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Integrating Scents Simulation in Virtual Reality Multisensory Environment for Industrial Products Evaluation

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ABSTRACT
The sense of smell has a great importance in our daily life. In recent years, scents have been used for marketing purposes for improving the person's mood and of communicating information about products as household cleaners and food. However, scents can be also used for any kind of products to communicate their features to customers. In the area of Virtual Reality several researches have focused on integrating scents in virtual environments. The research questions addressed in this work concern if scents can contribute to increase the users' sense of presence in the virtual environment, and also if Virtual Prototypes, including the sense of smell, can be used for evaluating products as effectively as studies performed in real environments. For this purpose, a Virtual Reality experimental framework including a prototype of a Wearable Olfactory Display has been set up, and experimental tests have been performed.

KEYWORDS
Multisensory environment; olfactory display; product evaluation

1. Introduction

Virtual Reality (VR) is an integrated trio of immersion, interaction and imagination [5]. These characteristics are considered as more effective if multiple sensorial channels are involved in the VR experience. These sensory modalities include vision, audition, touch, smell and taste [5]. Currently, most of the research works and devices in the area of Virtual Reality have focused on the visual, auditory, and tactile (haptic) simulation, while few of them have been carried out for what concerns smell and taste. Yet, also these senses are fundamental for human perception and, indeed, they could be helpful in order to reach a more effective level of immersiveness in VR experiences.

The sense of smell has a great importance in our daily life, even if, today, humans use more the senses of vision and hearing for interacting with the environment. The sense of smell is devoted to acquire and interpret chemical signals in the environment, and supports some basic biological and behavioural functions, as dangers recognition, identification of food, and social communication [18]. Nevertheless, scents have other functions and impacts on humans. Since the olfaction process involves many regions of the brain, in which both conscious and unconscious activities are carried out, scents can impact on physiological parameters, such as heart rate and skin conductance, and can induce activation or relaxation states in humans [1, 2]. In addition, scents can enhance learning activities, increase the level of attention, are deeply evocative [19], and can also influence moods [21].

On these bases, scents have been applied in the marketing research area, where several studies have been performed on the use of scents for eliciting positive moods in people, and for communicating information about products as perfumes, household cleaners and food. On the opposite side, few research works have been carried out in the field of industrial products not traditionally associated with scents, as household appliances, furniture, cars, and so on, but which can particularly benefit from their introduction. In fact, the use of pleasant scents for communicating product characteristics to users may represent a competitive advantage. Specifically, scents can evoke positive feelings and differentiate these products from others with very similar functionalities and appearance. Obviously, the new olfactory characteristic of industrial products has to be evaluated in order to investigate its impact on user's evaluation of the product, and if the designed relation between the product and the scent is appropriate for communicating the product characteristics. As it already happens for other characteristics of industrial products, Virtual Prototyping could be an effective tool for evaluating the new olfactory

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characteristic. Indeed, the use of Virtual Prototyping in the product development process is today a diffused practice [24] for evaluating and modifying design solutions, thus reducing the need to develop real prototypes. In addition, the use of multisensory approach, in which a combination of multiple sensory channels is used, allows the evaluation of multiple characteristics of the design solutions. For instance, Bordegoni et al. [3] demonstrated the effectiveness of using a multisensory approach based on the combination of vision, sound and touch in a design review activity. Consequently, in order to evaluate the new olfactory characteristic of industrial products, it is necessary to integrate also olfactory information in a VR multisensory environment by using devices capable of rendering scents.

Virtual Prototypes are typically implemented by using the most recent and innovative VR technology for 3D stereo visualization, 3D sound rendering, and haptic and tactile interaction. Recent studies have focused on integrating also scents in virtual environments, by means of devices named olfactory display [18]. An olfactory display is a device controlled by a computer that generates scented air and that provides a user with scents [18]. Specifically, because humans sense scents through the air, the role of an olfactory display is to generate scented air from odorous materials in a stocked form (liquid, soaked in porous materials, gelled, etc.) and to deliver the scented air to the human olfactory organ. The various technologies used to develop an olfactory display are categorized by scent generation methods and scent delivery methods [18]. These technologies have been used in several research projects [14, 16, 19, 26, 27, 28] that focused on the development of olfactory displays for specific purpose. Unfortunately, due to the fact that the personal olfactory displays so-far developed try to simulate a great number of scents, these are often cumbersome or very limited (in the number and quantity of scents that can be stored and generated, in the distance that the scented air can cover, and so on), and they have not found commercial success.

