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Original Article

An Overview of Olfactory Devices: Types, System Design, Applications and Future Trends

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Abstract

Nowadays, the most challenging task is achieving relaxation. Indeed it is important for our physical and mental health to get rid of all day stress. One of the utmost ubiquitous of all senses is the sense of smell but it is also the one which has hardly been explored in the field of Human and Computer Interaction. Human emotions and memories are closely associated with the sense of smell as it gives information about different events that are part of one's personal life, for example, the smell of fire, and pollution, it also helps us when we are looking for food or even sometimes it works as an alarm for reminding us to do something important. This paper presents two different categories of olfactory devices that can be controlled from a remote location via a smartphone. We categorized these devices by means of the level of concentration and the intensity of smell they are producing. We also talk about the basic structure and system design of olfactory devices. Furthermore, this paper presents a set of applications where the olfactory devices are used and the associated software framework. We also discuss different tests that were conducted in order to show the usability of olfactory devices and their results.

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INTRODUCTION

The sense of smell plays vital roles in our daily lives. Not only because it helps as an alarm that informs us about different events, but also the smell of a flower, tree and wet grass makes our lives refreshing and peaceful [1]. The feeling of smell brings memories that are more emotionally filled, apart from all those memories that are initiated via other senses [2]. While designing user interfaces, the main objective is to make such tools that will let the user carry out different tasks but with low energy, time and struggle. We bear in mind user's point of view about the system when designing user interfaces, such as how useful the system is, how comfortable it is while being used and the effectiveness as well [3]. Smell is an important part of the experience when the user is trying to observe the environment. E.g. smelling the sand after first rain and trees when walking through a Juniper Forest or the usual and loving smell of the own home.

Still similarly independent, the artificial smell is used to improve user understandings. Human observation of smell is tremendously changeable with people changing in their overall olfactory visualization as well as in the way they observe specific smells. This makes it very challenging to design for specific kind of understandings similarly between different users. However, scent basically contains information about the state of things in our neighborhood, likewise to the smell of a burning fire [4]. The olfactory

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system takes an excellent position among the five senses in the neurological processing of sensory stimuli. The two areas of the brain amygdala and hippocampus that are responsible for regulating emotions and memories are directly connected to the olfactory device. On the other hand, these areas do not allow other senses like sound touch and sight to pass through. The thalamus is the brain region that enables the senses of sight, sound, and touch to go through, which is why these senses can disrupt sleep [2]. Smell-based interactions are a promising sector for HCI due to the unique characteristics of olfactory devices as a modality. Olfactory devices employ artificially released fragrances to evoke emotions and experiences in users during everyday life. For example, a wearable olfactory device that can be worn as a pendant on a necklace is one such example [1].

The main idea here is to increase received mobile notifications by means of using smell as an additional emotional notification channel. One can highlight the messages of the user's life partner by producing an attractive connected smell such as flowers [5]. Fig. 1 shows a user receiving mobile notifications via Inscent wearable device form life partner. By using the capability of smell to alert the users, another example could be to remind the user about an upcoming event (e.g. an exam). This paper focuses on olfactory devices that can bring positive changes in human behavior. Optimistic and destructive sensations are not only transfer between people via imitation of visualization and hearing but also through smell [6].

Fig. 1. Shows the received mobile notification from life partner [2].

Recent research has shown that individuals may reduce their stress and anxiety levels by utilizing essential oils in the olfactory device. For instance, a single night of olfactory distant conditioning during sleep significantly reduced cigarette smoking behavior in the sleeplessness state and maintained it for several days. In the domains of research laboratories, such beneficial studies continue to persist. The main objective behind the design of the olfactory device was to make a technology that will help people lessen trauma and anxiety in their daily lives without being dependent on any medical assistant or other tracking devices [2].

The remainder of this paper is structured as follows. Section II presents an overview of two types of olfactory devices. In section III we discuss the related work. In section IV a brief overview of system design is provided. Section V describes the major categories of design spaces. In section VI the design parameters of olfactory devices are discussed. Section VII presents the interaction spaces. In section VIII we briefly discuss the software framework and section IX presents the different applications. Section X describes the different tests and XI explains the respective results. Section XII compares the olfactory interactions with other modalities. Section XIII presents the limitations and section XIV describes the future developments of olfactory devices. Finally, section XV concludes the paper.

