Design of a Virtual Reality Scenario and Scent Generator for Sensory Training

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***Abstract*— In the food industry, what makes the difference between a company and its competitors is the quality of its food product, and one of the components that makes quality is the flavor of a product. As trends shift to meet consumer's health and wellness desires formulas are changed with companies trying to retain the same flavoring. This shifting has led to the increased demand of sensory analysis tests. Some of the limitations for sensory analysis is the required space to have the individual booths, time consuming preparation, and material costs. But even with the previous limitations, one of the most important is the training of new users and calibration of existing users. With the development of virtual reality this problem can be more easily rectified by creating a virtual scenario that utilizes all senses and reduces cost of training. The main objective of this research is the development of a virtual scenario for sensory training. This is achieved by recreating a traditional testing environment and training program to analyze scents provided by a scent generator prototype. The methodology will include the design of the training, recreating the environment, programming the interaction with the user and finally the development of a scent generator to release scents.**

Keywords—Virtual Reality, sensory training, mechatronics.

I. INTRODUCTION

The Institute of Food Technologists (IFT) established that "sensory evaluation is a scientific discipline that is used to evoke, measure, analyze, and interpret those responses to products as perceived through the sense of sight, smell, hearing, touch, and taste" [1, 2]. Using sensory evaluation one can understand how humans perceive and respond to the various stimuli in food. Understanding the complex nature of sensory perception and consumer behavior is applied as a quality tool in the product development process to recognize the main consumer drivers while making decisions. Sensory analysis is based on average data obtained by either trained users or consumers evaluating food products under controlled conditions in a sensory laboratory using traditional individual booths with specifically controlled features such as; colors, light, and other aspects of the environment. Due to the increasing market and competitors, the need of sensory analysis is becoming increased in food science for developing new products and in industry for developing high quality products but at the same time reducing costs. Sensory analysis is being used as a powerful tool in quality control assuring the customer satisfaction.

The odor of a product is detected when its volatiles enter the nasal passage and are perceived by the olfactory system. Odor refers when the volatiles are sniffed through the nose (voluntarily or otherwise). Aroma is the odor of a food product, and fragrance is the odor of a perfume or cosmetic [3]. In this research we will refer to the volatile compounds used as scents. The sense of smell is employed daily and is concerned with making sensory memory identifying chemical signals from one's surroundings such as; danger triggers, favorite food, and even correlating smells to a feeling or an experience. Regarding the olfaction process, scent detection involves many regions of the brain, in which both conscious and unconscious activities are carried out [4]. In addition, scents can enhance learning activities, increase the level of attention, and are deeply evocative [5].

Virtual environments or virtual scenarios are custom-made 3D virtual worlds created out of 3D models, which allows trainees to interact and immerse themselves in "worlds" that are distant, expensive, hazardous, or inaccessible. Virtual scenarios are also known as, "artificial reality", "virtual worlds", and "synthetic environments" [6]. Reference [7] defined Virtual Reality as a closed computer system that consists of a virtual environment, a physical environment, as well as a software and hardware interface, which allows interaction between a human and a computer.

Advances in technology have evolved interfaced systems allowing for the introduction of virtual reality and virtual scenarios into food science. Research on this field is becoming more explored as a rich context for marketing consumer evaluations in virtual reality environment such as coffee shops,

bars, and laboratories. Reference [8] related to the virtual reality as a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more sense, giving the feeling of being mentally immersed or present in the simulation. This definition comes from four key elements that one experiences in virtual reality, which are: a virtual world, immersion, sensory feedback, and interactivity.

The application of this technology in the food science will continue to grow. Through this, the sensory science field will have a revolution of their basic understandings of multisensory experiences with immersive controlled environments that can be customized to meet demands using CAD.

Sensory analysis has been developed in a traditional laboratory with an individual booth, with controlled conditions to evaluate the consumer test preference through conscious responses, but the results haven't always been positive. In their research [9] proposed that consumer preference will be conducted based on unconscious decision making which involve behavior responses to the product.

