Is the Light On or Off? A Simple Auditory-Based Tool to Help Visually-Impaired People Check the Light Device Status

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ABSTRACT

Everyday activities and routines should be easy to perform for everyone, including those who are totally blind. This paper introduces a simple audio-based tool aimed at supporting visually-impaired people in checking whether the light in a room is on or off. In this context, we discuss the main issues and considerations for totally blind users with regard to a specific seemingly simple task, which is light detection. The proposed prototype is based on a simple circuit and a form of auditory feedback which informs the user whether they are switching on or off the light. The evaluation conducted by involving blind and sighted people confirmed the usefulness of the proposed tool.

CCS CONCEPTS

• Human-centered computing~Accessibility design and evaluation methods • Human-centered computing~Accessibility systems and tools • Human-centered computing~Sound-based input / output

KEYWORDS

Smart home, Home Automation, Visually-impaired

1 Introduction

Full autonomy when performing everyday tasks and activities is a challenge for people with disabilities, including the visually-impaired [9]. Innovation and Information and Communication Technology (ICT) are increasingly exploring new opportunities by proposing tools, methodologies and assistive technologies aimed at overcoming the numerous barriers [4], [7], [12]. Web-based applications and mobile apps have been proposed to make carrying out everyday activities easier and more convenient, such as those related to Home Automation [1] [4], [8]. However, in many cases for people who cannot see, interacting with Web and mobile apps can be difficult and /or require good digital skills [3]. The combination of an older generation with vision-impairments may be a reason for poor familiarity with advanced technology services and apps managed in particular via smartphones and tablets [2]. In addition, performing repeatedly and frequently everyday tasks like checking the light state can require a lot of effort due to the numerous gestures or steps even for skilled users who are very familiar with apps and mobile devices. ICT should be used to design system to provide support for very common tasks in a simple and immediate way regardless of the users' disability or technical knowledge.

In this work we propose a tool that does not rely on an app or a Home Automation System. We present a very simple audio-based tool to be integrated into the lighting system or into light bulbs (including smart ones) in order to check the lighting status. The device is aimed at totally blind people not familiar with technology, nevertheless it is useful for those very confident with technology as it allows them to check the status more easily, conveniently and quickly. In short, our goal is to propose a simple electronic tool able to (1) give feedback on the lighting status to a person who is totally blind; (2) offer a low cost solution; (3) be easily used by anyone; and (4) which can be added to smart light bulbs.

This paper is organized as follows: the next section reports the issues encountered by people who are totally blind when they have to check the lighting status; section 3 introduces the methodology used in this study; section 4 describes the potential use scenarios as well as the proposed solutions by introducing the audio-based prototype. Sections 5 presents a preliminary test. The conclusions end the paper.

2 Motivation and issues

People who are totally blind could be interested in several everyday tasks and activities to be performed autonomously at home [9]. Leporini et al. [10] collected expectations and preferences from 42 visually-impaired people. The results highlighted a wide interest in Home Automation, but at the same time also the main difficulties and concerns about being able to use it effectively. 81% of the users interviewed declared a particular interest in being able to use the lighting system easily. More specifically, people who are totally blind wish to control the light status (on/off) autonomously, especially when they live alone or are temporarily alone. To check the lighting status, people can use specific tools or mobile apps based on a phone camera or light sensor (e.g. pointing at the ceiling) which emit a higher or lower sound depending on the light's intensity. Examples are Light Detector [5], Seeing AI [13] and Seeing Assistant [14] apps and light probes and detectors [11]. However, some limitations and concerns have also been expressed (1) Specific assistive portable

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devices (a) are relatively expensive and (b) need to be always to hand. (2) Specific mobile apps require (a) a smartphone always to hand, (b) user interfaces effectively accessible, and (c) a confident use of touch-screen interaction.