Olfactory Devices

An olfactory device is an olfactory substitute for visual inputs, an equivalent of a graphical display. It uses solid air to deliver olfactory stimulation [7]. It places a range of scents on cue for a fixed time monitored by a spurt of odorless air to clear for the following scent. In front of the component, discrete scent covers about 3-6 meters, depending on the number of fans that are used. Scents have the ability that they can be activated from a virtual reality environment [8]. According to Barfield and Danas [9], an olfactory device is a mix of hardware, software, and chemicals meant to convey olfactory data to the participant. This section of the paper will discuss the two main wearable and ubiquitous categories of olfactory devices [8]. An olfactory gadget is a counterpart to a graphical one.

Ubiquitous Type Device

Ubiquitous is a category of olfactory devices where the device is set up in the environs for example room, hall and car. While earlier ubiquitous type devices basically spread the fragrance over a whole room, extending the scent

into the entire surroundings is a disadvantage because it is difficult to dissolve the previous aroma after it is spread into the air [10]. This makes it difficult to adjust the smell within a limited period, depending on the growth of an interactive program. A creative, manageable olfactory gadget designed by ATR Media Information Science Laboratories. This method uses an air pistol to transport much-scented air across free space from a projection-designed olfactory device to a location close to a user's nose. The fundamental approach of this system is to spot the position of the user's nose using computer vision-based face tracing technology [8] [11].

Once the nose area has been marked, the device tracks it by pattern matching and releases the smell from a cannon to the position. The ubiquitous olfactory device uses projection as a function that allows user to enjoy the smell without wearing dense and hefty devices. By means of limiting the scent, the device can send different smells to user's by simply spreading the scent into an entire room. This feature of the ubiquitous olfactory device makes it difficult to use in a large space, such as in an open-air environment, because it has a narrow range for releasing smell [8]. Fig. 2 shows different ubiquitous olfactory devices.

Fig. 2. Ubiquitous Olfactory Devices [12].

Wearable Type Device

Wearable is a category of olfactory devices where the device is worn by the user. For instance, Scent collars, Insence, Smoke garments, and essence. Wearable-type devices present the fragrance precisely and enlarge the user's field of activity. This suggests using the gadget in large areas as well as outdoor surroundings. Yamada built one prototype for a wearable-type olfactory device with pipes to distribute the generated aroma to the user's nose [8]. This system combines a positioning system that detects the user's position and collects data about the position using the RFID tag reader [9]. Scent production is done by injecting the scent drops directly into or near the user's nose. The fragrance material is kept in fluid form to make the olfactory device smaller. While bringing these two systems together, it is possible to reduce the amount of scent air used, which is ineffective when the user breathes out and the scent air spreads into the environment. This will result in an advantage of saving scent material so that the wearable olfactory device can be used for a longer period [13]. Fig. 3 shows different types of wearable olfactory devices that can be used as a necklace.

Fig. 3. Wearable Olfactory Devices [2] [14].

RELATED WORK

The latest innovations in smell diffusion devices for consumer markets and the design of smell-based interfaces have garnered increasing interest. Thus, mechanical engineering and automotive design fields are now more actively researching smell-based devices [15]. The history of multi-sensory research traces back to experiments where certain scents were emitted during movies to help viewers associate the smells with scenes in the film [16]. While the olfactory system has been pretty much studied in psychology, neuroscience, chemistry, and even art, personal technology remains very quiet [6]. Most modern health-related devices, from fitness trackers to sleep monitors, rely upon visual displays and audio cues [14]. Different works have focused on the applications and challenges of olfactory devices [4], yet they remain limited in what they do in the overall digital communication technologies. Most research works with the devices themselves

are presented nowadays, taking most devices to be designed using layered aroma models. Fig. 4 presents several olfactory devices.

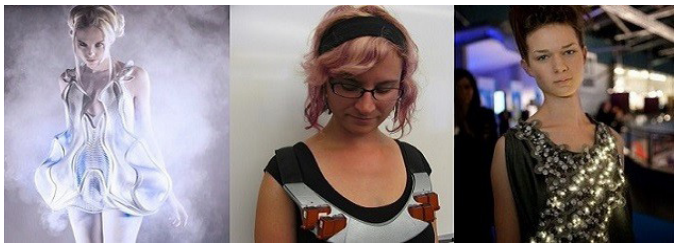

Fig. 4. Olfactory Climate Dress,Scent Collar and Smoke Dress [2] [17] [18].

Kaye explored the various dimensions of scent and asked scholars to introduce scented output into their designs [19]. The subtlest dimension of scent aimed to make it suitable for presentations that were primarily destined to be de-stressing in nature. This avoids overemphasizing certain fragrances as intense in favor of letting the consumer come to terms with the aroma and make meaning of the quality of several smells. Modern scent-rich technologies are impossible to blend into everyday life today, and they are restricted only to devices that neither look nice nor can be carried in a pocket. Some fashion designers tested wearable smell applications, using their bodies as atomizers or embedding scent into them [4]. One of the most notable examples is the ICT Scent Collar [20], a simulated-use scent-delivery tool in the shape of a collar or apron.