For consumption preference tests, creating different environments such as; controlled laboratory environments, bars, and restaurants is highly impactful on the research to analyze responses and gather sensory feedback evaluating the same product. As [10] mentioned in their article, recreating an immersive environment has an ecological advantage, reducing the relatively large amount of space required, the expenses, and time-consumption.

The emergence of virtual reality technology has opened a gateway of opportunities to sensory improvement. The purpose of this project is to create a laboratory in a Virtual Scenario with individual booths to have the same criteria for training, in an immersive environment, that will allow the subject feel the experience of the traditional method. To achieve this, a small scent generator was made to give the advantage of portable sensory training. Utilizing a virtual scenario results in reducing time-consuming task, standardizing the scenario to repeat the training as needed, reducing cost of installation, and making an ecological test by reducing waste material.

II. Related work

A. Sensory Analysis

Sensory testing normally is conducted in a traditional laboratory using individual booths to keep focus on the food product and reduce interaction with people and surroundings. Nevertheless, when consumers really test the food product it could be in their home, a restaurant, a cafeteria or an airplane, which will affect the response not giving the same results as the traditional way.

There is some research about how eating in different environments influences the consumer on the perception and its acceptability. Reference [11] demonstrated the influence of the environment in affecting the consumers' hedonic, emotional, and electrophysiological responses while consuming chocolate ice cream in a laboratory, cafeteria, university area, and a city bus stop. In another study, it was found that consuming food in a traditional laboratory, using individual booths, the perception of the food presented had less hedonic quality compared to the same food consumed in a different environment [12]. It has been determined by [13] that the influence of environment on consuming identical food in a restaurant surrounding with a gourmet table compared to a booth environment with a plastic tray yielded results giving favorable responses to the appearance of food consumed in a gourmet table versus in a sensory testing booth.

Sensory analysis has multiple applications not only on the scientific field, but also in marketing and industry. The principal applications are quality control, product development, environment odor detection, evaluation on food and beverages, pharmaceutics, and cosmetics.

Scientific research has been done involving connections between emotions in response to aromas, like [4] they analyzed the relationship between emotional generation in response to odorants using the sense of smell.

There is some research in the marketing area that describes the linking between sensations and consumer perception to customer preference in the market. Reference [14] defined "sensory market" as marketing that engages the consumers' senses and affects their perception, judgment and behavior. Humans can correlate an experience to a smell. From a marketing point of view, aromas can be employed to evoke positive experiences with products used by consumers to gain companies preference in future purchases.

Sensory analysis requires certain sensitivity in humans to be able to detect and to identify compounds, normally research is conducted with a trained panel or expert panel. Results with an untrained panel will lead to required increase concentrations to enhance signal detection. Reference [15] enhanced sensitivity to odors developing the ability after repeated exposures of a volatile compound. These results suggest that untrained people can acquire olfactory sensitivity by repeated exposure to a compound or smell.

In sensory analysis discrimination tests are one of the main tests that are more useful. Discrimination tests have two scopes, they are used in sensory analysis to identify that there is a difference between samples or depending on the main purpose of the research to recognize that there is no difference between the samples. One type of discrimination test is the Triangle test, where the main scope is to recognize if a difference exists between two samples. The larger the number of subjects used in a Triangle test yields better results, although, a small number of subjects can give important results when the difference is easier to detect. The procedure consists in presenting three samples, where two of them are the same sample and the third one is the odd sample. The subject is asked to identify which of the three samples is the odd sample. The samples are coded in a three-digit number arrangement and presented in a random order AAB, ABA, BAA, BBA, BAB, ABB.

Food perception is a multisensory experience that involves the five senses and the feedback from different surrounding environments which plays a principal role in generating stimuli that a normal laboratory cannot create in front of a booth. Although, there is more research needed in the sensory field between the perception of a product and the interaction in an

immersive environment, there are some results obtained in real life experiments changing the conditions and the influence that it has when perception and liking products are of concern.

The research from [16], showed that testing conditions had an effective response even with an untrained panel, when testing in a laboratory or testing at home. The results where that testing under home conditions enhance the perception of the same product, the composition of the product didn't change, it was just the test environment.