Nevertheless, the introduction of scents simulation in VR multisensory environments could represent an easy and flexible tool for increasing the realism of the experience in the evaluation of industrial products characteristics. Moreover, the scents simulation could impact on others field of research in which VR multisensory environments are used, such as marketing studies, medical rehabilitation, gaming and so on. In order to verify these hypotheses, the research presented in this paper aims at verifying if the introduction of scents simulation can influence and improve the level of presence perceived by the users. Moreover, the research aims at evaluating in what way scents can influence the users' evaluation of products, and if the influence of scents on the users' assessment of products in a VR multisensory environment and in a real environment can be comparable. Specifically, in [6] the testing sessions only concern the users' evaluation of product in a VR multisensory environment in which scents are added, while in this work the authors aim also at investigating if there is a correlation between the perceived level of presence, influenced by the introduction of scents, and the users' evaluation of products.

For this purpose, an experimental framework has been defined, a prototype of a wearable olfactory display has been developed, and some preliminary testing sessions have been performed. The collected data have been analysed for identifying any possible difference and correlation in the users' evaluation of the perceived level of presence and products with the used scent typology, and have been compared to results of testing sessions carried out in a real environment [4].

2. Related Works

The sense of smell has a great importance in our daily life, because it is devoted to acquire and interpret chemical signals in the environment and supports some basic biological functions, as danger recognition, location and identification of food, and social communication [18].

Many regions of the human brain are involved in the process of olfactory reception and interpretation. In particular, these regions are the cerebral cortex, the thalamus and the frontal cortex and the limbic system. The cerebral cortex, the thalamus, and the frontal cortex are involved in the cognitive processes of identification, recognition and measurement of olfactory stimulus, integrating and comparing it with other types of information (past experiences, stimuli from other senses, etc.). The limbic system is, however, the more irrational structure, considered as "primitive" and linked to human instincts. This part governs the unconscious and emotional components of perception and, together with the hippocampus, is responsible for the human olfactory memory. It is, therefore, possible that a perceived scent evokes memories, unconscious responses at the emotional level even before the olfactory stimulus is consciously perceived and recognized.

For these reasons, scents can improve a person's mood, as well as enhance learning activities, increase attention level, and are deeply evocative [19, 20]. Concerning the link between smell and memory, studies have been done from basic science, psychology and marketing points of view [15]. Many studies focused on the ability of scent signals, compared to signals sent to other sensory channels, to evoke autobiographical memories, or memories

of people, events, products, environments and also scents met or experienced long time ago [7]. This is related to the fact that, after a scent is experienced and associated in our memory with a specific emotional experience, it is able to evoke the associated emotion when later encountered [11]. Furthermore, researches demonstrated that scents can impact on physiological parameters, such as heart rate or skin conductance, and consequently can induce activation or relaxation states in people [2, 9]. Scents can also influence moods: while pleasant scents can induce positive moods, unpleasant scents can induce negative ones [22]. This property has been applied in the marketing research area, in which several works have been performed on the use of scents for eliciting positive moods in people, and for communicating information about products as perfumes, household cleaners and food. Studies found out that congruent scents in the environment can be used for improving the time spent by customers in a store [17]. Also, researchers found that pleasant scents can enhance evaluations of products [4] and of stores [23].

In the mass market, often the perceived quality of the products is associated with their scents [12]. Then, companies add scents to several commercial products, as household cleaners, in order to communicate to users the feeling of clean, and foods so as to supplement their organoleptic characteristics. In this latter case, the addition of scents (such as artificial flavours) allows companies to standardize the taste, filling any gaps caused by the food characteristics, and the possible changes in food preparation.