The 'Smoke Dress' by artist Anouk Wipprecht identifies a person approaching and producing a smoke effect. Another example of the smelly wear technology is climate dress, which has a response to air CO2 levels. It can power and display a dynamic light because the embroidery is a good conductor of electricity and data, transforming itself from slow rhythmic pulses to fast, irregular patterns as soon as the concentration of CO2 is changed [21]. The style of device, which is so elegant and wirelessly controlled for everyday use, with a computerized controller operating the device according to contextual and biological data from the user, represents some essential contributions that differentiate this work from previous research [18].

SYSTEM DESIGN

All the form factors and resources were considered to make olfactory prototypes appealing, practical, and suitable for all types of users. The range covered by the scent produced by these devices is generally around 3-6 meters in front of the component, depending on the number of fans used. Scents may be activated within a virtual reality environment [22]. Usually, odor materials are kept as liquids or in a solid state saturated with liquid, allowing them to be sensed after being spread into the air. As such, the scent material should be vaporized and transmitted to the human olfactory system. These include evaporation, mixing, and odor delivery, which are the three principal functions used in an odor machine's operation [23].

Scent generation integrates evaporation and blending; hence, these three functions may overlap since most of the olfactory devices integrate all of them. The order of these functions can also differ with the device configuration; in some devices, blending is done before evaporation. The technology of scent generation is quite old, but recent advances have made it possible to control scent generation using computer systems [23][22]. The next section of this paper describes three principal functions of an olfactory device. Figure 5 illustrates the structure of a simple olfactory device.

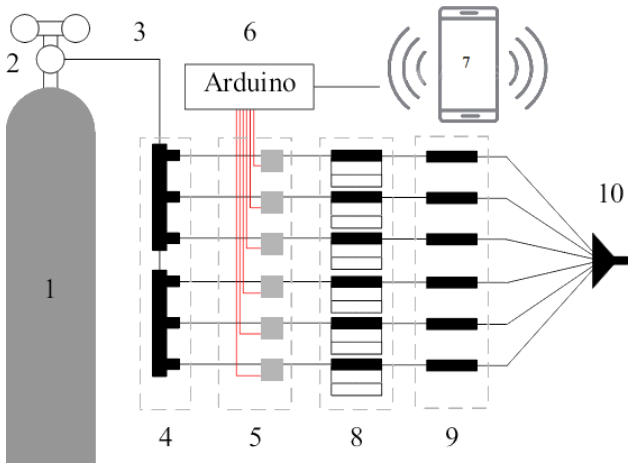

Fig. 5. Structure of the scent-delivery device: 1 - air tank, 2-manometer, 3 - plastic tube, 4 - two manifolds, 5 - six electric valves, 6- Arduinohoard, 7 - Mobile, 8 - six jars containing the scents, 9 - six one-way valves,10. output nozzle [24].

Evaporation

Evaporation is the process by which scent ingredients injected into device-containing jars produce an odor. It is especially helpful for alarms [22] since it allows modifying the timing, exposure length, and quantity emitted. This aspect was considered in design decisions concerning the materials used, as high temperatures are dangerous from an engineering perspective in confined small wearable devices [25]. Fig 6 explains the scent generation process.

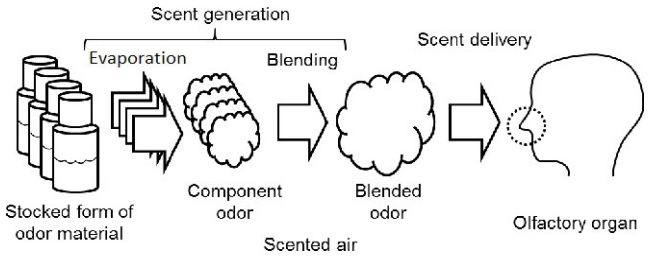

Fig. 6. Roles of an olfactory device: scent generation and scent delivery [22].

Natural Evaporation

I s also a slow release of super volatile chemical constituents in the atmosphere, such as that observed in old perfume, where smells diffuse with time. Some companies use only natural evaporation while supplementing with other types is not used; however, this makes it ideal for ecological scent diffusion systems where precise control isn't necessary [26] [27].

