Multisensory Floral Clock

Enhanced Multisensory Timekeeping with Technological Design

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Abstract. In recent years, there has been a growing interest in biophilic design and its beneficial effects on human well-being. This article explores the concept of biophilic multisensory timekeeping design through the creation of a Multisensory Floral Clock. Inspired by Carl Linnaeus's 18th-century floral clock, this innovative project integrates visual and olfactory elements to provide a calming and immersive timekeeping experience. Each hour is represented by a mechanical flower that opens and releases a corresponding scent, aligned with natural patterns of blooming. The design leverages biophilic principles and historical and contemporary multisensory timekeeping practices, such as Chinese and Japanese incense clocks, to enhance the experience of everyday life. This article focuses on presenting the design and conceptual framework, discussing the benefits of biophilic design/art, the challenges of floral scent integration, and the potential impact on emotional, cognitive, and physiological well-being. This article primarily explores whether the Multisensory Floral Clock can reduce the stress associated with conventional timekeeping by offering a more engaging and nature-connected experience, with pilot testing and audience feedback to be conducted in future studies.

Keywords: Biophilic Design, Multisensory Timekeeping, Floral Scents.

1 Introduction

In recent years, there has been a rapidly growing interest in biophilia [1,2], as well as a growing awareness of the beneficial effects of contact with nature, such as enhanced emotional well-being, stress reduction, and attention restoration [3, 4]. Recent studies have also shown that viewing biophilic art could have a similar effect [5]. Flowers may be especially effective in this regard [6,7]. Additionally, floral scents may contribute to reducing stress, enhancing restoration, and relieving anxiety [8].

Building on this understanding, biophilia and anthophilia design/art (a design approach that intentionally integrates humans' love and affinity for flowers into various aspects of design and art) benefit human well-being. Consequently, the concept of biophilic multisensory timekeeping design could further enhance people's daily lives by using these principles. Historically, time was often marked by auditory cues, such as the chiming of church bells, and of course, the visual element of clock-watching has always played a central role. Practices such as Chinese and Japanese incense

clocks, as well as modern applications like Patrick Palcic's Scent Clock, have also explored the use of olfactory cues. Multisensory timekeeping seeks to create a more engaging experience by incorporating additional sensory elements. However, few projects have attempted to integrate biophilic design principles into this multisensory timekeeping approach.

This article presents the design concept of a Multisensory Floral Clock, inspired by Carl Linnaeus's 18th-century floral clock, which combines visual and olfactory elements to create a calming and immersive timekeeping experience. The passing of each hour is represented by a different mechanical flower that opens and releases a corresponding scent, aligning with the natural blooming patterns of natural flowers. By directly integrating both visual and olfactory elements, the Multisensory Floral Clock extends the visions of artists like Paul Cézanne, who once sought to evoke olfactory sensory experiences through his work (see [9], for a review). Furthermore, the integration of multiple senses enhances the connection to nature, providing a better effect on people's sense of well-being than a unisensory approach. The project uses the principles of biophilic design and the benefits of multisensory timekeeping, taking advantage of real flowers' timeliness to improve well-being.

2 Literature Review

2.1 Biophilic Design and Its Benefits

"Biophilia" was originally defined by Fromm [10] in 1973 in *The Anatomy of Human Destructiveness* as "the passionate love of life and of all that is alive; it is the wish to further growth, whether in a person, a plant, an idea, or a social group" (p. 365). Wilson [2] in 1984 defined it as "the innate tendency to focus on life and lifelike processes" (p. 1). Biophilic design, advocated by Kellert et al. [11], is a design approach that intentionally integrates humans' innate connection to natural systems and processes into the built environment. Later, Browning et al. [12] proposed an extended approach that included "14 patterns of biophilic design," such as visual connection with nature, non-visual connection with nature, non-rhythmic sensory stimuli, dynamic and diffuse light, connection with natural systems, biomorphic forms and patterns, material connection with nature, complexity and order etc. (see [12] for the full table and explanation).