Some studies have investigated lighting systems handled by people with disabilities. For instance, in [6] the control of the lighting system is for those who have residual vision. The work [8] proposes a solution based on voice control, but the commands to use are usually aimed at switching on/off the lights, but are not designed to check simply the status, which may be a useful activity for those who cannot see. In addition, solutions like this one require a home automation system as well as always having an internet connection activated. However, for repetitive everyday tasks, solutions based on simple interaction should be encouraged. Our proposed device requires a simple interaction, can be installed in each room and offers a first feedback level with no other device to hand. This can help both skilled and people with no or a limited familiarity with technology and it can work also when an internet connection is not available.

3 Method

Our idea is to propose a stand-alone tool to be used by people who are blind, which is accessible regardless of their abilities and familiarity with computers and touch-screen devices. Our goal is to propose a solution able to: (1) check easily whether the light is turned on/off in a room; (2) avoid the need for the user to carry with them specific ad-hoc tools or mobile devices; (3) avoid the need for any digital skills. To this end, we designed an electronic circuit which can be installed on the home lighting system without requiring additional tools and apps. Furthermore, the proposed solution is aimed at offering a low cost prototype.

4 The prototype

4.1 Motivating use scenarios

Scenario 1. Alan is a totally blind boy. It is Saturday evening and he is alone at home since his family has gone out. His friends are coming, they just rang the doorbell. It is the evening, so the lights in the kitchen and in the living rooms should be on. Has his family left any lights on before they left? Alan should quickly check to see if they are on or off. He could do it using the assistive light detector, but he doesn't know where it is right now. Alan could locate it by exploring the rooms one by one in order to find it, but there is not enough time: he has to open the door. Fortunately, he recently installed the proposed tool: by pressing the switch, a short sound announces that the light is switched on. Alan can thus confidently open the door with the knowledge that the lights are on.

Scenario 2. Chris is a totally blind person. He likes traveling very much and he is on a trip with a group of friends He is in a single room in the hotel. Chris decides to order something to drink from reception. When the member of staff leaves the room, Chris needs to know if the lights have been switched on or off. In addition, he does not like to sleep knowing that the lights may be on, even if he cannot see the light at all. He does not have an assistive light detector with him. Fortunately, the hotel has installed the audio-based tool in the lighting system. By switching on the light Chris can recognize the very short sound signaling that the light has been turned on.

4.2 Description and features

We developed a stand-alone tool which can be installed on the lighting system to quickly and easily check the light status. The tool needs to be installed in each chandelier fitting or in one switch controlling different chandeliers. When the light is switched on in a room, an auditory feedback signal – i.e. a short sound - can be perceived by the user. When turned off, no sound is produced. The sound is about 2 seconds long and is reproduced via a piezoelectric buzzer of 12 V. The main features of the proposed prototype can be summarized as:

1. *Auditory feedback*. A short sound (beep) is emitted when turning the light on.
2. *Natural interaction*. Neither special portable devices (such as assistive technology), nor mobile apps, nor Web applications are required. The user interacts with the tool simply by switching on / off the lights.
3. *Easy installation*. The tool is simply inserted into the light fitting; one device is required for each fitting. A minimum amount of rewiring is required.
4. *Multiple-switching. The user can* control the status even when the set of lights can be turned on/off from different switches.
5. *Replicability.* A low cost solution, which can be developed via a relatively simple electronic circuit and adapted to different types of light fitting.
6. *Limited power consumption*. The device is a very low energy consumption tool with a minimal impact on the environment.
7. *Exploitation*. The tool can be used in combination with other smart features and provide information on the status also when an internet connection is not available.

4.3 The design

In order to develop the prototype, an electronic circuit of 220V AC was designed (see Figure 1) without the use of a transformer. The circuit can be adapted also for a different voltage value (including LEDs) by replacing some electronic components. The absence of the transformer has the advantage of negligible heat generation and allows for the reduced dimensions of the device.