Enhanced Evaporation by Air Flow

Air flow would increase the rate of evaporation. Techniques involving evaporation through airflow are surface evaporation, bubbling, and the use of filled containers with gel or porous materials to improve fragrance diffusion more effectively [22].

Heating

Heating is a classical technique applied for the evaporation of fragrances, commonly used in vases and incense to release odor. For instance, when woods are warmed, the fragrance molecules get released from them. However, heating cannot be applied to all fragrance molecules since many structures will change with the elevated temperature. Kim et al. [22] developed a passive olfactory device using a temperature-sensitive hydrogel driven by a Peltier element to control the temperature reliably. Heating has numerous advantages, including smaller compartment size, controllable energy and time variables, and fast odor release [9]. In relation to this topic, in [19], the authors applied heating processes for vaporizing mixtures of essential oils dissolved with very viscous carrier liquids for similar reasons.

Blending

Blending creates aromatic air by combining selected fragrance elements in set proportions to produce a pleasant blend. This process enables exposure to different fragrances or a scent that changes with time. There must be some mechanism for this effect, to cycle between different smells or blend them simultaneously [28]. A blender mixes many module smells to produce an emergent smell containing the desired

chemical composition at defined concentrations. Moreover, a blender can also act as a selector between various smells [19].

Scent-source Swapping

Is the automatic swapping of aromatic components by swapping containers or jars. Ordinarily, an arrow-shaped mechanism is used in this swapping operation [27].

Fluid-based Blending

A liquid mixes the fragrances with other dilution liquids such as alcohol. This dilutes essential oils and also increases accuracy in the mixing process. Pure solutions are usually so concentrated that they cannot mix directly, so moist solutions carrying essential oils are allowed to drip drop wise to create a mixed solution with the proportion of fragrances desired [29][19].

Scent Delivery

The fragrance delivery is the transfer of aromatic air to a person after fragrance volatilization. The manner of transfer depends on the concerned application [24]. Some considerations are as follows: what number of users the system should service simultaneously, the level of mobility of the user, and the rate at which the user has intended to switch over several smells for where aromas are to be diffused to many individuals simultaneously, such as theatres, a good strategy is to diffuse fragrances in the hall, thus a significant quantity of aromatic material [9]. Where the aroma is to be used personally, then space used for diffusion must be small. An attachment or enclosure will help contain the aroma and prevent unwanted spread in such situations. Fig. 7 shows a few ways of delivering aromas.

Natural Diffusion

Is when the fragrance diffuses from areas of high concentration and moves towards areas of lesser concentration aided by gentle currents. Consequently, the emitted aroma from a source of that fragrance within a room tends to keep diffusing itself throughout that room. It is the original mode of fragrance interaction; their uniform coverage in a room enables someone to appreciate the fragrances for a while. Therefore, long-period exposure to these fragrances effectively communicates environmental information [19].

Wind (Air Flow): In this technique, odors may be delivered to the user's nose through dynamic delivery based on airflow. Here, the odor-emitting part is placed away from the user since it is only perceived when the fragrant air reaches them. In natural diffusion, the device may present odors for lesser durations [22].

DESIGN SPACES FOR OLFACTORY DEVICES

In HCI design, a design space defines the limits of a problem space and the solutions inside it. Often shown in dimensions that reflect the design decisions to be considered as well as the several possibilities for every choice [8], design spaces are Olfactory devices that share design spaces with other digital devices, and certain factors of olfactory devices greatly affect these design spaces.

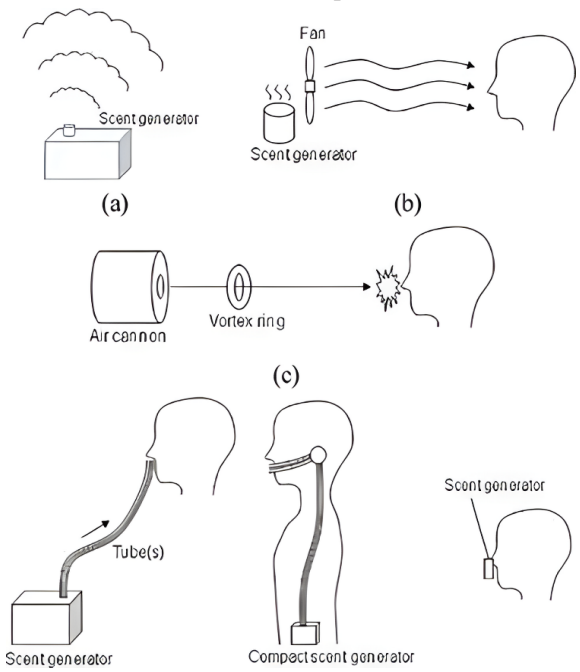

Fig. 7. Scent delivery methods: Natural difussion, Wind (Air Flow)[19].