B. *Virtual Reality*

Introducing a multisensory experience in a virtual reality environment could evoke and increase the feeling of realism while working in an immersive scenario actually seems like working or learning in a real-life experience, but with the advantages of having controlled the variables and make it available for more people.

In reference [8], they mention as one of the four key elements is the sensory feedback as an ingredient essential to virtual reality. In most virtual scenarios the visual sense is the only sense that receives feedback, though virtual environments also exist that display exclusively haptic (tough) experiences. Nowadays, researchers have demonstrated that the sense of smell has important presence in the feedback when being immersed in a virtual medium or environment, and this is possible due to the new technology and development.

Scientific research has been done involving the sensory approach through the five senses and their reaction in front of stimuli in an immersive environment. Reference [5] based on an illusion they built a "meta cookie+" and changed the appearance and scent of the cookie using virtual reality without doing any change to the chemical composition of the food. They proposed that changing the appearance and scent of the food product can impact the perception.

Reference [17] proposed that introducing scents simulation in virtual reality environments can enhance the users' sense of presence and concede analysis of the impact through scents while judging products.

Virtual reality has endless applications depending on needs that arise. It proposes to solve or approach situations that initially seemed economically unattainable and even proposes to carry out activities with greater security and practicality. In neurosurgical medicine, the use of virtual reality helped to train surgeons, providing an environment as closed to reality to feel immersed in a real operating room without the high cost, and reducing the legal and ethical concerns by practicing with patients [6].

C. *Scent Generator*

In the scientific field the term olfactometers or dynamic sniffer refer to a device designed to generate odors controlled by computers with a determined flow, concentration, frequency and standardized parameters, normally used in laboratories for research. Generally, because of the size and weight they are not comfortable to use and are not portable. One example of a transportable and wearable device is the Essence necklace design by [18] controlled remotely by smartphone to release a scent using a piezoelectric transducer that can be used in everyday life situations, the release of the scent will be based on contextual data from the user. Its limitation was that it can release one scent although changing scents depends on the user, but it needs to be done one at a time.

Another wearable device studied by [19] was an odor generator that was housed and carried in a backpack with scents being conveyed through tubes to the user's nose.

Previous work has been studied using a computer-controlled device that released scents in a virtual environment, this device is named Olfactory Display [20]. Unfortunately, the prototypes trying to release a great number of scents makes it cumbersome and not a very pleasant experience while being used as a head set. The research project by [21], worked with a portable olfactory device called MFOD (Multi-Fragrance Olfactory Display) that released eight fragrances in a controlled manner through airflow from solid fragrance release. They evaluated how impactful odors generated by the MFOD were on user's taste perception.

III. Design and Implementation

A. *Concept Design*

The evolution of the sensory training application requires the follow of sequential steps, each step takes action of important implementations for the final design (Fig. 1).

The first step of the development process requires the design specifications of the training in which you have a tutorial and a test evaluation for the subject displaying on the screen in front of the sensory booth where the sensory evaluation will take place.