Research by Ryan et al. [13] has demonstrated that biophilic design has positive effects on psychological, physiological, and cognitive health. Studies in neuroscience, endocrinology, and other fields have demonstrated that incorporating natural elements into the built environment can potentially give rise to various benefits, including attention restoration, stress reduction, an enhanced sense of emotional well-being, relaxation, and improved cognitive performance. Biophilic design has also been used in architecture and interior design. Söderlund and Newman [14] discuss the growing prominence of biophilic design, describing it as a significant social movement aimed at re-establishing the innate human connection with nature to address contemporary urban issues.

It is important to recognize how engagement with nature can occur via any of our senses. Indeed, recent research shows that stimulating several senses simultaneously likely promotes the beneficial effects of biophilic design on social, cognitive, and emotional well-being [3]. Non-visual connections with nature are also one of the 14 patterns in biophilic design, including designs that involve hearing, touch, smell, and taste. These connections can positively affect mental health and encourage a sense of tranquility [13].

A multitude of studies presenting non-visual and — particularly relevant for the present case — olfactory biophilic experiences exist in the literature. Consider, for instance, Kim et al. [15], who demonstrated that aromatherapy (defined as the use of essential oils for therapeutic purposes [16]) can help to reduce the need for morphine and analgesics after surgery. Meanwhile, Li et al. [17] established that essential oils from trees have a positive effect on the immune system. Dr Kate McLean, an artist who has worked on the development of city sensory maps, argues that olfactory stimuli can stimulate imagination [18]. Haehner et al. [19] have identified specific odours that can help reduce anxiety, enhance attention, and positively influence mood. Traverso [20] has shown that tracking the odours present in a city over time can provide salient insights documenting social and cultural change, and nature smellscapes have been demonstrated to exert a particularly beneficial effect by triggering both sensory awareness and memories [21].

However, implementing biophilic design comes with drawbacks and challenges. Higher initial costs and ongoing maintenance impose financial barriers, and complex technologies lead to technical and logistical challenges. Environmental concerns also arise since the introduction of non-native plant species for aesthetic purposes can disrupt local ecosystems. Additionally, many biophilic solutions require significant amounts of water [5].

Based on a survey of 106 participants, Lutrin et al. [5] proposed an alternative approach through biophilic art (artistic renditions that incorporate elements of nature). ~~Indeed, historically, artists like Paul Cézanne, whose works such as "Mont Sainte-Victoire" and "The Garden at Les Lauves" can be seen as early examples of biophilic art, which can mitigate some of these challenges by offering similar benefits to well-being without the high costs and maintenance associated with real plants~~. Lutrin et al. found that biophilic art has a similar impact on well-being compared to biophilia, is cost-effective and easy to implement, environmentally sustainable, more accessible, and flexible. Indeed, historically, artists like Paul Cézanne, whose works such as "Mont Sainte-Victoire" and "The Garden at Les Lauves" can be seen as early examples of biophilic art, which can mitigate some of these challenges by offering similar benefits to well-being without the high costs and maintenance associated with real plants. Additionally, biophilic effects can be achieved with digital devices that mimic nature, such as artificial skies and views of nature through virtual reality [22]. There is evidence that both experiencing real nature and seeing images of nature can reduce stress, lower blood pressure, and improve overall happiness and cognitive performance [23-26].

Anthophilia Art/Design

Within the biophilic design approach, flowers play a special role. Viewing flowers has been shown to elicit a positive emotional response [27]. They can convey messages (as in the strapline “Say it with flowers”), evoke emotions, set a mood, or express subtle feelings without the need for words. Flowers have served as muses for numerous artists. Over the centuries, artists from Claude Monet to Vincent van Gogh, Gustav Klimt to Andy Warhol, have all used flowers to tell stories [28]. In recent years, the human aesthetic response to flowers has increasingly been recognized [29-32]. For example, Meadow, an immersive robotic flower installation that blossoms, created by Amsterdam-based studio Drift, is designed to express characters and emotions, and informal feedback from the audience suggests it may have a calming effect [33, 34].

