Thomley [15] reported that pleasant scents (lemon, floral) improve the performance of anagram tasks (rearranging the letters of a word to form new words) by 10–17% in both low and moderate stress scenarios. Barker et al. [13] investigated the effects of a pleasant scent (peppermint) on the transcription of nonsensical letter combinations. They reported that transcription speed is significantly slower but more accurate in presence of the scent. Bao and Yamanaka [12] also reported a positive effect of pleasant scents (chamomile tea, black tea) on the accuracy rate of data entry task on a spreadsheet. Bordegoni et al. [20] showed that context-specific odors enhance individual's reading experience, as well as the level of concentration when learning. Covaci et al. [25] reported similar results with an educational game. Du et al. [31] showed that exposure to essential oil (lemon, grape-seed) emissions result in a faster reaction time, but significantly worsen response inhibition control and memory sensitivity. Barker et al. [13], however, failed to find a significant effect of a pleasant scent (peppermint) on memory tasks with a Milton Bradley's Simon electronic memory device. Likewise, Ademoye and Ghinea [3] reported that olfaction does not significantly influence the recall of information content presented at the end of multimedia video clips. Knasko [47] also failed to find an effect of a pleasant scent (lavender) on drawing performance. Ghinea and Ademoye [37], in contrast, reported a negative effect of video content appropriate scents (burnt, flowery, foul, fruity, resinous, spicy) on content recall performance (12% lower accuracy rate).

Bodnar et al. [19] compared an olfactory feedback method with the traditional visual and auditory feedback methods on a desktop computer. The system provided two different types of notifications, differentiated using the scents of cloves and eucalyptus. In the

(a) The base and the cover (b) Assembled diffuser (c) Mist emission

Figure 1: The 100 ml InnoGear AD310 diffuser used in the studies.

study, the olfactory feedback method was found to be less effective in delivering notifications than the other methods. In similar studies, Warnock et al. [88, 89] found out that disruptions with olfactory feedback methods are comparable to disruptions with visual and auditory feedback methods, but the former takes significantly longer to process than the latter feedback methods. Maggioni et al. [54], however, reported conflicting results. They showed that olfactory notifications improve user confidence and performance in identifying the urgency level of a message, without compromising the reaction time and disruption levels. Dmitrenko et al. [29] provided in-car notifications on three different driving-related messages using four scents (lemon, lavender, peppermint, rose). Results revealed that drivers are able to establish a mapping between specific driving-related messages and scents. A follow-up study revealed that drivers perceive these olfactory notifications as less distracting, more comfortable, and more helpful than visual notifications [28]. Brewster et al. [22] developed a scent-based photo searching system. In a study, participants first tagged photos using a set of smell and tag names, then returned two weeks later to answer questions on their photos. In the study, scent tags showed promise, but did not perform as well as textual tags. In a related work, Ademoye and Ghinea [2] showed that users are more tolerant of synchronization skews when media appropriate scents are provided ahead of the audiovisual content. Lai [48] installed a scent-emitted artwork in a museum and found out that it attracts visitors to stay longer than the other works.

A different study revealed that ambient scent (coffee) increases both the sense of presence in a virtual environment and memory for the objects in the environment [27]. Braun [21], Narciso et al. [62], Ranasinghe et al. [70] confirmed these findings. Tortell et al. [85] reported similar results with environmentally appropriate scents in a video game. Likewise, Madzharov et al. [53] argued that people in a coffee-scented environment perform better on an analytical reasoning task compared to an unscented environment due to heightened performance expectations. However, a later study, also using environmentally appropriate scents (ocean mist, maple syrup), failed to replicate these results [46]. Baus and Bouchard [17] also failed to find any effects of pleasant scents (apple pie, cinnamon) on presence in VR.

The conflicting results in the literature might be attributed to the common use of pre-selected scents, usually just one, in these studies. Notably, none of these studies allowed users to choose their preferred scents. Given that individual scent preferences are likely to vary, this could lead to inconsistent effects on their performance and preferences in the study. Additionally, the varied experimental protocols across studies, even for the same tasks, and the differences in questionnaires and methods for calculating performance metrics, complicate comparisons and replication of results.

3 USER STUDY 1: FIFTEEN-DAY DIARY STUDY

We conducted a fifteen-day diary study to inform the design of the final study. This preliminary study focused on the fifteen most common scents, examining their optimal settings using a standard diffuser to minimize confounding variables in the final study. In the study, three participants kept detailed records of the intensity of the scents, the number of drops needed to balance the intensity of the scents, the durability of the scents, and any perceivable differences between the essential and fragrance oils.

3.1 Apparatus

We used a 100 ml InnoGear AD310 diffuser ($10 \times 10 \times 14$ cm, ; 204 g, brown) in the study (Fig. 1). The device has an eight-color LED ring (orange, yellow, red, cyan, green, blue, purple, white) at its base that can be turned off or set to fixed or cycling colors. In the study, we turned off this feature to eliminate any potential effects of color on performance [45]. The diffuser can disperse a stream of room-temperature mist in two modes: intermittent that pauses every 30 seconds for 30 seconds and continuous that continuously runs for 3–4 hours. We used five Cliganic essential (Fig. 2a) and ten Holamay fragrance oils (Fig. 2b) in the study. Essential oils are sourced 100% from aromatic plant parts, while fragrance oils are made of both aromatic plant parts and synthetic components [80]. Based on the Aftelier Natural Perfume Wheel [4], we only selected the scents that are less likely to cause allergies or health hazards (e.g., excluded spice scents). The complete list of scents is presented in Table 1.