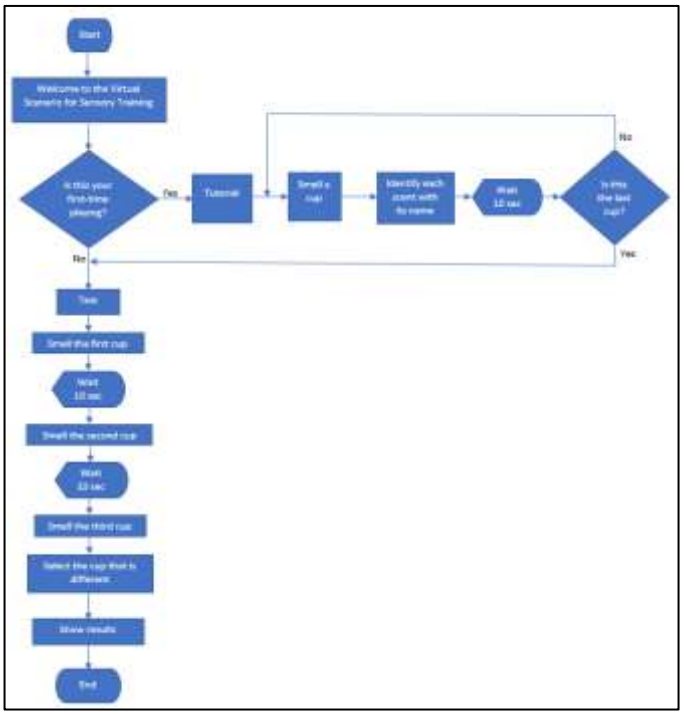

Fig. 1. Sensory Training Diagram

In Fig. 1 it is shown the flow that will take place starting with the welcoming to the virtual scenario for sensory training followed up by an introduction of the environment, then the subject will be asked to choose between the tutorial or the test option. In the tutorial, an introduction will display explaining the nature of the logistic with the five scents that will be released through the scent generator. If the user needs to try a scent again in order to be able to completely identify the scents, they will be allowed to re-take the tutorial. When the subject is finished with the identification of the scents, the subject will be referred to do the test evaluation. In the test evaluation, an introduction to the evaluation is performed, and the user will have to identify the odd sample. The result will display in the screen when the test is done.

B. Virtual Reality

In order to create the immersive environment, the first step was designing the CADs using SolidWorks and then optimizing the mesh (Fig. 2) of each design thorough 3D Studio Max.

The environment includes the individual booths used in a sensory laboratory, the trays and the cups required for the scent's representation, the screen for displaying the instructions for the training, and the entire elements for the laboratory.

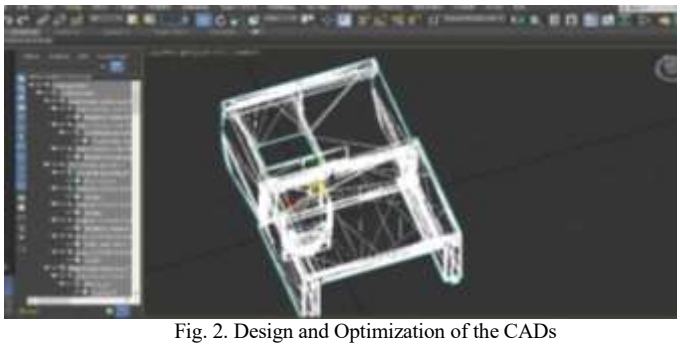

Fig. 2. Design and Optimization of the CADs

C. Scent Generator Designcr

In this paper, a Scent Generator (Fig. 3) is designed using SolidWorks to release multiple scents for training. The SolidWorks license number used was 9020008310893632 VYMPWH8. The Scent Generator consists of an Arduino Uno connected to a relay that uses 6 volts to activate six peristaltic pumps which utilize hoses

Fig. 3. Scent Generator Design

to transfer scents from their containers to the user. With this design, five pumps are dedicated to transferring scents, while the sixth is designated to suck and cleanse the system. In order to not contaminate the surrounding environment, pump six has coffee grounds that are used to neutralize the scents sucked into it.

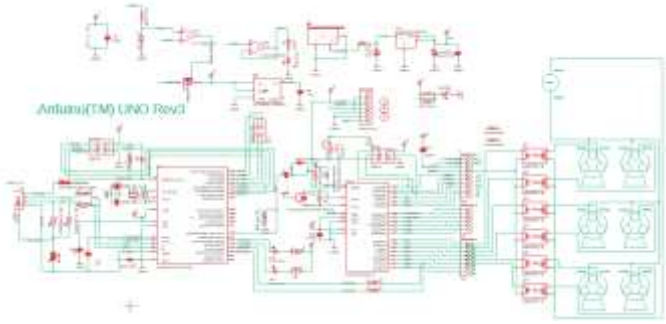

Fig. 4. The Wiring Diagram of the Arduino Uno, the Relays, and the Pumps Connected

In the Fig. 5 it is shown how the architecture of the Scent Generator is connected using the headset, the computer, and finally the user.