One of the main determinants of how much people believe using the object calls for low effort is usability. The second element is the efficiency of the olfactory device, more significantly, how precisely and efficiently users might complete various jobs. Effectiveness and usability are intimately linked, users can more precisely complete tasks the simpler an olfactory device is to use. Learnability is the third consideration of how fast beginners can pick up system use. It is one of the most essential aspects in the design space after usability, mainly because many people are not familiar with olfactory devices [30]. Due to the varying applications, characteristics, and design aspects, the design spaces for olfactory devices can be divided into two major categories by reforming the subgroups of current studies.

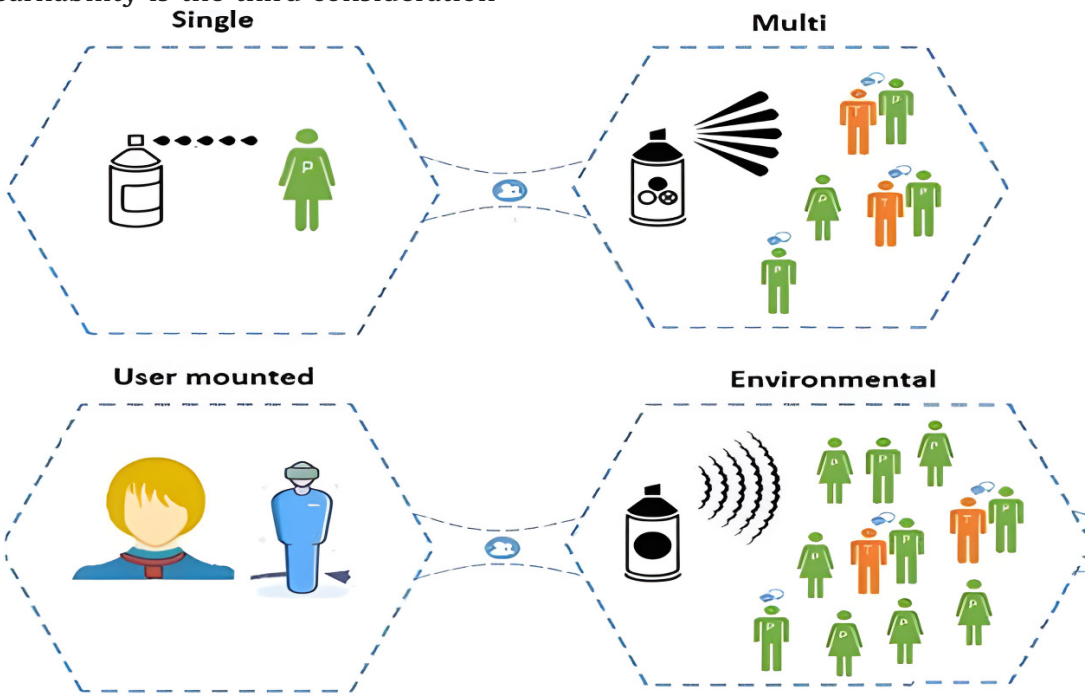

Fig. 8. illustrates the different categories of design spaces.

Physical Design Spaces

This category of the design spaces defines the external characteristics of the olfactory device where the device can operate and where it can be perceived by the user. Physical design spaces are further divided into four sub-categories [30].

Single-Dimension Design Space

Single dimension de- sign space defines the external features, where one single user is aimed by the olfactory device.

Multi-Dimension Design Space

Multi-dimension design space defines the external characteristics where more than one user or multiple users are aimed by the olfactory device.

User-Mounted Design Space

User-mounted design space defines the external features where the olfactory device is affixed on a user's body.

Environmental Design Space

Environmental design space defines the external aspect in terms of the physical area that can be covered by the olfactory device.

Functional Design Spaces

This category of the design spaces defines the area which provides the functions of olfactory devices that are built in the software system. Functional design spaces are further divided into three sub-categories, olfactory user interface, application, and specification. [30].

Olfactory User Interface (OUI) Space

OUI space de- fines the icon, buttons on the display where the user can see the output of functions performed by the olfactory devices.

Application Space

The application space defines the set of function or features that a wearable device provides by itself.

Specification Space

The specification defines the dif- ferent parts inside the olfactory device and how they work

together in orders to release the scent [30]. Table.1 shows the comparison between the different categories of the design spaces and their usage in different olfactory devices.