3.2 Participants

For the study, we recruited three participants (Fig. 2c), aged between 19 and 20 years (M = 19.3, SD = 0.6), all of whom identified as women. They were undergraduate students majoring in Computer Science,

(a) Essential oils **(b) Fragrance oils** **(c) A participant of the diary study**

Figure 2: The (a) essential and (b) fragrance oils used in the study, and (c) a participant of the diary study working in her dormitory room with the diffuser in intermittent mist mode.

Bioengineering, and Psychology at a local university and had no prior experience with scent diffusers. Additionally, none of the participants had allergies to the scents used in the study.

3.3 Procedure

The study took place in a 24 m^2 dormitory room shared by the participants. We provided them with a diffuser, the oils and fragrances, and a pipette for precise measurement. Following a shared schedule over fifteen days, the participants used one distinct scent per day. They experimented with varying quantities, ranging from 1 to 10 drops per 50 ml of water, in different diffuser settings and room locations, at various times of the day when all were available. They were instructed to maintain the room temperature between 20° and 25° Celsius and to keep windows and doors closed while using the diffuser. They recorded their observations on diffuser settings, as well as the perceived intensity and durability of each scent. Although the room was shared, each participant maintained an individual diary and was advised not to share their notes or thoughts with the others, ensuring independent evaluations.

3.4 Results

Upon completion of the study, a researcher compared and summarized the diary entries. Participants recommended placing the diffuser within 1 m of the user with the mist facing the user, as the quality of the scents degraded when placed further from that. They recommended against using the diffuser in continuous mist mode to prevent olfactory fatigue. Besides, the room got too misty when the diffuser was in continuous mist mode for extended period of time.

Table 1: The scents used in the studies (in alphabetical order) along with their perceived intensity (mild, moderate, or strong) and durability when the diffuser is placed within 1 m of the users. The number of drops represent the amount of oil needed to make the intensity of the scents comparable.

#	Scent	Oil Type[a]	Scent Type[b]	Scent Intensity	Oil per 50 ml[c]	Durability (minute)	Diffuser Mode
1	Apple	Fragrance	Fruity	Mild	3 drops	3	Intermittent Mist
2	Blood Orange	Fragrance	Fruity	Moderate	5 drops	6	Intermittent Mist
3	Blueberry	Fragrance	Fruity	Strong	5 drops	10	Intermittent Mist
4	Coconut	Fragrance	Fruity	Strong	5 drops	14	Intermittent Mist
5	Eucalyptus	Essential	Medicinal	Moderate	6 drops	5	Intermittent Mist
6	Grape	Fragrance	Fruity	Strong	5 drops	9	Intermittent Mist
7	Lavender	Essential	Floral	Strong	5 drops	9	Intermittent Mist
8	Lemongrass	Essential	Herbal	Strong	3 drops	16	Intermittent Mist
9	Mango	Fragrance	Fruity	Mild	5 drops	3	Intermittent Mist
10	Melon	Fragrance	Fruity	Mild	5 drops	2	Intermittent Mist
11	Orange	Essential	Fruity	Moderate	6 drops	10	Intermittent Mist
12	Peppermint	Essential	Mint	Strong	5 drops	14	Intermittent Mist
13	Pineapple	Fragrance	Fruity	Mild	5 drops	3	Intermittent Mist
14	Strawberry	Fragrance	Fruity	Strong	5 drops	12	Intermittent Mist
15	Watermelon	Fragrance	Fruity	Moderate	3 drops	7	Intermittent Mist

[a]Essential oils are sourced 100% from aromatic plant parts, while fragrance oils are made of both aromatic plant parts and synthetic components [80].
[b]Scents are categorized using the Aftelier Natural Perfume Wheel [4].
[c]One drop is about 0.05 ml.

The scents were olfactible almost immediately after turning on the diffuser. However, they found the scents to be different in intensity, thus recommended adjusting the amount of drops per 50 ml of water to make them somewhat comparable. Different densities and other properties of the oils also required adjusting the amount of drops. For example, despite having a strong scent, "grape" needed five drops of oil to maintain the intensity.

They reported that scents are gone withing 2–16 minutes of turning the diffuser off without any extra effort (such as using a fan). But the scents linger on the inside of diffuser, thus recommended washing the tank after each use. Interestingly, participants did not perceive any difference between the essential and fragrance oils. Table 1 summarizes the findings of the study.

4 USER STUDY 2: WITHOUT & WITH SCENT

We conducted a second user study involving twenty-eight participants to compare text composition and transcription performance, both without and with the presence of a self-selected pleasant scent. Specifically, this study was structured to test the hypotheses presented in Table 2.