Flowers and floral scents have a more beneficial effect on human well-being than other forms of exposure to nature, such as, for example, simply viewing pictures of nature scenes [27]. Indeed, humans appear to share significant commonalities with plant pollinators in terms of their olfactory preferences [35]. Research conducted by Liu in 2002 demonstrated that floral scents may offer significant benefits. For female participants, the visual effects of cut flower arrangements and the olfactory effects of lavender scents significantly decreased electrodermal activity, suggesting greater relaxation and lower arousal. Furthermore, lavender scents significantly lowered sadness and anger/aggression. Both male and female participants experienced enhanced cognitive performance: male participants showed improved calculation accuracy with the visual effects of cut flower arrangements, while female participants exhibited better calculation speed and accuracy with both the visual effects of cut flower arrangements and the olfactory effects of lavender fragrance [8]. These findings suggest that integrating floral elements into design can enhance both emotional well-being and cognitive performance.

2.2 Multisensory Timekeeping

2.2.1 Historical Multisensory Timekeeping

Chinese and Japanese Incense Clocks (16th Century A.D.)

In terms of using scent to demarcate time, both Chinese and Japanese cultures have an extensive history of using so-called incense clocks, which were documented as early as the sixth century A.D. [36-38]. In this case, the idea was that the passing of time was marked by scent of burning incense. The process involved grounding and pounding wood into a powder, then transformed it into a paste and molded it into various forms, such as cords and sticks. Some of these are crafted from fragrant woods, such as sandalwood. The cords typically feature five marks to distinguish evening or night, and people could also choose incense based on the duration they intend to measure. Short incense is used for brief temporal intervals, whereas long and spiral incense can be used for extended periods (i.e., up to a number of days. Observers could measure the time with relative precision by observing the progress of burning incense. For those desiring precise timekeeping, a small weight was often added to the cords,

with a brass basin placed beneath. When the fire reaches the mark on the small weight, it drops, creating a sound like an alarm [36].

Sadakichi Hartmann's Perfume Concert (1913)

In the early 20th century, the art critic and writer Sadakichi Hartmann presented the first perfume concert, named A Trip to Japan in Sixteen Minutes. During this performance, eight different perfumes were used to signify departure from New York to Japan [39]. While this was not a traditional timekeeping method, Hartmann creatively marked the passage of time in the journey through scent. Although the attempt was a total failure (in fact, the show was forced to end due to audience interruptions), the Institute for Art and Olfaction remade the performance in 2014 and offers an annual award to acknowledge Hartmann's pioneering role in the field [40].

2.2.2 Contemporary Multisensory Timekeeping

Air freshener system by Procter & Gamble (2004)

In 2004, Procter & Gamble introduced Scentstories by Febreze, a household device for dispersing fragrance into the air marketed as a "CD air freshener system" [41, 42]. However, while this plug-in system enabled a range of different fragrances (five in total) to be released from the device at different times, it is important to note that there was no attempt to align or synchronize the fragrances with the time of day at which they might be experienced in nature, assuming that such complex fragrances could be associated with a specific plant. Additionally, Febreze Scentstories failed and was placed on P&G's wall of failure for several reasons: Consumers went 'nose blind' 15 minutes after the scent was released, and the shape of the air freshener confused people into thinking it was a CD player rather than something related to scents [43].

Ode (2014)

One might also consider here Ode, designed by Lizzie Ostrom a few years ago, to encourage eating among early-stage dementia patients (who were still living at home) through use of food scent alarms [44]. In particular, the idea was that this plug-in device would release the relevant food aromas thrice daily to remind those who might otherwise forget to eat at mealtimes [3]. A pilot project demonstrated that this mealtime alarm successfully encouraged participants who used it to eat more than a control group that did not have the benefit of this temporal intervention.

