Towards Usable Olfactory Human-Computer Interfaces for Education

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Abstract

Olfactory displays (digital systems that generate and diffuse odors to a human user with a purpose and meaning) have been proposed and researched to support learning and training in a number of educational settings. According to recent research, this emerging type of human-computer interfaces has great potential for stimulating information recall, helping immerse learners into educational simulations, and supporting other human senses for learning. However, little is known on the usability aspects (effectiveness, efficacy, and satisfaction of use) of olfactory displays for learning. To be usable, olfactory displays need to be carefully designed as well as properly applied to educational settings. This paper discusses a proposal for future research on usable educational olfactory displays. Issues such as type of odors, odor diffusing and removal technologies, educational gaming software to be used with olfactory displays, and educational aspects will also be discussed.

1. Introduction

Olfactory displays (A digital system that generates and diffuses one or more odors to a human user with a purpose and meaning) have been proposed and used to support learning and training, stimulating information recall and helping immerse learners into 3D educational environments, as well as supporting other senses. Smell can convey meaningful and useful information at the computer/digital product interface. Other applications of olfactory display include smell as warning signals, and "mood enhancer" using aromatherapy techniques, since smell stimulates emotional responses. In addition, olfaction is a powerful recall stimulant [1]. Odors have a number of technical properties that can be successfully exploited in human-computer interaction (HCI), such as directional properties, intensity, the chemical nature of the odor, and hierarchical properties, among others [2].

In this paper we refer to the interface as the part of a computer or digital product where the user and the digital product meet and interact; it is the place where human-product or human-computer interaction takes place using one or more sensory channels [3]. Thus, an olfactory interface provides users with smells that convey meaningful information. This paper will focus on the generation and transmission of scents at the computer interface, applied to education. It will not touch upon "artificial noses" that detect particular molecules of odors, which are beyond the scope of our research.

Despite the advantages of olfactory displays, the sense of smell has been little researched in HCI, including its educational applications. One reason is because olfactory interfaces have challenges regarding smell generation, diffusion, and removal. Another reason is that the number of design and usability testing methods on smell interfaces is still very limited. Usability refers to effectiveness, efficacy, and satisfaction of use of a particular computer interface used in a specific context of use [3], in this case, an educational setting such as a classroom.

Artificially-created smells can be stored, generated and diffused at an interface using mechanical, chemical, or electro-chemical methods, or by using a combination of them. Kaye [4] describes the main technologies used for storing and generating odors in HCI. One method is to keep a scent compressed in a bottle and spray it over the air by means of a computer-controlled solenoid or motor. Another method of smell dispersion is using inkjet technology, which diffuses very small drops of a scent to the air or on a particular surface (e.g. paper). Heating a scented liquid, oil or wax can evaporate a scent and release its smell. Some scented waxes evaporate by themselves releasing an odor. In addition, the use of scratch-and-sniff stickers and other materials have been used to release a smell.

2. Cognitive and Educational Aspects of Olfactory Displays

The sense of smell has been overlooked in educational settings, despite odors can effectively help memorize pieces of information, evoke memories and trigger emotions in students [5], among other important applications. The use of odors by students in class may lead to active learning, since students can interact with reactive olfactory interfaces and multimodal interfaces with odors, even by manipulating and generating odors by themselves, supporting educational theories such as the Cognitive Theory of Multimedia Learning [6], and learning philosophies such as Constructivism.

It has been repeatedly found in the literature that using audio-visual information in multimedia is an effective way to support intellectual disabilities. In addition, there is a growing body of research about haptic (tactile) interfaces, which can make use of force and touch feedback for effectively assist people with cognitive disabilities. However, the sense of smell in educational human-computer interfaces for disabled users has not been studied sufficiently, although studies have shown that olfactory stimuli support sensory substitution, memorization, recall and the organization of information. Computer-generated stimuli may represent an auxiliary sensory channel that can be applied in assistive technologies to form part of an integral multimodal environment applied to education [6].

Holloway [7] described an experiment on olfaction and cognition conducted by Rachel Herz of the Monell Chemical Senses Center in Philadelphia, where a group of anxious students who were about to take an exam was given a list of words to remember. At the same time, the students were exposed to a particular smell (Holloway did not mention which smell it was). Another group of anxious students was given the same list of words, but this time their classroom was odorless. A week after the experiment was done, Herz re-exposed the smell to the two groups of students, and found that the group who were exposed to the smell for the second time had 50 percent better recall on the list of words than the control subjects did.