On the other hand, few research works and design practices have been carried out in the field of industrial products not traditionally associated with scents, but which can particularly benefit from their introduction. For example, some industrial products are linked, in the collective perception, to the scents of what they contain (as in the case of food packaging), or to the good or bad performances of the functions they are performing (as in the case of food in a refrigerator, the smell of washed cloth in the case of a washing machine, the smell of a dishwasher or a vacuum cleaner) or the perceived quality of the product (the car interiors, the quality of leather garments, and so on). Nevertheless, usually for these products their smell is not specifically designed, but relies on the characteristics of the product (as, for instance, the materials that constitute it), or on what the product will generate naturally, and could be both pleasant and unpleasant. However, in the second case, an unpleasant scent could affect the product judgments by users. On the contrary, the design and the use of pleasant scents for communicating product characteristics to users could represent a competitive advantage for these products. In fact, scents can evoke positive feelings and differentiate them from the others of the same category, thus impacting both in the conscious and unconscious levels of perception, and in the crucial buying decision.

In the area of Virtual Reality and simulation, several studies have focused on presenting scents in virtual environments, by developing both ubiquitous and personal olfactory displays. An olfactory display is a device controlled by a computer that generates scented air and provides a user with scents [18]. Because olfaction is a chemical sense, differently from the visual and the auditory ones that are based on physical stimuli, the rules for developing an olfactory display are different. The two main characteristics to take into account is the non-linearity of the olfaction (a change of intensity of the stimulus can result in a qualitative change in the subjective sensation), and the fact that there is not consensus on a classification of "primary" scents, and researchers are still trying to find out the minimum number of scent components required for achieving an acceptable quality of expressing arbitrary scents. Then, researchers in the ICT area have reduced the number of scent components to use according to specific applications in which they would like to use their devices. Because humans perceive scents through the air, the role of an olfactory display is to make scented air from scent materials in a stocked form with the desired components and concentration, and to deliver the scented air to the human olfactory organ. There are various technologies, categorized by scent generation and scent delivery methods, used to construct an olfactory display. In general, these technologies are used for carrying out the two main functions of an olfactory display: the generation and the delivery of scents [18].

The generation of scents depends on the kind of essences used, which usually are in a liquid form, and that can be soaked in porous materials, encapsulated or gelled. Then, various methods can be used to emit molecules of scents in accordance with their form: for example, one can use natural vaporization, airflow-based vaporization, heating, airflow-based atomization, direct atomization - piezoelectric method, and ultrasonic atomization. For what concerns scent delivery methods, there is, for example, the natural diffusion/convection, the use of wind, vortex ring, the use of tubes, and the direct injection. These technologies have been used in several research projects that focused on the development of ubiquitous or personal olfactory display for specific purposes. One of the main aims of these studies is to improve the users' experience of VR environments. Specifically, due to the demonstrated impacts of scents on people's physiological and psychological states, the scents

simulation could have a strong influence on the users' experience. In addition, some of these studies focused on the possibility of taking advantage of the characteristics of smell for developing more effective communication systems. For instance, Yanagida et al. [27] proposed an unencumbering olfactory display that conveys a clump of scented air from a remote place to the user's nose by using an "air cannon" that generates toroidal vortices of the scented air. Kim et al. [14] focused their research on developing an olfactory display based on a chemical container of temperature responsive hydrogel, which can have reversible phase transition between sol and gel, and controlled release of aroma by using a Peltier module to control the temperature. Yamada et al. [26] developed and evaluated two prototypes of wearable olfactory displays to present the spatiality of scent in an outdoor environment. Narumi et al. [19] developed a "Pseudo-gustatory" display for creating a gustatory sensation. This display presents flavours by means of a cross-modal effect elicited by visual and olfactory Augmented Reality. For this purpose, they developed the "MetaCookie+," by using the Edible Marker system, which can detect the state of each piece of bitten or divided food in real time, and the "Pseudo-gustation" method to change the perceived taste of food by changing its appearance and scent. Hirota et al. [13] developed an approach to implement and evaluate smell display to be used in multi-sensory theatres. They developed both an olfactory display system and a sensor system. In the olfactory display system, scents are vaporized in chambers to achieve saturated state, and then plain air is infusing for pushed out the scented air. Finally, some companies have developed and tried to sell virtual olfactory displays for personal computer use [8]. Examples are AromaJet (www.aromajet.com), DigiScents-iSmell, ScentAir (www.scentair.com), and TriSenx. They use a number of scents stored in cartridge, and upon receiving a signal describing a scent, they release a mixture of these scents. This is done, for example, by using pumps, and the resulting scented air is blown towards the user with a small fan.