SensaBubble (2014)

SensaBubble is a chrono-sensory mid-air display system developed by Seah et al. [45]. Bubbles filled with scented fog deliver information through multiple sensory modalities. The device creates scented bubbles that can visually display information projected onto them until they burst. Upon bursting, the scent is released, providing a temporal and sensory experience that persists longer than the visual display. The design parameters of the bubbles—including shape, size, longevity, frequency, bubble-cloud density, speed, trajectory, and the visual display on the bubble—can all be manipulated.

The system's potential applications include using scents to mark each hour, similar to traditional chime clocks or incense clocks. For instance, specific scents such as coffee in the morning, food aromas at lunchtime, and relaxing fragrances in the evening can be synchronized different times of the day. Additionally, the system can release a number of scented bubbles corresponding to the hour or project an image of the time when a passerby requests it [45].

Scent Clock by Patrick Palcic (2021)

Patrick Palcic's Scent Clock, exhibited at the Museum of Craft and Design, features twelve slender containers arranged side by side on a wall, each filled with a different fragrance. Every hour, a new scent is released into the air, inviting people to sense the passage of time through scent rather than numbers and sounds. The Scent Clock uses essential oils, synthetic fragrances, and perfumes. This innovative design allows users to experience time in a new way, making time literally hang in the air and be inhaled, thus creating a multisensory contemporary clock that blends the perception of time with olfactory stimuli [46, 47]. In addition to olfactory elements, the Multisensory Floral Clock integrates both olfactory and visual elements, allowing user to also benefit from the calming and restorative effects of visually seeing the flowers.

2.3 Multisensory Floral Clock

As early as 1924, Italian Futurist artist Fedele Azari explored the use of scent in art through his manifesto La Flora Futurista ed Equivalent Plastici di Odori Artificiali (The Futurist Flora and Plastic Equivalents of Artificial Odours) [48]. Azari critiqued the traditional sweet perfumes of flowers, arguing that they were insufficient for the modern nostrils that demanded more intense olfactory sensations. He proposed a new field of artistic creation involving plastic flowers that were "most original, absolutely invented, most colorful, most aromatic" [49].

Building on this vision and addressing gaps in traditional timekeeping methods, we propose an alternative approach that leverages the benefits of multisensory timekeeping and anthophilia design. One of the inspirations for this project is Swedish botanist Carl Linneaus's flower clock in the 18th century, a formation of flowers arranged in a clock sequence format. The idea is that people could tell the approximate time of day based on which flower happens to be open or closed [50]. The first version of the flower clock, designed by the first author Yang Gao, was exhibited at West Bund Art Center - Art & Design Education FutureLab in 2019 and the Machine Art Event at New York University Shanghai in the same year see https://yang-gao.art/Flower-Clock; and https://www.youtube.com/watch?v=Xwm15Ad4U5I for a video of the installation) (see Fig. 1).

The Multisensory Flower Clock aims to reframe our perception of time in a more relaxing and engaging manner, reducing the pressure associated with conventional timekeeping. Although we humans are visually dominant creatures [51], the visual sense is, under many conditions, overloaded [52-54]. Of course, for many real-world situations one needs precise temporal information, and the olfactory sense is not well-

placed to deliver such precision. However, the Multisensory Flower Clock provides the advantages of subtly nudging people towards a more approximate notion of time. This is achieved through the flowers' slow opening and the gradual increase in scent intensity, rather than a sudden, sharp onset of fragrance. Unlike the precise digital timekeeping in the modern era, this approach mirrors a more organic way of perceiving time. Similar to centuries ago in Europe, before watches were accessible, people usually relied on the church bells to wake up, have lunch and finish up work – providing time cues that were precise but less frequent [55]. This crated a more organic and subtle way to grasp the concept of time [56].