For composition, we expect substantial evidence to support hypotheses $H_{1.1}$ (speed), $H_{1.3}$ (contemplation), and $H_{1.5}$ (readability), drawing from the theory that composition involves complex processes like planning, retrieving information from long-term memory, and reviewing text. Flower and Hayes [34] characterize writing as a goal-directed activity involving these layered thinking processes, with writers constantly forming new goals and subgoals [73]. Given that a pleasant scent is known to improve mood [41, 45, 47] and enhance cognitive and analytical performance [15, 45, 53], it likely encourages deeper contemplation, leading to increased time and effort in composition. This is likely result in longer contemplation times and enhanced readability, while potentially slowing down entry speed. For transcription, we do not expect to find strong support for our hypotheses, as transcription involves a different, less complex process compared to text composition. According to Salthouse [76], transcription is seen as a series of parallel processes: converting text into chunks, breaking these chunks into sequences of characters, converting these characters into movement specifications, and executing these movements in a ballistic manner. Previous studies have not found a significant link between transcription typing performance and text comprehension [75]. Additionally, in transcription tasks, users can internalize text chunks before typing, thereby reducing the need for continuous visual attention and lowering cognitive demand once they begin typing [86].

4.1 Participants

We recruited twenty-eight participants through various emailing lists and postings on social networking sites. All participants underwent a pre-screening process for allergies to the examined scents, and those with allergies were excluded. Additionally, we excluded individuals with any permanent or temporary conditions that could impact olfaction, such as nasal obstructions, neurological conditions, medications, or illnesses (including COVID-19 and seasonal flu). We also confirmed that participants could commit to attending both sessions of the study, which were held on two separate days. Ultimately, twenty-eight participants met the eligibility criteria.

Their age ranged from 18 to 42 years (M = 25.4, SD = 6.5). Eighteen of them identified as women (64%) and ten as men (36%). Ten of them were high school graduates and current university students (43%), five had a bachelor's degree (18%), and the remaining eleven had a post-graduate degree (39%). Using the 5-point Interagency Language Roundtable (ILR) scale [35], eleven participants rated their proficiency in English at Level 5: Native or bilingual proficiency (39%), six at Level 4: Full professional proficiency (21%), nine at Level 3: Professional working proficiency (32%), and two at Level 2: Limited working proficiency (7%). None of them used a scent diffuser prior to the study. They all received U.S. $30 for participating in the study.

4.2 Apparatus

This study used the same diffuser and scent oils as the diary study (Section 3). In addition, it used an AMD Ryzen 3 3000 Series HP desktop computer (8GB RAM, AMD Radeon) with a 24" LED touchscreen display and an HP Pavilion 800 wireless keyboard and mouse combo. The system ran on a 64-bit Windows 10 operating system. For transcriptions tasks, the study used a commonly used web application [8]. For transcription tasks, we developed a similar web application. Both apps recorded all performance metrics directly. The apps were loaded on a Microsoft Edge v107 browser.

4.3 Design

We used a within-subjects design with two independent variables *scent* and *task*. The two levels of scent (*without scent* and *with scent*) were distributed between the two sessions, while the two levels of task (*composition* and *transcription*) were distributed within the sessions. In other words, participants performed both composition and transcription tasks in the sessions, either *without scent* or *with scent*. The study sessions were counterbalanced, but the task order within each session was not. Participants always began with the

Table 2: The hypotheses tested in the second user study. The red and black asterisks indicate full and partially significant results, respectively.

Composition Tasks	Transcription Tasks
$H_{1.1}$ *Self-selected pleasant scent affects entry speed* *	$H_{2.1}$ *Self-selected pleasant scent affects entry speed*
$H_{1.2}$ *Self-selected pleasant scent affects input accuracy*	$H_{2.2}$ *Self-selected pleasant scent affects input accuracy* *
$H_{1.3}$ *Self-selected pleasant scent affects contemplation time* *	
$H_{1.4}$ *Self-selected pleasant scent affects text length*	
$H_{1.5}$ *Self-selected pleasant scent affects text readability* *	

(a) Choosing a scent (b) Composing with scent (c) Transcribing without scent

Figure 3: Participants (a) picking a scent for the study, (b) composing text with scent, and (c) transcribing text without scent.

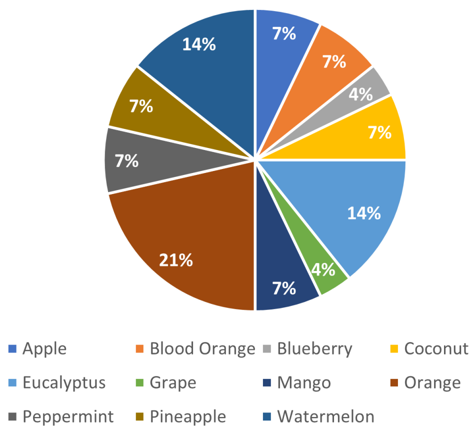
transcription task, following insights from a pilot study where starting with composition made participants feel rushed, impacting their writing process. This effect was not observed when transcription was the initial task. In summary, participants transcribed in total $28 \times 2 \times 50 = 2{,}800$ phrases and composed in total $28 \times 2 \times 1 = 56$ essays. The dependent variables were the following performance metrics.