Unfortunately, due to the fact that personal olfactory displays so-far developed try to simulate a great number of scents, these are often cumbersome or very limited (in the number of scents that can be stored and generated, in the quantity of scents that can be emitted, in the distance that the scented air can cover, and so on), and they have not found commercial success.

Nevertheless, the introduction of scents simulation in multisensory VR environment could represent an easy and flexible tool for evaluating industrial products characteristics.

3. Main Idea

In the research presented in this paper the authors make the hypothesis that the introduction of scents simulation in VR multisensory environments can contribute in increasing the users' sense of presence in the virtual environment and can allow evaluating the influence of scents on the users' assessment of products.

In particular, the research presented in this paper aims at evaluating:

- in which way scents can influence the level of presence in a VR multisensory environment,
- in what way scents can influence the users' assessment of products, and
- if the influence of scents on the users' assessment of products in a VR multisensory environment and in a real environment can be comparable.

For this purpose, a VR multisensory framework, including a prototype of a Wearable Olfactory Display, has been set up, and experimental testing sessions have been performed.

The experimental framework is a VR multisensory environment consisting of an Oculus Head Mounted Display (http://www.oculusvr.com/) used for displaying a digital scene in an immersive modality, and a prototype of a Wearable Olfactory Display capable of rendering one scent at a time. The authors decided to use a 2 (pleasant versus unpleasant) X 2 (congruent versus incongruent) between-subject method. This method, in which the only variable parameter is the scent, has been chosen in order to reduce the possible variables to take into account and that can impact on the experimental analysis. Moreover, the authors included a no-scent control condition for comparing users' evaluations in odour and odourless conditions. Consequently, five distinct groups of subjects were asked to perform the same testing session. For each group, made up of 15 subjects, one of the four selected scents (lavender-pleasant and congruent, orange-pleasant and incongruent, smoke-unpleasant and congruent, and anchovy-unpleasant and incongruent) rendered by the prototype of a Wearable Olfactory Display has been added to the virtual scene.

The virtual scene is made up of the digital models of three commercial washing machines, placed in a virtual room, the background of which is the picture of a household appliances store (Fig. 1). The shapes of the washing machines are different, while their colours have been made uniform.

Figure 1. The virtual environment with the 3D models and the background shown to the users.

The Wearable Olfactory Display (Fig. 2) consists of air cannons for:

- the generation of scents, by using the ultrasonic atomization method (in which fine particles from a liquid are generated by using ultrasonic energy);
- the delivery of scents, by using a direct injection method.

In each air cannon, a small cylinder of porous cotton is placed and used as scented water cartridge. Commercial water-soluble flavours are used, diluted with water. The cylinder of porous cotton is drenched with the scented water and, under the effect of ultrasonic energy, a scented mist is generated and released in the air, which is eventually smelled by the user. For obtaining a non-cumbersome and comfortably Wearable Olfactory Display, the air cannons have been placed on the external part of commercial earphones (one air cannon in each side of the earphones). By using this solution the scented air can easily reach the user's noise and, in addition, the Wearable Olfactory Display is non-cumbersome and confortable for the user. These features of the Wearable Olfactory Display are quite innovative in comparison with the existing systems presented in Section 2. Indeed, some of them [13, 14, 27] are not wearable and have to be placed on a desk close to the user's nose, while the other prototypes [19, 26], also if presented as "wearable", are cumbersome and heavy.