3. Past Research on Olfactory Displays for Learning

Olfactory information displayed in a computer interface (including virtual reality environments) can be a powerful support for learning, since it could be useful for reducing stress in learners, as well as "enhance memory performance through better problem solving, reduce response times, produce fewer errors, increase recall, recognition, and retention, and enhance productivity, alertness, and physical performance" [8].

Tijou et al. [9] described technical aspects on the implementation of a desktop (using a computer monitor) and fully-immersive (using a head mounted display) virtual reality (VR) system to be used to investigate the effect of olfaction on learning, retention, and recall of 3D structures of organic molecules. With this system, students could watch 3D graphical molecular models either in the monitor or the head mounted display configuration, and interact with the molecular models using a special mouse or with their tracked head movements. What is particularly intriguing in this VR system is that some molecular models were associated to particular odors, according to molecules' names, to be smelled by the students. For example, the molecule vanillin was associated with vanilla odor. Odors were automatically generated (according to the molecule being watched) trough two commercially-available smell spreaders, both working with fans to send the odors to the student. However, Tijou et al. Did not mention in their paper any test done with students. We consider that the association between learning materials' names and odors (as Tijou et al. did in their configuration) can be potentially used in many other learning domains.

Richard et al. [10] described the ''Nice-smelling Interactive Multimedia Alphabet'' project, where a multimodal educational application was developed that included visual, auditory and olfactory information. The main objective of this multimodal application was to support learning of of letters of the alphabet.

Kwok et al. [11] carried out a research project called SAMAL (Smart AMbience for Affective Learning), where developed and tested a multimodal ambient room with visual, auditory and olfactory stimuli. One of the objectives of SAMAL was to integrate cognitive and affective issues with the purpose of enhancing learning, and studying emotional and affective experience of students while receiving multimodal stimuli, and thus find out its learning effectiveness. The ambient room included 3D stereo projection, 3D interaction using a Wii-mote, high-fidelity audio, and olfactory display in the form of spray dispensers, among other features. SAMAL provided students with a number of different ambient "scenarios" to evoke different cognitive and affective states of mind and feelings. For example, a scenario called "Blue Hat Smart Ambient" provided students with a 3D projection of a quiet road displayed along with a sound of heavy rain, and students perceived in the ambient a smell of violets. According to Kwok et al., all these stimuli were designed with the objective of promoting "feeling of calm and wakening needed for better control and direction" in students while solving a problem. In another scenario, a smell of green apples were dispersed to "stimulate a fresh, liberated and free thinking feelings needed for triggering new or wild ideas." Preliminary statistical findings of post-tests showed that the SAMAL multimodal system as a whole did influence affective experiences of students

and it improved their learning effectiveness. However, Kwok et al. did not describe in their paper the particular effects of smell on students' cognitive processes and affective issues, nor the odor generation mechanism.

Garcia-Ruiz et al. [12] described an usability evaluation that tested the integration of an odor in an educational 3D virtual environment (a virtual town) developed for second language learning. Twelve computer science graduate students tested the multimodal virtual environment where their main task was to follow oral instructions in English (their non-native language) for going from point A to B in the virtual town, using the mouse. At the time of carrying out the task, the participants smelled fresh leaves of mint (Mentha Spicata). Each student had to take three mint leaves, rub them with their fingers to release their odor, and smell them while navigating through the virtual environment. A System Usability Scale (SUS) questionnaire was administered as post-test to each participant. Preliminary results shown overall good usability of the multimodal virtual environment + the smell of mint leaves. Garcia Ruiz et al.'s main finding was that mint odor helped students minimize their anxiety when listened to the oral instructions and performed the virtual town walk-trough.

4. Our Proposal for Future research on Educational Olfactory Displays

Having discussed previous research on olfactory interfaces for learning, we will pursue the answer of the following research questions, with regards to the usability of educational olfactory displays:

- What type of odor generation technology is most suitable for educational settings, such as a computer room or a classroom?
- How odor removal will be dealt in educational settings?
- Are current olfactory technologies safe for students and teachers?
- Will current olfactory technologies be difficult to install and maintain in educational settings?
- Will current olfactory display technologies effectively support other didactic media used in class, such as visual aids?
- What type of educational materials are suitable for learning with the support of olfactory displays?
- What educational gains will be obtained with regards to using olfactory displays in educational settings?
- Since gaming technology (hardware and software) has been used successfully in educational settings [3], what type of gaming technology can be used in conjunction with olfactory displays for effectively deliver educational contents?