- **Words per minute** (wpm) represents the average number of words typed in a minute. For calculation purposes, 5 characters, including spaces and symbols, are considered as one word [9]. The formula used is: $wpm = \frac{|T|-1}{S} \times 60 \times \frac{1}{5}$, where S denotes the time in seconds from the first to the last key press. The constants 60 and $\frac{1}{5}$ represent the number of seconds in a minute and the average word length in characters, respectively. The subtraction of 1 accounts for the initial character entry preparation time.
- **Contemplation time** measures the average time (seconds) users spend on planning, translating, or reviewing the text [73]. Based on the combination of average novice verification (1.2 seconds) and preparation time (1.2 seconds), a threshold of 2.4 seconds is set to identify contemplation [10]. Periods of inactivity exceeding this threshold, indicated by no caret movement, are considered as contemplation.
- **Typing words per minute** (t-wpm) calculates the average number of words typed per minute, specifically excluding contemplation time. This metric focuses solely on the duration of character entry, representing raw typing speed. To compute t-wpm, the composed text is divided into chunks at points of contemplation. The standard wpm formula is then applied to the concatenated chunks, with the immediate characters following each contemplation excluded using the -1 adjustment in the formula: $t\text{-}wpm = \sum_{i=1}^{i=n}(\frac{|T_i|-1}{S_i})\times 60 \times \frac{1}{5}$, where i represents the total number of chunks based on contemplation count, S_i is the time in seconds from the first to the last keystroke for the i-th chunk, and $|T_i|$ is the length of that chunk.
- **Error rate** (%) is the average ratio of the total number of incorrect characters in the transcribed text to the length of the transcribed text. This metric cannot used directly on composition tasks due to the absence of a source text (the compostedtext cannot be compared with a source text) [51]. Hence, we counted incorrect characters in the composed text using the JavaScript SpellCheck [61]. Abbreviations and any misspelled words with more than three-character differences were considered as out-of-vocabulary (OOV) words, and were excluded from the calculation.
- **Length** is the average number of characters in a composed text, including space and symbols.
- **Readability score** is calculated using the revised Dale-Chall formula, which provides a numerical measure of text comprehension difficulty: $0.1579\times\left(\frac{\textit{difficult words}}{\textit{words}} \times 100\right)+0.0496\times\left(\frac{\textit{words}}{\textit{sentences}}\right)$. Difficult words are those not in a list of 3,000 words known by fourth-grade American students [79], while *words* and *sentences* refer to the total counts in the text. Spelling errors are corrected before applying the formula, and OOV words are excluded. An additional 3.6365 is added to the raw score if difficult words exceed 5%. The Dale-Chall formula was selected due to its proven validity and consistency in assessing text difficulty [18].

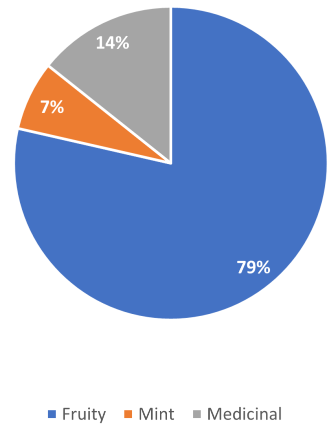
4.4 Procedure

The study was carried out in a quiet 14.2 m^2 lab, accommodating one participant at a time. To maintain a scent-neutral environment, we restricted any odorant sources, including perfumes, in the lab during the study. Upon arrival, participants were briefed about the research without revealing the hypotheses to avoid bias. After obtaining their informed consent and completing a demographics questionnaire, we introduced them to the study apps and allowed practice sessions, including writing a few lines and transcribing 1-3 short phrases. The study comprised two separate sessions: without scent and with scent, conducted on different days with a gap of 1-5 days. In each session, participants worked at a desktop computer (Fig. 3).

In the transcription task, participants transcribed 50 phrases from a corpus chosen for its typical lengths and alignment with English character frequencies [51]. Each phrase was displayed individually on the screen (Fig. 3c). Participants were instructed to read, understand, and transcribe each phrase as quickly and accurately as possible before pressing the Enter key for the next one. After



(a) Selected scents



(b) Selected scent types

Figure 4: Different (a) scents and (b) types of scents selected in the user study.

completing all the phrases, a mandatory break of 10-15 minutes was enforced. After the break, participants started the composition task. They could write essays on one of ten pre-selected "narrative and personal" essay topics (Table 3) or a self-chosen topic. The topics, carefully chosen to avoid complexity or emotional distress, aimed to stimulate high experiential demand [42]. Participants were instructed to select a topic they felt comfortable with. The app provided a text input area for essay composition, with no restrictions on length or time, allowing participants to write until they were satisfied. To ensure easier text analysis, the use of abbreviations, contractions, profanities, uncommon foreign words, and emojis was discouraged. The input area's height automatically matched the display's height to prevent any perceived need to match essay length to the input space. Participants could adjust the input area's size and submitted their essay by pressing a Submit button.