The air cannons are controlled by means of a software application specifically developed. The architecture of the Wearable Olfactory Display is shown in Fig. 2. The software application, which runs on a tablet, sends the user's input via wireless to an Arduino board (http://arduino.cc), which processes the input and sends the command of generating and emitting the scent to the air cannons.

4. Testing Sessions

In total, 75 subjects were asked to perform the experimental testing session. The subjects were students of the Design and of the Mechanical Engineering Schools of the Politecnico di Milano. Their average age is 24.5, and 45% of them are females. Each subject was received alone. Subjects were randomly assigned to one of the five experimental conditions. An informed consent was read and signed by each subject; they were voluntary and did not receive monetary compensation. Subjects were not aware of the presence of scents in the environment, and they were asked to evaluate their experience in the VR environment and also some characteristics of the virtual products (the pleasantness of the shape of the product and of the product components, the perceived level of usability, the perceived value of the product, the users' purchase intentions, etc.).

Each testing session was organized in a pre-testing, a testing, and a post-testing phase.

In the pre-testing phase, which lasted about 5 minutes, subjects were asked to fill in a short questionnaire for gathering background information about the subjects, including their age, sex and experience with HMD and VR. Also, subjects were asked if they are smoker or not, if they suffer from any allergy, and if they had a cold. In the testing phase, subjects were asked to wear the HMD and the earphones including the Olfactory Display, and then to look at the three virtual washing machines displayed through the HMD. The testing session lasted about 5 minutes. During the post-testing phase, which lasted about 20 minutes, qualitative data about the subjects' evaluation of the experience in the VR environment, and the evaluation of some properties of the washing

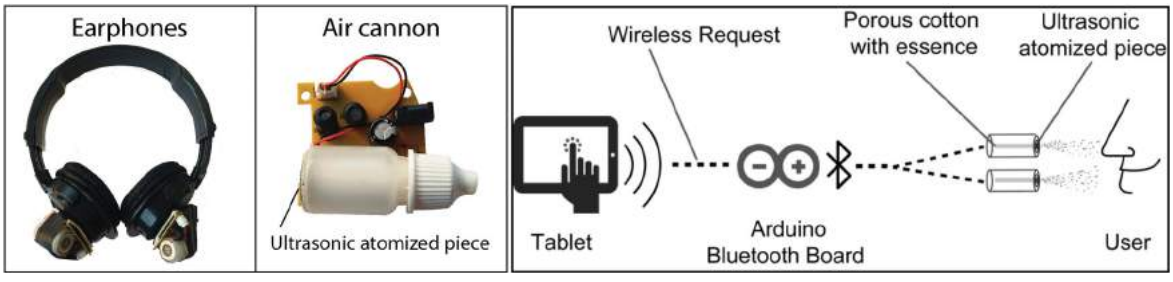

Figure 2. The prototype and the architecture of the Wearable Olfactory Display.

machines have been collected. In particular, subjects had to fill in several questionnaires: the first one concerned the user's experience in the VR environment and the perceived level of presence, while each of the other three questionnaires were devoted to the assessment of one of the virtual washing machines.

The questionnaire about the level of presence was based on that reported in [25], and adapted by the authors in order to better investigate the impact of the introduction of scents. Although no auditory simulation was present in the VR environment, the authors decided to include some questions related to the auditory aspects in the questionnaire administered to the participants [25]. By inserting these questions, the authors intended to leave the subjects not aware of the fact that tests were focalized only on the visual and olfactory simulations. In this questionnaire, similarly to [25], a seven-point scale format, based on the semantic differential principle [10], was used.

The questionnaires dedicated to the assessment of the virtual washing machines were dedicated to a specific washing machine. In this case, subjects were required to express assessments on the washing machine and on the shape of its main components, its perceived value, its perceived level of usability and washing performances, and so on. In these questionnaires, a six-point scale format was used.