Fig. 1. Kinetic installation of the Flower Clock by Yang Gao, exhibited at the West Bund Art Center - Art & Design Education FutureLab in 2019. Image source: www.yang-gao.art

3 Multisensory Floral Clock Design

3.1 Olfactory Timekeeping System

The Multisensory Flower Clock is a kinetic installation featuring twelve mechanical flowers, each crafted from laser-cut wood and fabric to represent a different hour. These flowers correspond to real-life blooming patterns: for instance, the carnation opens at 1 pm and the dandelion at 5 am. Each hour, the respective flower opens slowly and then closes over the next hour, releasing a corresponding scent when in bloom. This creates a calming and immersive experience that blends the visual, olfactory, and temporal senses.

3.2 Challenges in Floral Scent Design

While different flowers open at different times of day (and the composition of their plant volatiles also changes over the course of the day), not all of them necessarily have a floral fragrance. One challenge with the floral scent clock is that the behaviour of plants is tied to the light/dark cycle, rather than necessarily to a specific hour in the 24-hour cycle. Plant behaviour is, of course, also tied to seasons, location, temperature, and other factors. For example, night-flowering jasmine starts to scent the air after dark, which is around 1800 hrs in Colombia, but might not be until much later, if at all (e.g., think Northern Norway in the summer months), in different parts of the world and at different times of the year. Once the relevant fragrant floral notes have been identified, the next question is whether it is possible to source them for delivery in a digitally-controlled device. For scent production, we will explore devices like ScentVR, multi-scent players [57]. Also, to achieve a milder and more controlled delivery of scents, using a water-based aerosol similar to those in-home diffusers may be beneficial. These aerosols provide a gentler release of aromas, reducing the risk of overpowering the senses and allowing for a more consistent and pleasant scent experience. Thereafter comes the challenge of how to digitally control the delivery of scent [58].

3.3 Scent Design Considerations

Even for familiar smells, people can still struggle to recognize them blindly. Additionally, people's variation in odour thresholds change throughout the day [59]. It is worth considering how to design or allocate different fragrances to each flower when they open and close. The fragrance needs to be first related to the flower (it can be the same as the flower's fragrance or designed to have a connection to the flower). Second, they need to be distinct from each other. Furthermore, it is important to consider how to release the scent with each flower's opening, this ensuring that the preceding fragrance does not clash or influence the subsequent one. The problem of lingering / inadvertently mixing fragrances has often been highlighted with scented entertainments. For example, using a timer with a motor to dispense the scent every hour could be a viable solution. If the fragrance intensity correlates with chosen natural sensory rhythms, another design decision that has to be made is how to control the intensity, ensuring it is obvious for the audience to notice the changes in intensity. The flower clock's scent are unlikely to be familiar enough to be recognized by most people The flowers selected to feature in Table 1 for the flower clock are chosen based on their opening times to represent each hour and distinct fragrances. However, the final selection of flowers for the installation will depend on which fragrances can be sourced. Our pilot testing on fragrance discriminability and the impact of flower colour will further guide these selections. The table provides all the flowers with their opening hour corresponding to specific time, accompanied by their fragrances (flowers lacking fragrances are excluded from the table).

Table 1. Flowers' opening hours and corresponding fragrances (hour of flower opening only).