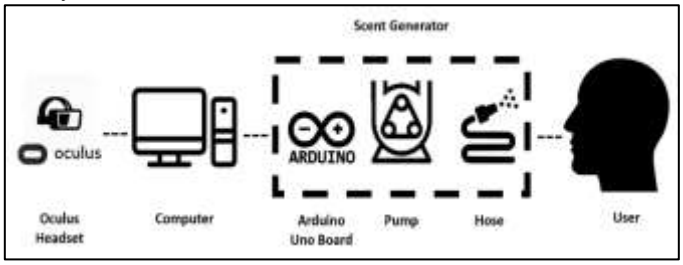

Fig. 5. The Architecture Diagram of the Scent Generator

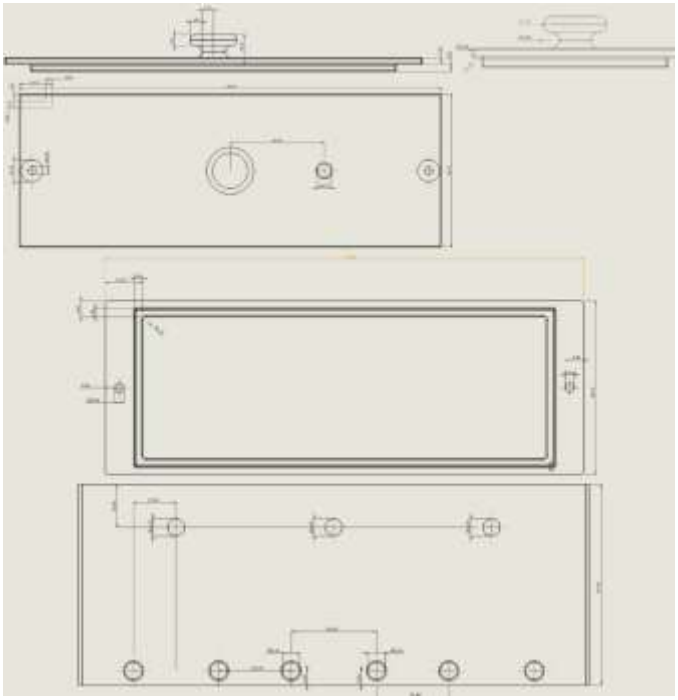

Fig. 6. CAD Models and Dimensions of The Lid (Top) and The Splitter and Hose Housing (Bottom)

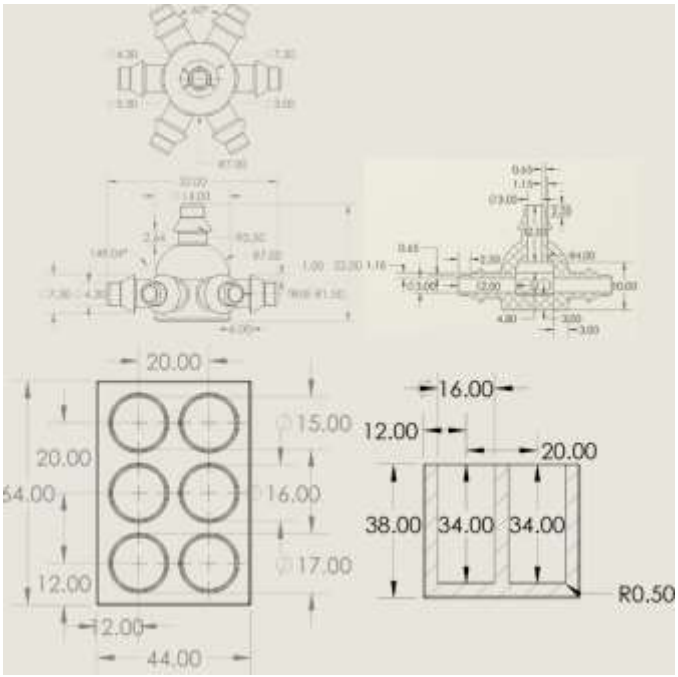

Fig. 7. CAD Models and Dimensions of the Splitter (Top) and the Scent Vial Holder (Bottom)

The Scent Generator was designed with 3D printing in mind as to conform to and house the standard parts we utilized in our electronics. In Fig. 6 through Fig. 9 the parts are shown and dimensioned as they were printed. All the dimensions shown are in millimeters.