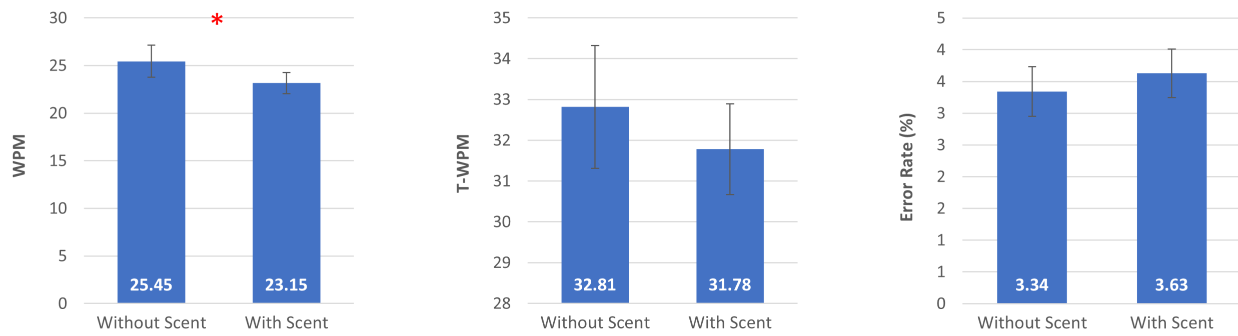
In the session with scent, participants began with a scent selection task (Fig. 3a), spending about fifteen minutes choosing their preferred scent from fifteen options. They then documented their choice and selection process in a questionnaire. The chosen scent was set up in a diffuser placed within 1 meter of the participant (Fig. 3b), using the corresponding settings from Table 1. The diffuser ran for a few minutes before the main tasks commenced, following the same procedure as above. The sessions were counterbalanced, with topics not being repeated across sessions. Between sessions, the diffuser tank was cleaned, and the study area aired out to remove residual scents. Post-session, participants completed a custom questionnaire evaluating the scent's impact on their text entry performance and experience. They also provided feedback on the study in a debrief session.

5 RESULTS

A Martinez-Iglewicz test revealed that the response variable residuals were normally distributed. A Mauchly's test indicated that the variances of populations were equal. Hence, we used a repeated-measures ANOVA for the within-subjects factors and a paired-samples t-test on the data filtered for the composition and transcription tasks. We also report effect sizes for the statistically significant results, namely eta-squared (η^2) for ANOVA and Cohen's d for t-test. All tests in the study resulted in large effect sizes ($\eta^2 \geq 0.1$

Table 3: Distribution of topic selection for composition.

Topics	Without Scent	With Scent	Total Ratio
1) Your favorite vacation with your family	2	3	9%
2) A trip you will never forget	6	3	16%
3) A time you made friends in an unusual circumstance	0	3	5%
4) Your first day at a new school	3	3	11%
5) The best birthday party you have ever had	1	0	2%
6) The best day of your life	2	0	4%
7) Your best friend and how you met	7	3	18%
8) The best present you have ever received	1	3	7%
9) A story from a trip	2	2	7%
10) Learning a life lesson	2	2	7%
Self-selected topic	2	6	14%



(a) Words per minute **(b) Typing words per minute** **(c) Error rate (%)**

Figure 5: Average entry speeds in (a) wpm and (b) t-wpm and (b) average error rates (%) in composition task without and with scent. Error bars represent ±1 standard error. Red asterisks represent statistically significant differences.

and $d \geq 0.8$ [7]), suggesting a high probability that the observed relationships will remain consistent across further research.

5.1 Scent Selection

Participants took between 5 to 20 minutes to choose a scent for the study. The majority opted for fruity scents (N = 22, 79%), such as orange and watermelon, followed by medicinal (N = 4, 14%) and mint scents (N = 2, 7%). Fig. 4b illustrates the distribution of the types of scents selected by participants. The most popular choices were orange (N = 6, 21%), watermelon (N = 4, 14%), and eucalyptus (N = 4, 14%). Fig. 4a depicts the distribution of scents picked by the participants. The post-study debrief session and responses to the questionnaire revealed that the majority of participants (N = 16, 57%) selected a scent because it enhanced their mood. They reported that the selected scent made them feel "happy" or "calm", and found it "refreshing" or "relaxing", providing a sense of "comfort". Five participants (18%) chose a scent because it evoked a happy memory, while the remaining 21% (N = 6) cited both reasons. In the post-study debrief session, none of the participants expressed any dissatisfaction or regret about their chosen scent. Additionally, we conducted a comparison of the scent intensity ratings obtained in the first study (diary study) and this study using a Kolmogorov-Smirnov test, which failed to reveal a significant difference between the cumulative distributions of the two data sets ($D(22) = 0.27, p = 0.8$). This outcome suggests that participants in both studies rated the intensity of the scents in a similar manner.