5. Results Analysis

After the tests, the collected data have been analysed for verifying the influence of scents on the level of presence in a VR environment and on the users' evaluation of products. Besides, it has been analysed if the obtained results could be comparable with those of Bosmans [4]. According to this study, scents congruent with the product category can have a strong influence on consumers' product evaluations.

For this purpose, both the collected data of the first questionnaire (concerning the level of presence) and the other three questionnaires (concerning the washing machines) have been analysed. Specifically, for what concerns the level of presence, for each question of the questionnaire and each scent (or no scent, for the no-scent control condition), the medium value of the collected users' evaluations has been calculated. Moreover, for what concerns the users' evaluations of the products, the medium value of the collected users' evaluations has been calculated for each question of the questionnaire, each scent (or no scent, for the no-scent control condition) and also for each washing machine.

The first research question addressed in this paper concerns "in which way scents can influence the level of presence in a VR environment". The results of the experimental testing sessions demonstrate that the introduction of scents can contribute in increasing the users' sense of presence in the virtual environment.

Specifically, for all the questions, the medium values of the users' evaluations in the test with scents are higher than the medium values collected in the odourless conditions. In addition, the use of the pleasant scent (orange) positively influences the users' evaluation of some characteristics of the users' experience of the VR environment. In particular, considering the questions in which a positive mark means an improved users' experience (the total number of these questions is 19), in 58% of the cases the medium value of the users' evaluations in the test with the orange scent is the highest one, while in 31,5% of the cases these values are the second highest ones. On the opposite side, also the use of the unpleasant and incongruent scent (anchovy) positively influences the users' experience of the VR environment. Indeed, in 26,5% of the "positive" questions the medium values of the users' evaluations have been collected in tests with the anchovy scent, and the same percentage has been collected in the case in which the medium values obtained in tests with the anchovy scent are the second highest one. We argue that these results may be due to the fact that humans perceive both the orange and anchovy scents as more intense. Consequently, these scents allow for a more stimulating VR environment, able to improve the users' experience and the level of presence.

More specifically, for what concerns the responsiveness of the VR environment to the users' actions, the medium value of the users' evaluations in the test with the orange scent is the highest one. Similar results have been collected with the orange scent in the case of:

- the perceived level of involvement for what concerns the visual, and the olfactory aspects;
- the consistency of the virtual and real-world experiences;
- the possibility of actively observe the environment by using vision and examine objects from multiple viewpoints;
- the involvement in the VR experience.

For what concerns anchovy scent, which has collected the highest medium value of the users' evaluations, it is worth reporting that the use of this scent had positively influenced the perceived engagement of all the users' sense, the localization of scents (but not their identification) and the level of satisfaction in the interaction with the environment.

The second research question addressed in this paper concerns "in which way scents can influence the users'

evaluation of products". In this case, the analysis of the collected data demonstrates that the use of scents positively influences the users' evaluations of the products. Indeed, even if there are important differences in the evaluation of the three washing machines (mainly for what concerns the washing machine number 1, considered by users as less satisfactory from an aesthetic point of view), the use of congruent and pleasant scent (lavender) positively influences the users' evaluation of some characteristics of the washing machines.

Specifically, considering the questions in which a positive mark means an improved users' experience (the total number of these questions is 13), in the 64% of the cases the medium value of the users' evaluations in the test with the lavender scent is the highest one, while in the 18% of the cases these values are the second highest ones.

In particular, for what concerns:

- the pleasantness of the product shape, the medium value of the users' evaluations collected in the test with the lavender scent is the highest one in 83% of the cases;
- the pleasantness of the shape of product components (the window and the interface), the medium value of the users' evaluations in the test with the lavender scent is the highest in 50% of the cases, while in 33% of the cases the highest medium value has been collected in the test with the orange scent;
- the users' evaluation of the perceived level of usability of the product, in 45,5% of the cases the medium value of users' evaluations in the test with the lavender scent is the highest one;
- the perceived value of the product, the medium value of users' evaluations after the test with the lavender scent is the highest one for all the three washing machines;
- the users' purchase intentions, the medium value of the users' evaluations in the test with the lavender scent is the highest in 67% of the cases.