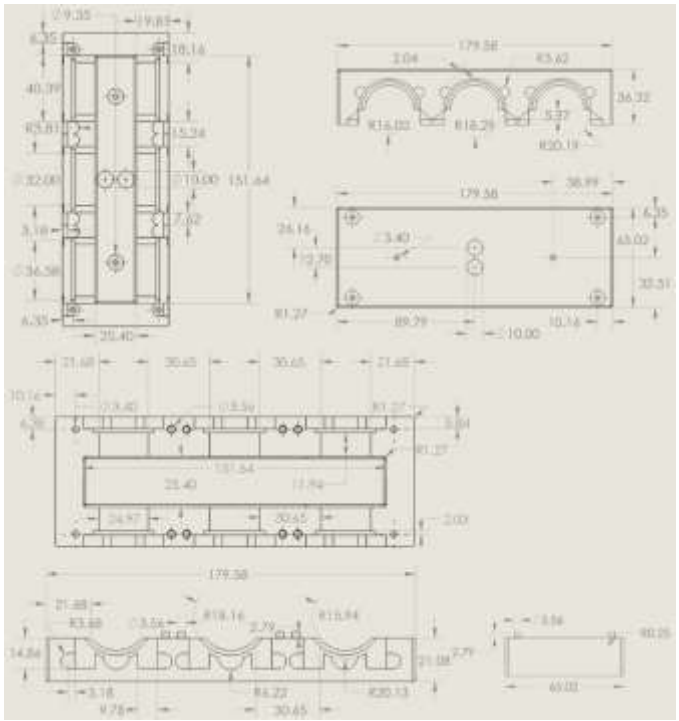

Fig. 8 CAD Models and Dimensions of the Top Half of the Pump Holder (Top) and Bottom Half of the Pump Holder (Bottom)

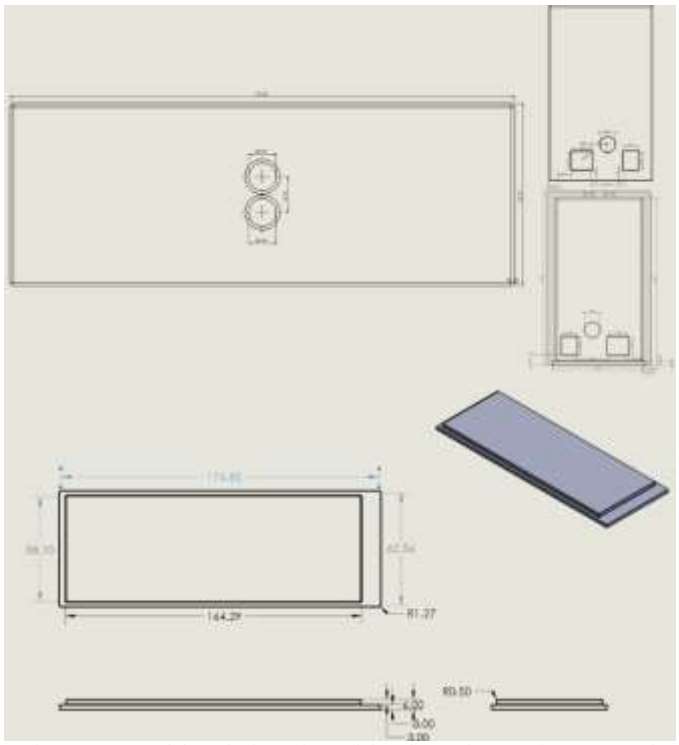

Fig. 9. CAD Models and Dimensions of the Electronics Housing (Top) and Base (Bottom)

IV. RESULTS

A. Scent Generator

The Scent Generator prototype was printed using a 3D printer. The prototype contained in the bottom the integration of the Arduino and a relay (Fig. 10), which were connected to the peristaltic pumps and from each pump, a hose connects from one end the scent and from the other end to a splitter (Fig. 11) creating the connection of the multiple scents that finally was integrated into one central hose that helped released the scent to the user by the headset (Fig. 12).