DESIGN PARAMETERS FOR OLFACTORY DEVICES

The olfactory devices face a variety of computational tasks, as well as the assignment of odorant amount and distinctiveness[26]. One of the main functions of scent delivery is to regulate olfactory stimuli according to distance, dilution and time [27].

Distance

Yanagida discovered multiple interaction distances with an air cannon method [28], this shows that distance also plays a significant role from the design point of view. In the case of producing smoke through heating, researchers suggest that the olfactory device be placed 70 cm from the tester to prevent any hazards [31].

Dilution

Dilution is an important design parameter that may affect decisions appropriate to the concentration and quality of olfactory stimulation. Odors were used to demonstrate an association between smell and vision via a mixed model [28]. This model mixes apricot, lavender, rose, and vanilla in various dilutions. The reason behind selecting the amount of dilution was obvious, and the changes in smell were significant [25][10].

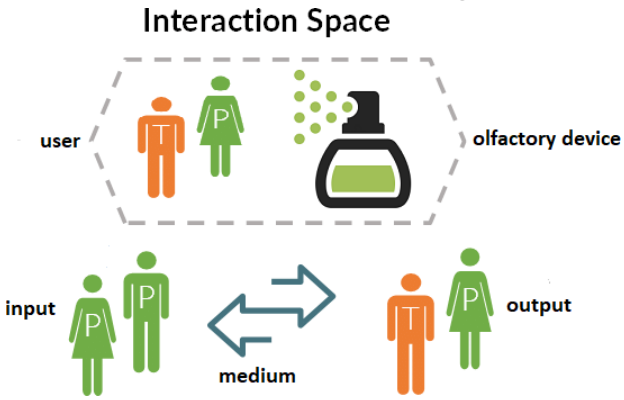

Fig. 8. Shows Olfactory Design spaces.

Time

The timing of the scent emission is another critical factor. In [27], Noguchi suggested that the emission of the scent should depend on the system's design and the user's needs. For instance, fragrances have a release time that varies from 0 to 1 second. This method needs an accurate identification of the participant's inhalation time. Furthermore, the distance of scent delivery used in this study is relatively short compared to typical mid-air applications. Current research ignores the effect on olfactory stimulation and perception since it focuses on solving the airflow problem using best estimations. It is critical to investigate olfactory interfaces in various situations, including virtual spaces, desktop games, multimedia apps, and in-car interactions [13][23].

INTERACTION SPACES FOR OLFACTORY DEVICES

Smell defines the territory of a space. People might know that there is a fish market or bakery somewhere in the area before arriving at the destination [7][32]. An olfactory identity is more constant across diverse factors than identities for the other senses [27]. Researchers have faced many design issues in developing olfactory interfaces related to physical spaces and parameters like institutions, exhibition halls, and automotive contexts [29]. The information processing model of HCI is a good departure point for classifying the olfactory devices. According to this model, communication involves a two-way handshake between information exchanged between a user and a computer or a device over two different interfaces. The model involves an interface that combines multiple units' input, output, communication medium, and interaction space. Information flowing from humans to computers must first travel through an input interface using a communication medium.

On its way, part of humans' energy is converted into an inside representation of the device itself. On the other hand, data transferred from the device to the human should go through an output interface where the energy produced by the device is converted into an internal representation of the user [33]. Figure 9 shows the interaction spaces of olfactory devices. In

addition, Lai [19] designed a museum room in which scent-delivery devices provoke users to explore a work of modern art. Haque [9] defined an interaction space as a space that shifts olfactory regions and boundaries, where people can interact with different smells while navigating the room.

In the automotive context, Funato et al [4] [9] and Yoshida et al [33] presented complete explanations of an olfactory interaction space in the context of simulated driving. Funato et al. used air guns to dispense scent, while Yoshida et al. used scent chambers connected to an air compressor. Both of these research efforts aimed to solve the problem of keeping sleepy drivers awake using awakening smells. These examples show the potential of the construction of olfactory interaction spaces. But on the other side, there are some issues remain unsolved, such as when to provide fragrances and room air ventilation. The lack of standardized structures for the olfactory interaction spaces halts research in these areas. Figure 8 shows the Interactions of the spaces in olfactory devices.