5.2 Composition vs. Transcription

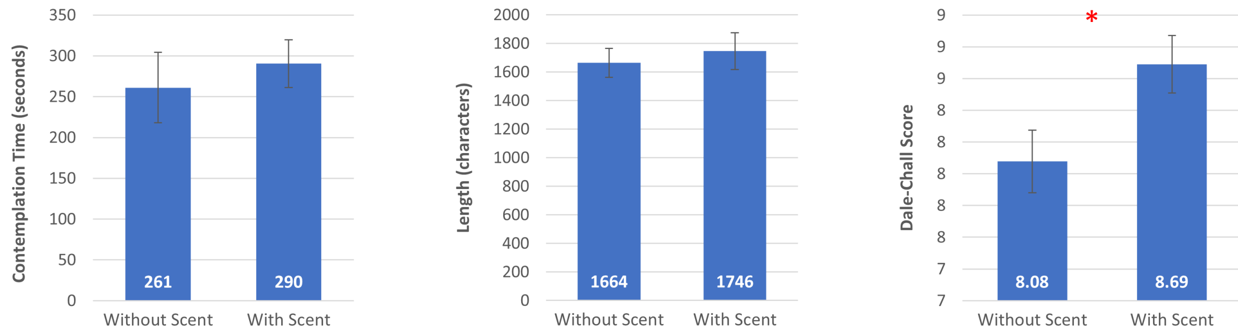
An ANOVA identified a significant main effect of task on both entry speed ($F_{1,27} = 152.92, p < .00001, \eta^2 = 0.65$) and error rate ($F_{1,27} = 81.10, p < .00001, \eta^2 = 0.45$). Participants were 54% faster (24.3 wpm vs. 52.8 wpm) and 80% more accurate (3.5% vs. 0.7%) with transcription tasks than with composition tasks. A Tukey-Kramer multiple-comparison test revealed that composition with scent had a significantly slower entry speed than both transcription conditions, while both transcription conditions yielded significantly lower error rates than the both composition conditions. An ANOVA also identified a significant main effect of scent entry speed ($F_{1,11} = 4.47, p < .05, \eta^2 = 0.01$). However, no significant main effect was idenfiied on error rate ($F_{1,27} = 1.33, p = .26$).

5.3 Composition Results

A complete composition session took about 40 minutes to complete, excluding the time for instruction, demonstration, and practice. The majority of participants (71%, N = 20) chose writing topics from the provided list. The remaining eight participants (29%) selected their own topics, examples of which include *"My favorite quote and why"* and *"My first day being a teaching assistant"*. Table 3 presents the distribution of topic selection, highlighting that topic 7, *"Your best friend and how you met"*, was the most chosen (18%), followed by topic 2, *"A trip you will never forget"* (21%). The selection frequencies for the other topics were relatively similar.

5.3.1 Entry Speed and Accuracy. A t-test identified a significant effect of scent on entry speed ($t_{27} = -2.13, p = .04, d = 5.7$). The average entry speeds without scent and with scent were 25.45 wpm (SD = 8.93) and 23.15 wpm (SD = 5.78), respectively (Fig. 5a). Expectedly, a t-test failed to identify a significant effect of scent on entry speed without contemplation time ($t_{27} = -1.32, p = .19$). The average entry speeds, excluding contemplation time, were 32.81 t-wpm (SD = 7.98) without scent and 31.78 t-wpm (SD = 5.88) with scent (Fig. 5b). A t-test also failed to identify a significant effect of scent on error rate ($t_{27} = 0.62, p = .54$). The average error rates were 3.34% (SD = 2.07) and 3.63% (SD = 2.03) without scent and with scent, respectively (Fig. 5c).

5.3.2 Contemplation Time and Length. A t-test failed to identify a significant main effect of scent on contemplation time ($t_{27} = 0.82, p = .42$). On average, participants spent 261 seconds (SD = 228) contemplating what to write without scent, and 290 seconds (SD = 155) when a scent was present (Fig. 6a). Given the notably higher average contemplation time with scent compared to without, we further analyzed the data by categorizing participants based on typing speed. Those below the mean minus standard deviation (16.96 wpm) were labeled as slow typists (N = 6), while others were classified as fast typists (N = 22). We then conducted an RM-ANOVA on this grouped data. The test revealed a significant effect of typing speed group on contemplation time ($F_{1,26} = 26.78, p < .0001, \eta^2 = 0.4$).



(a) Contemplation **(b) Length** **(c) Readability**

Figure 6: Average (a) contemplation times (seconds) (b) lengths (characters), and readability scores (Dale-Chall) of composition without and with scent. Error bars represent ±1 standard error. Red asterisks represent statistically significant differences.

Subsequent analysis using the Tukey-Kramer multiple-comparison test showed that slow typists spent significantly more time contemplating when exposed to scent than their faster counterparts.

5.3.3 Text Length and Readability. A t-test failed to identify a significant effect of scent on length ($t_{27} = 0.70, p = .49$). Participants entered on average 1,664 characters (SD = 538) without scent and 1,746 characters (SD = 683) with scent (Fig. 6b). However, a significant effect of scent on the readability of the composed essays was identified ($t_{27} = 2.64, p = .01, d = 1.3$). The average readability scores were 8.08 (SD = 1.04) without scent and 8.69 (SD = 0.96) with scent (Fig. 6c). To investigate whether English proficiency and education level of the participants influenced this outcome, we conducted further analysis. A Pearson Chi-Square test did not show a significant effect of English proficiency scores on readability scores in either condition: without scent ($\chi^2(78) = 80.4, p = .4$) and with scent ($\chi^2(78) = 84, p = .3$). Similarly, education level did not significantly affect readability scores in both conditions: without scent ($\chi^2(78) = 79.8, p = .42$) and with scent ($\chi^2(78) = 79.8, p = .42$).

