Colorama: Extra Color Sensation for the Color-Deficient with Gene Therapy and Modal Augmentation

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ABSTRACT

Color-deficient people may be confronted with disadvantages and discomfort when navigating through a society that relies heavily on color as medium of communication in their daily lives. Daltonization as automated methods to improve color images for color-deficient people has traditionally been proposed by the field of image processing. Also, Sensory Substitution Devices from vision-to-touch or vision-to-hearing have been developed for the blind, and could be adapted to the needs of the color-deficient as well. And last but not least, a gene therapy for creating trichromacy in dichromatic monkeys has been proposed that might be applicable for humans as well in the future. All three approaches can be used to facilitate the life of color-deficient people with different up- and downsides to each method. Firstly, gene therapy holds the promise of a complete cure and regain of the lost color perception, while being highly intrusive and holding still unknown costs, risks and long-term effects on the patients' health. Secondly, SSDs provide an approximate substitution of the lost color sense, at the same time as it is somewhat intrusive and cannot copy all aspects related to the attributes of colors to a full degree. Thirdly, daltonization is probably most effective and can even help other groups of people that have problems distinguishing colors like the elderly, but it cannot fully emulate lost color perception. I argue that, while all three methods can promise interesting results, daltonization should be the method in focus of public attention when evaluating all alternatives in the light of usability and accessibility.

1. INTRODUCTION

Color deficiency exists in about 8% of the male population. Color-deficient people have problems distinguishing certain colors, or do not perceive certain colors at all. Most color-deficient people have problems with colors along the red–green axis. The problems of color-deficient people are closely related to reduced usability and accessibility in daily life situations. Discomfort and problems for color-deficient people in daily life are closely connected to social settings where our society heavily relies on color-coding as can be seen on how color is used in geographic maps, advertising, communication etc. We might use so-called daltonization methods, Sensory Substitution Devices (SSDs) – most commonly realized as vision-to-touch or vision-to-hearing – or even gene therapy. To evaluate each method, it makes sense to use categories such as efficiency, costs, feasibility etc. with special focus on the improvement in the light of accessibility and usability for a lesser or greater extend of people. In this paper, I am going to present the different methods, discuss their advantages and disadvantages in order to answer the question, how each of the presented approaches might help to increase accessibility and improve usability of electronic media for color-deficient people.

2. BACKGROUND

Daltonization methods are automated methods from the field of image processing to increase image quality for color-deficient people, some of which are mentioned in a previous paper (Simon-Liedtke, Farup and Laeng 2015). Daltonization methods help to regain lost information and to facilitate differentiation of colors that are otherwise hard to distinguish for color-deficient people by increasing global and/or local color contrast. Daltonization methods can be implemented on practically any computing device and various applications like for example on computers, smart phones, printers etc., for web browsers, camera interfaces, etc., as color profiles, filters, lookup-tables etc.

Sensory Substitution Systems (SSDs) have been developed mainly for the blind to translate visual information into other senses, like for example into touch and/or hearing by "systematically converting properties of vision […] into auditory properties […] or tactile properties […] by means of a man-made device" (Ward and Wright 2014). Ward and Wright (ibid.) mention several implementations related to the two main categories of Haptic SSDs, i.e. SSDs that translate to the sense of touch, and Auditory SSDs, i.e. SSDs that are translate to the sense of hearing. Haptic SSDs are for example the TVSS and the TDU that project tactile information to the back or the tongue of the user respectively (ibid.). In terms of Auditory SSDs, devices like "seeColOr" that encodes color as orchestral instruments, "The Vibe" or "The vOICe" that convert a two-dimensional gray-scale image into a two-dimensional sound image have been mentioned by Ward and Wright (ibid.). Also, the "eyeborg" project by Harbisson and Montandon (2013) deserves to be mentioned, in which a chip that is permanently attached to the back of the head of achromats maps light frequencies to sound frequencies, making color "hearable"

Mancuso et al. (2009) proposed a somatic gene therapy to create trichromacy in dichromatic squirrel monkeys. The treatment consists of a viral injection caring an L-opsin gene into the retina of male squirrel monkeys: A specie, of which females are usually trichromats whereas and of which males are dichromats. After the treatment, male squirrel monkeys displayed a clear trichromatic behavior. To-date, however, there are no published studies about the applicability for humans and/or long-term effects on the health of the squirrel monkeys.