Table 1

The Comparison Between Design Spaces

Design Space	Category	Description	Device Example
	Single-Dimension	A single user is aimed by the ol- factory device.	Essence, InScent and BioEssence
Physical	Multi-Dimension	More than one user or multiple users are aimed by the olfactory device.	Car-Scent, Vortex Activ USB, Scentee on an iPad, iPhone DUO, Aroma Shooter
	User-Mounted Environmental	The olfactory device is affixed on a user's body.	Smoke dress, Climate dress, Head mounted olfactory displays Climate dress
		Physical area that can be covered by the olfactory device.	
Functional	Olfactory User Interface	Visual representation of olfactory functions.	Icons, Buttons, Links
	Application Specification	Features provided by the olfactory device.	Alarm, Message notifications Battery, Scent containers, Fan
		Different components of olfactory devices.	

Yanagida et al. [9] introduced an olfactory design setup based on no strict application background, which allowed the same gun to deliver its own stimulus for each of several users seated just a few centimeters apart: vertex ring technology was adapted, with a small amount of scented material injected into the vortex [8].

SOFTWARE FRAMEWORK

A holistic mobile software framework for user phones running on mobile operating systems has been developed to enable the use of olfactory devices in everyday life and widen application possibilities [2]. The framework works as a service that can be accessed by one or several applications and primarily manages the flow of notifications linked to the olfactory device [3].

Fragrant Notification

The framework enables users to make their cell phones' basic notification capabilities more sophisticated because it automatically produces odors [16]. Different triggers and events can be specified, including the sender's name, the message's contents, an application, or any possible combination of these factors. Users can also set time constraints within the framework [2].

Distant Service

In the framework, the primary purpose of Google Cloud Messaging (GCM) is to send direct notifications to the background service [3]. This also allows access to external applications from the phone. Such a framework can be integrated with other systems irrespective of the platform or language used for programming. The user can change the configuration remotely using GCM as well. GCM delivers the message to the background service to send a scent notification from any mobile application by deploying the interface [34]. This avoids the misuse of the olfactory device. Moreover, it has an authentication feature to check whether the desired scent container is inserted correctly [2].

APPLICATIONS

Computer-generated smells have become quite rampant to augment human understanding and user interest through multimedia and HCI

[15]. Wearable and ubiquitous devices provide many real-world applications that consider users' physiological conditions. This section discusses a few selected applications of the device [35].

Sleep

Numerous studies have discovered the use of scent to help induce sleep due to its probable soothing effects. Field et al. [22] reported an example of someone who has used lavender to improve sleep quality. On the contrary, Schredl et al. [19] discovered that specific smells influence the emotional tone of dreams as well. Specifically, they showed that the aroma of roses during sleep made the dream more positive, whereas the odor of rotten eggs (H_2S) led to negative dreams [35].

Strain and Anxiety

The power of pleasant smell can reduce psychological problems such as strain or anxiety in an effective way [19]. For example, the smell of lavender has been one of the most commonly used scents to reduce the level of nervousness while being in the exam hall or getting ready for an interview. Stress and anxiety are directly connected to the heart, that's why both cause an increase in heart rate and breathing rate. Current olfactory devices allow the user to select an option of automatically identifying relevant events and then activating scents when they are needed [36] [12].

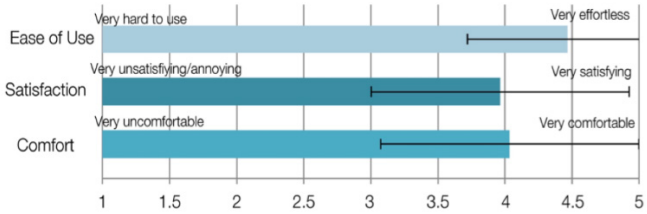

Fig. 9. Shows the Olfactory Interaction Spaces.

Depression

Studies have shown that using essential oils such as citrus [2] or rosy fragrances may effectively reduce low mood states. Scientists are now investigating how mild, pleasant scents could be used to manipulate brain glucose levels in diagnosing depression [22].

Learning and Intellectual Performance

Research has shown that peppermint odor can arouse attention, and individuals will be focused on various activities while alerting. Other research has further shown that introducing the same smell that occurred when the learning process was taking place helps one remember things. Thus, an olfactory device would allow the retrieval of information learned by introducing the scent connected with the information [2].

Pain

Many studies are showing that the effects of fragrances do influence pain. An example would be a study by Prescott and Wilkie [37], wherein test subjects wore masks that smelled different; it revealed that lovely fragrances enhance endurance towards pain. In addition, an experiment indicated that a lavender fragrance spray sprayed on the hands was inhaled to ease delivery pains for women [37].