Time	Flower/Plant	Fragrance
0200	Morning Glory	"A light fragrance" [60]
0300	Goat's Beard	
0400	Rough Hawkbit	"Smell strongly and sweetly of honey when expanded in the full sunshine" [61]
0500	Dandelion	"A subtle, bitter-sweet and aromatic note with whispers of citrus and rose" [62]
0500	Hawk's Beard	"A honey-like odour in the sunshine" [63]
0600	(Orange) Hawkweed	"A distinctive sour smell" [64]
0600	Catmint	"A spicy sage-like, or minty, scent from the leaves, stems and flowers" [65]
0700	White Waterlily	Sweet [66]
0700	African Marigold	"A musky, pungent smell" [67]
0800	African Daisy	"A distinctive earthy fragrance" [68]
0900	(Hardy) Iceplant	"A light, almond-like scent" [69]
0900	Gentian	"A distinct dusty, bittersweet scent" [70]
1000	California Poppy	"A free-spirited floral scent with a signature poppy accord and tender muskiness" [71]
1100	Star of Bethlehem	"A distinctive onion smell" [72]
1200	Passion Flower	"A delicious, fruity fragrance that smells like guavas" [73]
1300	Wild Carnation	"Spicy, clove-like, or reminiscent of a combination of cinnamon and nutmeg" [74]
1400	Afternoon Squill	"A tender aroma" [75]
1600	Four O'clock	"Lemony and sweet" [76]
1700	Night-flowering Catchfly	Sweet and strong fragrance [77]
1800	Moonflower	"Sweet and sour" [78]
1900	Night-flowering Jasmine	"Sweet scent" [79]
1900	White Campion	"A heady scent" [80]
2000-2200	Night Flowering Cereus	"A thick perfume resembling magnolia or gardenia" [81]
2100-2200	Flowering Tobacco	"Jasmine-like scent" [82]

3.4 Installation Design

The multisensory flower clock ~~is~~ will be controlled by Arduino (Fig. 2 shows the technical diagram for the previous installation), which will triggers the motor to slowly open the flower based on a real-time clock module. The flower is designed by specially designed bendable laser-cut pattern on thin wood (Fig. 3) and hard organza (Fig. 4), and a scent release module will be added for the fragrance compnent.

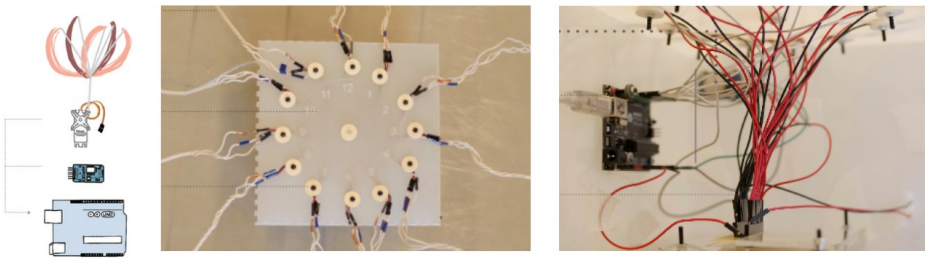

Fig. 1. Arduino setup.

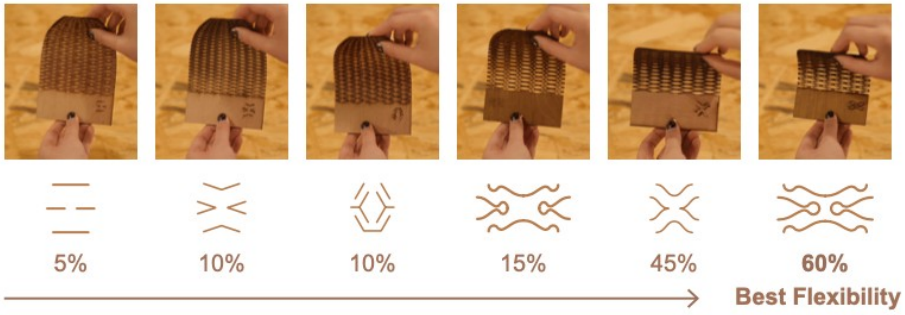

Fig. 1. Test the flexibility of different pattern (Laser Cut).

Fig. 1. Test with different fabrics.

Fig. 1. Flower selection for floral clock v.1.