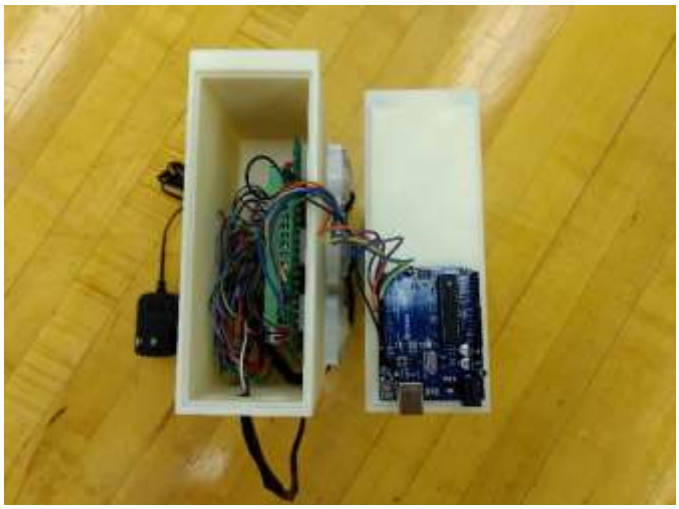

Fig. 10. Arduino and Relay Integration

One restriction of the prototype design was that the time required to release the scent was ten seconds due to the hose's distance from the splitter to the headset. This is the reason it's specified in the training the time required to cleanse the system.

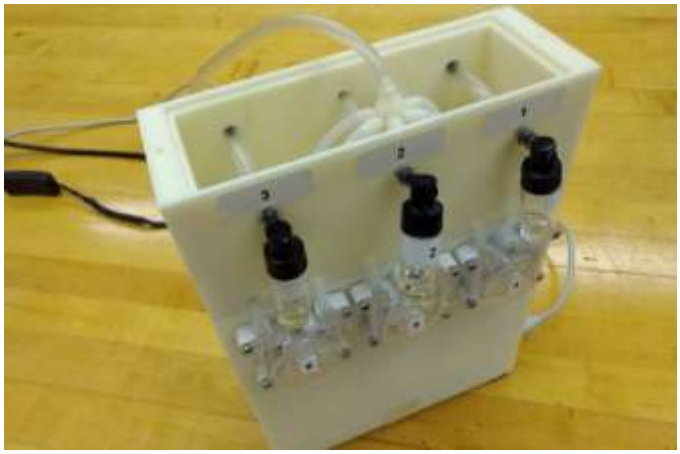

Fig. 11. Multiple Scents Connection

Fig. 12. Integration of Scent Generator

B. Virtual Reality Scenario Design

The training was divided into five cases to give the correct sequential flow, each case is explained and shown in the next figures with the audio scripts that the user heard while being immersed in the environment.

The first screen, shown in Fig. 13, the user heard and read: "Welcome to the virtual scenario for sensory training. Today you will be participating in a test to determine the differences between smells." Next, the user heard: "If this is not your first time playing, go ahead and click to the test. If it is your first time playing, click on the tutorial where you'll get acquainted with the different smells." This explains the reason of having two buttons on the screen, one for the "Tutorial" and the second one for the "Test", in case if the user just wants to take the test.