Social Interactions and Immersive Environments

With Virtual Reality, the added sense of smell enhances engagement in a digital space and completes the overall sensory environment [38]. Beyond immersive systems, odor devices can also work as an indirect way to communicate with distant users. Our brains continuously respond to environmental cues, and we use our sense of smell unconsciously in interactions with others. There are different odorless scents like hormones which can be used to interact with users in a social environment [35] [38]. Human beings can hide different kinds of smells that are related to their emotional state such as the "smell of anxiety" or "violence". Using olfactory devices like InScent, Essence, and BioEssence the user can have broad control over the hidden smell signals that could possibly activate stronger social replies between subjects [16].

TESTS

A set of tests were conducted to evaluate olfactory wearable devices like InScent, BioEssence, and Essence in a mobile, ev- eryday life context. The experiments were mainly about testing the robustness and usage of the models for a long period of time in various situations. To test the usability of the devices a group of

participants including male and female with different categories was requested to use the olfactory device a few days in different locations. Majority of the participants 65% said they are not using any type of necklace or other accessory special when they are outside. This factor can be considered as a drawback of olfactory wearable devices. But 35% users were happy to use necklace for receiving mobile notification [2]. Later on, analytical interviews were conducted, where the baseline was to establish a mutual understanding for using scent based devices for receiving mobile notifications [22].

RESULTS

After testing the olfactory prototypes the results showed that the olfactory devices are robust enough to be used for a long time in different locations and on the other hand they are extremely lightweight [9]. During the tests, participants were asked to describe the experience of using the olfactory device in different circumstances, they stated that they were using the olfactory device for the entire day but they really didnt feel that it was heftier and they also found it stylish [39]. A few participants said that the smell of notification was extremely strong because of which they got a headache. In contrast, other participants said that they didnt even smell anything because the concentration of scent was very weak or sometimes became more obvious, either stronger or a bit different but it was never a problem, the scents were all soothing and it increased the freshness and improved the environment [2]. Fig. 10 the graph shows the results of user experience.

In one of the interviews, the participants were asked to describe their intentions of either they will use an olfactory device for receiving mobile notification or not. Some partici- pants answered they would use the device for relaxation and meditation. A few said they will use it while they are learning so that the can stay attentive. Some users said they would prefer to use it in private spaces, not in public [3].

Olfactory in Comparison with Other Modalities

Olfactory modality is a pleasing and cheerful way of no- tifying about messages, compared to other modalities like sound, vibration or blinking lights. On the other hand, it is less reliable which makes it less prominent when it comes to the reliability because the notifications could be misused or misinterpreted. Nonetheless, it is also perceived as less- disturbing modality and can be very healthy [2]. Different scents can add anticipation and emotion to the moment of being informed and involve a very personal meaning. For this reason, olfactory notifications should not act as a replacement for other output modalities, but rather accompaniment to send supplementary meaning, i.e. to increase a notification. The sense of smell has the power to stay longer, in distinction with other senses. It will stay longer when getting stronger over a short time and then getting weaker gradually. This was one of the properties of olfactory devices which was appreciated by the participants during the tests, they stated that this was something very good and easy to realize about the occurrence, it was not something that gives an impression of notifying or alerting, it was something very relaxing [2].

CONSTRAINTS

The requirement of refilling the containers in olfactory devices is one of the main limitations of current prototypes, although refilling is dependent on the smell delivery cycle chosen by the user. Another limitation is the size of the olfactory device, in order to overcome the need of refilling the size of the device will not be increased even though the goal is to make it as smaller as possible so that can be used in daily life [3]. So far the focus was on enhancing notifications. Odors nevertheless could also be used to help to keep and to remember memories. Via this, users could actively use a unique smell when encountering a nice situation to later help to remember this event [40].

POSSIBLE DEVELOPMENTS

Favorable improvements for the future designs of olfactory devices are to make the size as small as possible, secondly by using flexible materials and lightweight but strong elec- tronic components will let the developers make a lightweight olfactory device. These improvements are especially related to the wearable olfactory devices. To allow the use of smell for many scenarios without the need to replace the container, for example, peppermint to concentrate while studying and lavender to rest. Other possible improvements can be to make the olfactory device more immersive by using Virtual Reality [22] [41].

Fig. 10. Shows that the users generally found easy and effortless to wear the necklace [3].

CONCLUSION

Scent has long been used as a form of artistic expression. This paper provides a brief introduction to olfactory devices that can be operated manually or automatically to produce an indirect spray of olfactory. Based on previous research, we recommend that future designs include a capability to change the smell delivery cycle and allow users to customize their settings. The outstanding characteristics and applications of olfactory devices should be explored further for HCI systems.

Competing Interests

The authors did not declare any competing interest.

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