Universal Design is defined by The Center for Universal Design (CUD) (2008) through a quote of Ron Mace as "the design of products and environments to be usable by all people, to the greatest extend possible, without the need for adaptation or specialized design". In universal design, we take into consideration the fact that people or groups of people have different needs and possibilities, which we do have to take into account when designing an (interactive) media outlet. CUD (1998) lists therefore seven principles facilitating the implementation of a successful universal design, including equitable use, flexibility, simplicity, perceptibility, error tolerance, low physical effort, and size and space. An important aspect of universal design is the question of usability, i.e. "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO 1998). A usability evaluation should measure to which extent a color-deficient user is able to extract-correct visual information from a photography or an information graphic like maps, public transportation schedule etc. Next to the principles of universal design and usability, I include the following aspects of the discussed methods: Firstly, if there is any notable improvement for the color-deficient users, secondly, the aspect of practicality and feasibility, and, thirdly, the aspect of intuition and training.

3. DISCUSSION

Daltonization methods do not help color-deficient people to actually perceive more colors, but they help to change colors in a way that colors that are otherwise easily confused become more distinct from each other. These methods reach their limit in cases where a lot of colors are present in an image and the possibilities of rearranging color contrasts get exhausted. By contrast, most daltonization methods are efficient in terms of costs and computation. They are also easily implementable on most electronic output devices like computers, smart phones etc. for both screens and prints – after prior pre-processing. They can be realized as filters, apps, lookup-tables etc. making it easy to use for every color-deficient person that owns a smart phone, tablet or computer. Moreover, daltonization follows the usability guidelines of equitable use, flexibility, perceptibility, low physical effort, and size and space. I believe that the easy availability of daltonization methods, especially in combination with color deficiency simulation methods as listed in a previous article (Simon-Liedtke, Farup and Laeng 2015) also helps to increase awareness for color deficiency in normal-sighted people, since normal-sighted people as well can try out daltonization without huge costs or effort.

On the one hand, SSDs require a certain adaptation period before enabling simple and intuitive use, even though most participants reported to have adapted very well after the initial training phase (Ward and Wright 2014). Some implementations do not provide lesser physical effort with respect to the CUD guidelines, especially in the case that tactile information is obtained through fingers. However, other devices have been proposed that are attached to the body directly without further interaction (ibid.). Also, the physical nature of visual, haptic and acoustic stimuli may lead to obstacles. Consider for example the range of the senses: Things can be seen from very far away, whereas sound has undeniable range limitations, and touch can basically only be perceived from very nearby. This would make it difficult to translate certain visual information into other senses. Furthermore, SSDs might interfere with other stimuli. If sound is for example being used to transport color, there will be problems in conversations with others. Last but not least, SSDs are somewhat intrusive because it means that the color-deficient person has to carry around additional devices, like for example the "eyeborg" prosthetic, that might even be somewhat expensive. On the other hand, SSDs can make colors truly sensible: Harbisson, for example, reported that he actually started to hear colors (Harbisson and Montandon 2013). Ward and Wright (2014) point out that SSDs might lead to artificially acquired synesthesia, i.e. that participants start to both hear and see colors, respectively both feel and see. The argument of device costs can be limited to the degree that most modern smart phones are already capable of giving haptic or auditory feedback, a fact that might reduce costs and intrusiveness of SSDs. And last but not least, SSDs can be combined with virtually any form of sensor that measures any kind of electromagnetic radiation or fields, thus it might enable people to perceive UV- and/or NIR-radiation, electronic and/or magnetic fields etc.

Admittedly, gene therapy is a somewhat young field of research to-date, such that the full extend of the treatment, long-term risks and harms, costs etc. are not fully comprehensible. There are certain shortcomings in the documentation of aspects related to safety in the gene therapy study by Mancuso *et al.* (2009). And since no adaptation has been made for humans, there is no prediction about costs and harms for humans; let alone if the procedure is even applicable for humans. Moreover, the procedure is highly intrusive since it alters the genetic code of the participant. On the other hand, though, it is the solution that truly "cures" color deficiency leading to the only real sensation of the color dimensionality that is lost for color-deficient people. Moreover, it could be used to create tetrachromacy, i.e. the ability to perceive more colors than normal-sighted people can (Jordan *et al.* 2010)

4. CONCLUSION

Daltonization provides effective and easily implementable help of improving media outlets but it cannot create additional visual perception. SSDs show deficits concerning simplicity, physical effort, nature and range of the stimuli, integrability, compatibility and costs but provide huge advantages of SSDs related to equitable use, flexibility, perceptible information, error tolerance, size and space, and creation of a truly new sense. Thirdly, gene therapy raises question concerning safety and feasibility at the possibility of truly curing color deficiency. I, as a computer scientist, believe that daltonization to-date surely provides the best solution in daily life in the light of universal design, at the same time as the possibilities of SSDs and gene therapy should be further investigated.

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