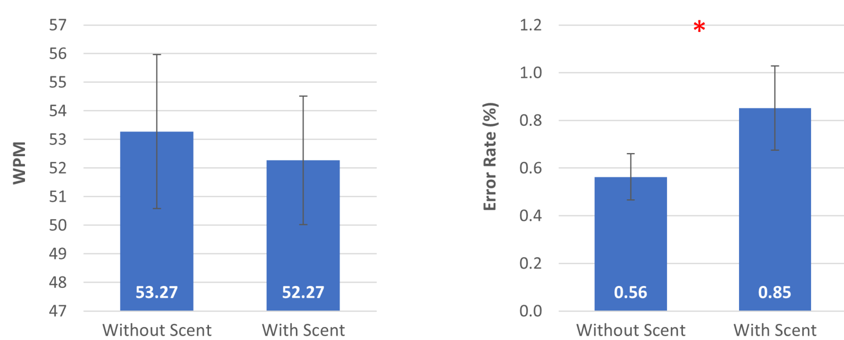
5.4 Transcription Results

A complete transcription session took about 40 minutes to complete, excluding instruction, demonstration, and practice. We did not record the length or the readability of the text since in this session the participants copied the phrases presented to them from a set [51]. For the same reason, we did not calculate the contemplation time or the typing words per minute (t-wpm).

5.4.1 Entry Speed and Accuracy. A t-test failed to identify a significant effect of scent on transcription entry speed ($t_{27} = -1.13, p = .27$). On average entry speed without scent and with scent were 53.27 wpm (SD = 14.22) and 52.27 wpm (SD = 11.91), respectively (Fig. 7a). However, a t-test identified a significant effect of scent on error rate ($t_{27} = 2.32, p = .03, d = 4.7$). The average error rates were 0.56% (SD = 0.51) and 0.85% (SD = 0.93) without scent and with scent, respectively (Fig. 7b).

5.5 Subjective Feedback

The majority of participants reported that the presence of scent positively influenced their speed and accuracy in both text composition and transcription tasks. They generally did not find the



(a) Speed **(b) Accuracy**

Figure 7: Average (a) entry speeds (wpm) and (b) error rates (%) of transcription without and with scent. Error bars represent ±1 standard error. Red asterisks represent statistically significant differences.

Table 4: Percentage of participants agreed, disagreed, or were neutral of the questionnaire statements. The largest percentage is highlighted in a bold font.

	Composition			Transcription		
	Agree	Neutral	Disagree	Agree	Neutral	Disagree
Perceived Speed	**89%**	4%	7%	**82%**	11%	7%
Perceived Accuracy	**86%**	7%	7%	**68%**	18%	14%
Distraction	7%	18%	**75%**	11%	4%	**86%**
Enjoyment	**89%**	7%	4%	**96%**	0%	4%
Willingness	**93%**	0%	7%	**93%**	4%	4%

scent distracting and almost all enjoyed its presence, expressing willingness to continue using a diffuser while typing on computers. Table 4 presents the results of the questionnaire.

6 DISCUSSION

A post-hoc power analysis was conducted to assess the adequacy of the sample size for this investigation. The analysis showed that all statistically significant results attained high powers: ranging from 1.0 to 0.99 in t-tests, and between 1.0 and 0.95 for ANOVA, all exceeding the widely accepted threshold of 0.80 [7]. These findings confirm that the sample size used in this study was sufficiently large to ensure the reliability of the results.

6.1 Scent Selection Strategies

The results suggest that the positive effects on mood and associations with happy memories contribute to the pleasantness of a scent. A majority of the participants (57%) selected a scent because it elicited feelings of happiness or calmness, offering a sense of comfort. One participant (male, 28 years old, who chose pineapple) commented, *"I like pineapple and its smell. It makes me feel the sweetness and it's kind of calming. Besides, the scent of pineapple is rare in daily life and seems fresh to me."* About 21% of participants picked a scent that evoked a happy memory. For example, one participant (female, 20 years old, who picked apple) wrote, *"The scent of apple reminds me of the fall season and my grandma's apple pie, giving me peace of mind."* The remaining 21% of participants identified both the effects on mood and the associated memories as reasons for finding a scent pleasant. One participant (female, 19 years old, who chose orange) wrote, *"This is really fresh... I usually like fresh/green scents because they make me feel happy, relaxed, and calm. It reminds me of sitting outside after it has stopped raining, and of the song "Like Water" by Wendy, which talks about being grateful."*

6.2 Composition vs. Transcription Tasks

Participants demonstrated significantly faster and more accurate performance in transcription typing compared to composition tasks. Specifically, they were 54% faster and 80% more accurate in transcription typing tasks. These results align with previous studies which suggest that transcription typing tasks are often decomposed by users into ballistic keystroke actions, typically without a concerted effort to comprehend the source text [75, 76]. Consequently, transcription typing demands less cognitive effort and visual attention than composition [86]. Indeed, various processes involved in transcription typing often overlap in time, enabling users to type very quickly *"with interkey intervals averaging only a fraction of the typical choice reaction time"* [76].