For what concerns users' evaluations of the perceived washing performances of the washing machines, it is worth reporting that it seems to be not related to the use of scents. Indeed, the highest medium value of users' evaluations occurs similarly in the test with lavender (33% of the cases), orange (33%), smoke (22%) and anchovy (22%), while the odourless test in the 66% of the cases collected the second highest medium value of users' evaluations.

In addition, for what concerns the third research question addressed in this paper, the results demonstrate that the influence of scents on users' assessment of products in a VR multisensory environment and in a real environment can be comparable. In fact, the results obtained match with those obtained in a real environment [4], even if the two studies present some differences. Firstly, the testing sessions in the Bosmans' study have been carried out focusing only on ambient scents, while in our work scents are directly associated with the product. In addition, in the Bosmans' study only pleasant scents (and a no-scent control condition) have been used, while in this work the authors used both pleasant and unpleasant scents. Despite these differences, both in the Bosmans' study carried out in a real environment and in the present study, it has been proven that scents that are congruent with the product category can have a strong influence on users' product evaluation. This demonstrates that similar results can be obtained from studies on the influence of scents on the users' evaluation of products in a VR and real environment.

6. Conclusions

The research presented in this paper concerns the possibility of improving the users' experience of VR multisensory environments via the introduction of scents simulation. Indeed, since smell is linked to humans' visceral emotions, and can impact on people's mood and feelings, it can also have impact on virtual simulations of environments, situations and products.

The use of Virtual Prototyping in the product development process is today a diffused practice for evaluating and modifying design solutions. Moreover, the use of VR multisensory environments in design review activities has already proven its effectiveness, and the introduction of scents simulation could make the design review activities more engaging and complete. Nevertheless, also if several studies have focused on presenting scents in VR environments, the olfactory displays so-far developed are often cumbersome to wear, or very limited in the quantity and number of scents that can be stored and generated.

In an envisaged scenario in which the scent design discipline, applied up to date for products and environments traditionally associated with scents, could bring to other categories of products, as household appliances, furniture, cars, and so on, in order to characterize them and communicate their features to potential customers, the designed scent, as well as the other characteristics of the products, needs to be evaluated.

Consequently, the research questions addressed in this paper concern whether the introduction of scents in VR multisensory environments can be used for evaluating products as effectively as studies performed in real environments, and also whether scents can contribute in increasing the users' sense of presence in the virtual environment. For this purpose, a VR experimental

framework has been set up, a prototype of a Wearable Olfactory Display has been developed, and experimental testing sessions have been designed and performed.

The analysis of the data collected in the experimental tests demonstrates that the use of scents positively influences the user's experience of the VR environment and the perceived level of presence. Specifically, the medium values of the user's evaluation of characteristics as the responsiveness of the VR environment to the users' actions, the naturalness of the interaction with the VR environment, the perceived level of involvement in the VR experience and the consistency of the virtual and real-world experiences, are improved if scents are added to the VR environment.

Also, the analysis of the data related to the users' evaluations of the washing machines demonstrates that the use of congruent and pleasant scent positively influences the users' evaluations of the product shape, and the perceived level of usability and value. Moreover, the authors argue that there is not a direct correlation between the perceived level of presence in VR multisensory environment, influenced by the introduction of scents, and the users' evaluation of products. Indeed, in the case of the users' evaluations of the level of presence in the VR environment, both the use of the pleasant and incongruent scent (orange) and unpleasant and incongruent scent (anchovy) positively influence the evaluations. On the opposite side, in the case of the users' evaluations of some characteristics of the products, the highest medium value has been collected in test with the use of congruent and pleasant scent (lavender). Eventually, the presented results match with those obtained in a real environment [6], and demonstrate that studies on the influence of scents on the users' evaluation of products in a VR environment and in a real environment are comparable.

Finally, since the introduction of scents in VR multisensory environments can improve the users' experience and the perceived level of presence, it can be also used in other applications in which VR multisensory environments are used, as for instance marketing studies, medical rehabilitation and gaming.

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