To test our ideas and answer our research questions on educational olfactory displays, we will develop an interactive educational 3D simulator for the sciences (see Figure 1), which will focus on supporting learning molecular biology. We chose this area of knowledge for our research because there is previous research on olfactory display and molecular biology (see the review of the work of [9] above), and we believe there is potential for supporting learning about molecular structures and their electro-chemical properties using all the learners' senses (including the sense of smell) in an interactive simulator. This multisensory type of learning is based on the Cognitive Theory of Multimedia Learning [6].

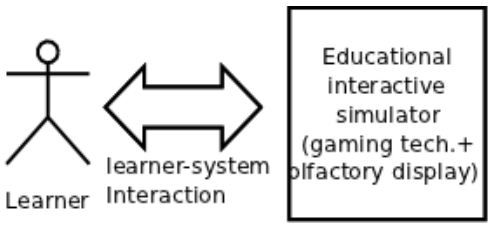

Figure 1. Our proposed simulator with olfactory display.

We will base the design of this simulator on the user-centered design (UCD) paradigm [3]. In this paradigm, students (users) will participate actively in all phases of the design and development of the simulator, giving constructive ideas, expressing his/her needs and expectations, and giving feedback, among other design issues. These students' activities will take part in usability evaluations that will be conducted iteratively during all the life cycle of the simulator development.

5. Acknowledgements

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6. Conclusion

This paper described a proposal for future research on olfactory displays applied to education. Our research will focus on the usability and user-centered design (UCD) of olfactory displays and its importance for learning. The research will also touch upon key technological issues such as the type of odors, odor diffusing and removal technologies, and educational gaming software to be used with the olfactory display.

7. References

[1] S. Chu, and J.J. Downes, "Odor-evoked autobiographical memories: Psychological investigations of Proustian phenomena", *Chemical Sensors*, 25, 2000, pp. 111–116.

[2] Y. Yanagida, "Olfactory interfaces", in P. Kortum, *HCI Beyond the GUI: The Human Factors of Non-traditional Interfaces*. Morgan Kaufman, Waltham, MA, 2008.

[3] Rogers, Y., H. Sharp, J. Preece, J. (2011). *Interaction design – beyond human-computer interaction*. 3rd edition, John Wiley & Sons, Chichester, UK, 2011.

[4] J. Kaye, "Making scents: Aromatic output for HCI", *Interactions,* ACM, New York, NY, 11(1), 2004, Pp 48-61.

[5] Baines, L., *A teacher's guide to multisensory learning*, Association for Supervision of and Curriculum Development (ASCD), Alexandria, VA, 2008.

[6] R.E. Mayer and R. Moreno, R. "A cognitive theory of multimedia learning: Implications for design principles", *Paper presented at the annual meeting of the ACM SIGCHI Conference on Human Factors in Computing Systems*, ACM, Los Angeles, CA, 1998.

[7] M. Holloway, "Seeking "smart drugs"". Scientific American, 9(4), 1998, Pp 39-51.

[8] D.A. Washburn, et al., Olfactory use in virtual environment training. *Modeling & Simulation*, 2(3), 2003, pp. 19–25.

[9] A. Tijou, E. Richard, P. Richard, "Using olfactive virtual environments for learning organic molecules", In Technologies for E-learning and Digital Entertainment, LNCS, Springer, New York, NY, 3942, 2006, pp. 1223-1233.

[10] E. Richard, A. Tijou, P. Richard, J.L. Ferrier, Multi-modal virtual environments for education with haptic and olfactory feedback. *Virtual Reality*, 2006, 10:207–225.

[11] R. Kwok, S. Han Cheng, H.H.S. Ip, J.S.L. Kong, "Design of Affectively Evocative Smart Ambient Media for Learning", Proc. of ACM Multimedia 2009 - Workshop on Ambient Media Computing Part 2: Media Data Integration, pp. 65-75, Beijing, China, 23 October, 2009.

[12] M.A. Garcia-Ruiz, A. Edwards, R. Aquino-Santos, O. Alvarez-Cardenas, G.M. Mayoral Baldivia, "Integrating the Sense of Smell in Virtual Reality for Second Language Learning", in Proceedings of Elearn, Association for the Advancement of Computing in Education (AACE), Las Vegas, NV, 2008.