4 Future development and application

In future iterations of this multisensory design project, we hope to investigate whether floral cues can also be used to indicate the weather conditions, and not just the time of day. Here, for instance, one might use sunflowers to signify sunny weather, while the so-called 'flower for a day', which only blooms after the rain, could be used as an ecologically accurate indicator of ambient weather conditions. The latter perhaps reflecting a record of the recent past rather than necessarily predicting imminent future conditions. However, it turns out that neither of these flowers are particularly fragrant. This highlights the challenge that not all flowers are naturally fragrant. In future iterations of this project, we hope to explore the creation of distinct fragrances for those flowers that are easily recognizable. Another challenge is trying to find the connection between timekeeping and natural sensory rhythms [83] and determining how to correlate scientific inputs and design outputs.

At the same time, there are also sensory rhythms of nature [83]: obviously the light- dark cycle, phototropism, as well as diurnal variations in sound levels and scent, not to mention temperature. The primary aim of the scent clock outlined here was to develop a multisensory timepiece that captures something of nature's sensory rhythms while engaging multiple senses to tell the time, thus emphasizing the connection to the sensory rhythms of nature. Given that a different flower is associated with each hour of the day, perhaps the clock may only release scent at dawn, midday, and dusk. For example, the flowers release scents when they open and exhibit other designed movements based on the chosen sensory rhythms of nature. Note that while the flower clock might provide more temporal information/precision during daylight hours, it is not limited to a 12-hour cycle and can offer sensory cues to help tell the time beyond these hours.

Over and above the technical challenges associated with bringing such a project to life, given the beneficial effects of floral scents on human well-being [84], it would be interesting to determine whether any well-being benefits could be demonstrated by linking to the olfactory nature effect [3, 85-88]. That said, the plants that may have the most beneficial effect on well-being/arousal (such as pelargonium/geranium) may not necessarily be tied to a specific time of day [21]. One might also consider using peppermint (a fragrant plant rather than specifically a flower) at the start of the day to wake people up, as it promotes general arousal, apparently increasing people's concentration [89, 90]. The fragrance of lavender, due to the presence of linalool, can also be used before bedtime to help promote relaxation and encourage sleep [91]. This association has been noted historically in the scenting of bed sheets in the west for centuries, supported by both literary and scientific evidence [92, 93].

Several limitations need to be addressed to enhance the Multisensory Floral Clock's effectiveness and user experience. One challenge is managing the intensity of scent release. It is very easy for aromas to become overpowering, and overly intense scents can overwhelm users, perhaps leading to discomfort rather than relaxation. Therefore, it is crucial to administer scents in a controlled manner, allowing them to diffuse naturally into the environment and trusting users' ability to perceive subtle aromas to prevent the scents from becoming intrusive. Additionally, users can rapidly adapt to continuous scents (like air fresheners), diminishing their effectiveness over time. However, by cycling through a variety of different scents, the multisensory floral clock can help counteract such adaptation and maintain a fresh and ongoing olfactory experience. Another challenge is ensuring the scents seem natural rather than synthetic. Pure aromas also tend to linger and have varied development and decay patterns, which can create a complex olfactory environment where multiple scents overlap, potentially leading to an undesirable mix of fragrances. Careful consideration must be given to the timing, sequence and the intensity of scent release to ensure a pleasant and coherent olfactory experience. Similar considerations were noted by Sadakichi Hartmann in his A Trip to Japan, where he faced challenges in effectively managing the propagation of scents to avoid overwhelming the audience [94, 95]. In addition, the combination of visual and olfactory effects should be correctly matched, otherwise it might cause confusion and anxiety [8]. Furthermore, considering the potential limitations of scent alone for certain functions, future iterations of the multisensory floral clock could explore the integration of sonic cues.

Future experiments also plan to investigate the project's impact on emotional, cognitive, and physiological well-being. Additionally, we will examine how the Multisensory Floral Clock influences participants' perception of time compared to conventional clocks [8, 101, 102] and evaluate its usability and overall user experience. We also hope to explore additional applications of crossmodal correspondences, building on the work of artists like Cézanne, who aimed to evoke sensory experiences beyond the visual [9], and create sensory experience that enhances well-being.

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