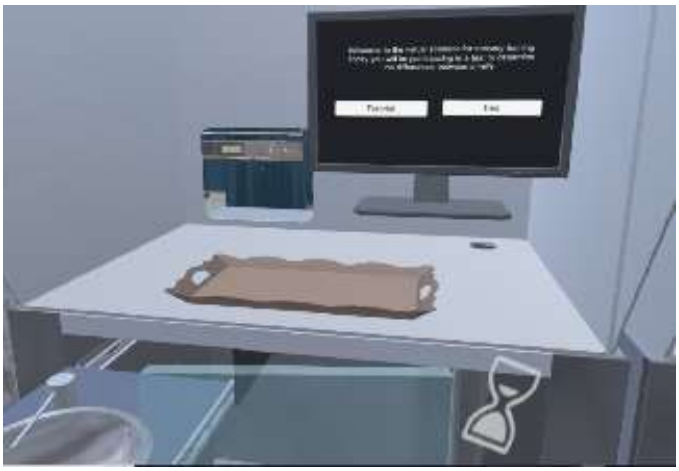

Fig.13. Virtual Reality Scenario Case 1

The second screen, shown in Fig. 14, referred to the "Tutorial" where the user read and heard: "Before you there are five different smells going from left to right, they are: bora bora, aqua, bamboo, midnight storm, and a blank." Next, the user heard: "The cups are picked up with a smooth grabbing motion and should be brought up to the box with a steady motion. Hold it there for ten seconds till you identify the scent. Make sure to place the cup back in its designated place after use. After setting down the cup, the sixth pump will kick on, wait at least ten seconds to clear the line and your nose". When the user finished identifying the scents they clicked the next button.

Fig. 14 Virtual Reality Scenario Case 2

In the third case, shown in Fig. 15, the user finished with the tutorial identifying the five smells. The user read and heard: "If you're now familiar with the smells, go ahead and click to the test. If you need more time keep going with the tutorials."

In case 4, shown in Fig. 16, the user chose the "Test" evaluation, in the screen the user read and heard: "Before you are three different cups, two are the same, and one is different. They all have random numbers on them, but your job is to discern which cup smells different. Once you're done smelling each cup, click the button that corresponds with the different smell. If you need to smell one again then do so before you make

a choice". Next, the user heard: "Utilizing a smooth grabbing motion pick up the cup and bring it to the box, holding it there for ten seconds till you can discern a scent. Make sure to place the cup back in its designated place after use. After setting down the cup, the sixth pump will kick on, wait at least ten seconds to clear the line and your nose."

Fig. 15 Virtual Reality Scenario Case 3

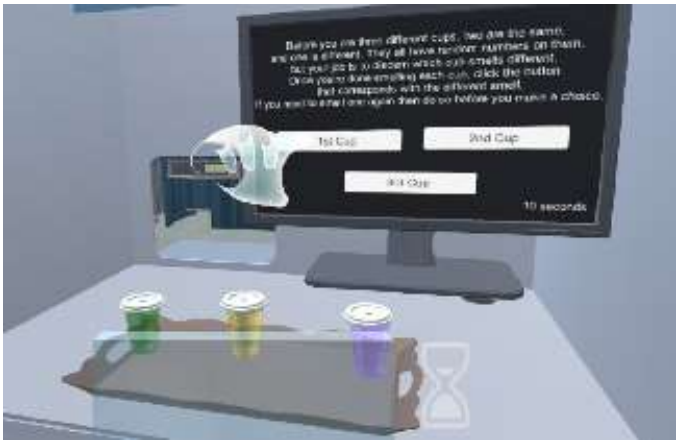

Fig. 16. Virtual Reality Scenario Case 4

Fig. 17 Virtual Reality Scenario Case 5

In the last case, shown in Fig. 17, the user finished the test evaluation and heard: "Here's your results. If you didn't get a perfect score, you will need to wait in order to retake the test. This is so your nose can reset. If this is your second take, you need to go back to the tutorial and refamiliarize yourself with the smells."

Fig. 18. User Immersed in the Training Environment Grabbing the Cup.

In the Fig. 18 it shows the user grabbing a cup and bringing up to the box with a steady motion, holding it there for ten seconds till the user identified the scent.

V. CONCLUSIONS

The results of the present study suggests that the integration of the virtual environment, the training, and the Scent Generator creates an immersive environment where the user can have a multisensory experience during the sensory training.

The present study also suggests that the Scent Generator can release five unique scents with its pumps, and with the sixth pump sucking it is able to cleanse the system. The design can be added to multiple virtual reality headsets. Due to the nature of the design one can send several smells to test in the virtual scenario.

For future work it's suggested to implement the Virtual Reality Scenario to train a sensory panel based on the design created on the present study. This would be used to provide a larger pool of candidates to test their products. It can be also used in other applications in which Virtual Reality needs a multisensory experience such as videogames or trainings in fields like medical or maintenance.

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