6.3 Effects of Scent

A t-test provided evidence supporting the alternative hypothesis $H_{1.1}$. Participants took significantly more time to compose text with scent than without (a 10% reduction in entry speed). This is presumably because pleasant scents put participants in a better, more relaxed mood, encouraging them to spend more time composing essays. This finding is supported by several prior studies that suggest people are generally less aroused, happier, and in a more pleasant mood when exposed to pleasant scents [5, 45, 47]. Notably, participants' raw typing speeds were comparable between the two conditions (33 vs. 32 t-wpm), indicating a specific effect on the composition process. Many participants acknowledged this effect. For example, one participant (22 years old, female, chose mango) commented, *"I felt that when writing the essay, I was in a better mood, which allowed me to be more elaborate on my creative side. The nice scent helped me unlock sweeter and nicer memories that made me think more about that day I experienced"*. However, another participant (20 years old, female, chose apple) found the scent distracting during composition, noting, *"While writing an essay, I felt overwhelmed by the scent. I could not focus on the narrative; my mind went blank as I craved apple pie"*.

Interestingly, there was no significant main effect of scent on contemplation time, despite the average time being longer with scent than without. Further analysis revealed that slower typists spent significantly more time contemplating what to write with scent than without, while faster typists did not show this trend, partially supporting $H_{1.3}$. We speculate this is because faster typists exhibit the expert behavior of thinking while typing rather than pausing frequently [76]. Additionally, scent significantly affected the readability of the composed text, with essays written with scent showing a 9% increase in readability scores compared to those without. This suggests that scent made participants more creative in their sentence formation and word choices. Several participants commented on this in the post-study questionnaire. For instance, one participant (26 years old, male, chose orange) wrote, *"With the smell, I felt more creative!"* Another (23 years old, female, chose watermelon) noted, *"The smell really opened up my creativity"*. However, there was no significant evidence supporting hypotheses $H_{1.2}$ (accuracy) and $H_{1.4}$ (text length), as anticipated.

A t-test did not provide sufficient evidence to support hypothesis $H_{2.1}$, as participants showed comparable transcription typing speeds with and without scent (53 vs. 52 wpm). This was anticipated, considering transcription involves a simpler process of repetitive ballistic movements [76], unlike text composition. Furthermore, transcription allows users to internalize text chunks before typing, reducing the need for sustained visual attention and cognitive load [86]. However, the results did support $H_{2.2}$, with participants making significantly more errors with scent than without (a 52% increase). This finding contradicts previous literature that suggested a positive effect of scent on transcription accuracy [12, 13]. Yet, we had anticipated this discrepancy based on the nature of transcription typing as a *"routine monotonous task"* requiring *"high attentiveness"* [13], which might have been impacted by the scents. While some participants reported increased attentiveness with scent during transcription tasks (20 years, female, chose blood orange, noted, *"I feel like the ambient smell helped me concentrate more."*), some reported feeling more captivated by the scent. For instance, one participant (22 years, male, chose blueberry) observed a difference in the effect of scent between composition and transcription tasks, stating, *"In the copying task, I felt a little dizzier than in the essay task"*.

6.4 User Preference

Nearly all participants enjoyed the presence of the scent in both conditions, did not find it distracting, and expressed a desire to continue using it while working on a computer (Table 4). Interestingly, many participants believed that the scent improved their text composition speed, despite evidence to the contrary showing a negative effect of scent. The debrief session clarified that this belief was based on the perception of typing time alone, excluding planning or editing phases. However, no evidence supported an improvement in raw typing speed due to scent. Participants also perceived themselves as more accurate when composing with scent, though this was not empirically observed.

For transcription typing, while participants felt faster with scent, the actual effect on speed was negligible. Opinions were divided regarding transcription accuracy. About 68% felt they were faster, but the rest either perceived more errors or were indifferent. In reality, error rates were higher when transcribing with scent. These findings highlight that self-reported effects of scent on performance may not always align with actual results, despite being a common metric in relevant literature. Further studies are needed to further investigate this phenomenon. However, discrepancy between perceived and actual performances is not uncommon in the literature as perception is not solely based on performance [49, 65]. This highlights the need for using both quantitative and qualitative metrics in research for a more thorough analysis.

7 CONCLUSION & FUTURE WORK

To our knowledge, this is the first empirical study to explore the effects of self-selected pleasant scents on text composition and transcription performance. Participants chose scents from fifteen common options, and results revealed that scent presence slowed down text composition, likely due to a greater focus on text quality, without affecting accuracy or length. In transcription tasks, while typing speed remained unchanged, scent adversely impacted accuracy, suggesting a possible effect on concentration. Despite these findings, participants reported feeling more effective and enjoyed the scent, expressing a preference for its continued use.

This research paves the way for further studies on the influence of scents in computer-based tasks and the field of olfactory displays. However, it had limitations, notably a lack of diversity in age, education, and cultural backgrounds among participants. Future research will aim to address these gaps by including a more diverse sample and expanding the scope to include additional computer-based tasks and games. We also plan to explore the effects of wearable scent-emitting devices on mobile interactions.

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