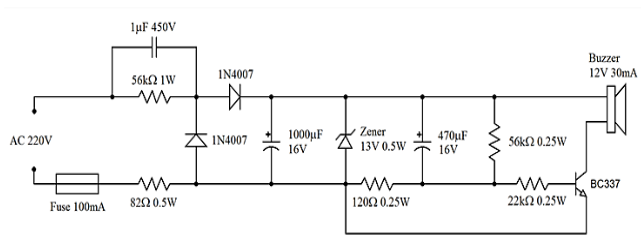

Figure 1: Diagram of the electronic circuit

The supplied voltage was reduced to 12V DC by means of a two-diode rectifier, two capacitors and a Zener diode. A 220 V fuse is inserted for the circuit protection.
The buzzer that emits the sound is fed via a transistor, which in turn receives the pulse from the 470 μF electrolytic capacitor and the 120 Ohm resistor ("RC" circuit). The electrolytic capacitor is quickly discharged through the 56 kOhm resistor when the 220 V AC current is switched off. The electronic circuit with all the components placed onto the circuit board is shown in Figure 2.

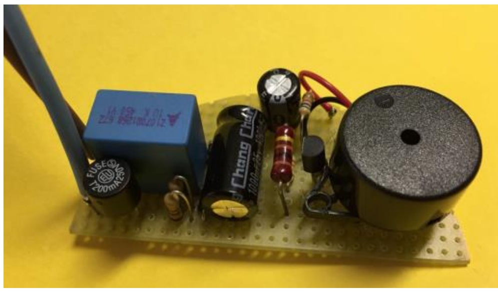

Figure 2: Image of the electronic circuit

A dielectric resin epoxy was employed to embed the electronic circuit in order to protect and insulate the components in such a way that the potential hazard in touching the 220 V parts of the circuit during the installation was removed. Figure 3 is the image showing two prototypes encapsulated with the resin. The total cost of the components needed to build the prototype is in the order of 10 euro.

Figure 3: Prototypes encapsulated in the dielectric resin

The connection of this electronic circuit must be carried out in parallel with the light fitting's power supply.
The shape of the prototype presented here was designed to be housed inside the ceiling support of a chandelier light (see Figure 4).

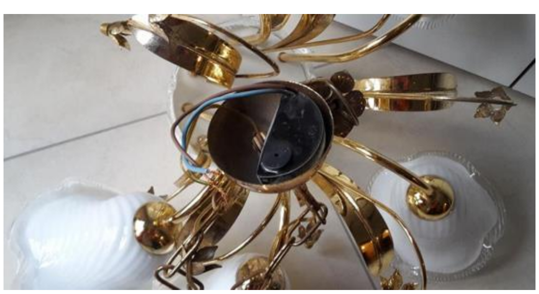

Figure 4: Prototype placed in the ceiling support of the light

In this case a prototype device was provided in a form which is easily positioned within the fitting. Different shapes and sizes can be provided e.g. for installation inside the wall electrical box where the switch is installed or where the electrical cables, which connect to the light, are intercepted, or even inside the switch

5 Evaluation

5.1 Method

The tool was installed at the home of one of the authors who has used it regularly for 4 years without any issues. For the evaluation, seven totally blind people (aged from 26 to 77 years old; 4 male and 3 female) and five sighted users (aged from 35 to 75) were asked to use the audio-based tool. The test was conducted in order to obtain feedback from users who are totally blind as well as from sighted people. The latter were included also to understand if there is an undesired impact because the tool reproduces a sound every time the light is switched on. Three rooms were selected to perform the test: the kitchen, bathroom and living room. The three rooms illustrated three different scenarios. In the first case, the kitchen contained just one switch and no device was installed. The second room, the bathroom, also had just one light switch, however, the device was installed. In the living room, on the contrary, there were three light switches and the device was installed.
All the participants were asked to see if and how they could determine if the light was on or off in the three rooms in the order described. The blind participants were asked to comment on the (1) usefulness of the tool, and (2) appropriateness of the auditory feedback. Sighted users were specifically asked to indicate if the sound used to give auditory feedback would bother them. Both groups were asked their preference from the four installation types: (a) light bulb, (b) chandelier, (c) switch, and (d) any of these modalities. The opinions were rated from 1 (the most negative value) to 5 (the most positive value).

5.2 Results

In the kitchen, three blind people asserted it was not possible to obtain information about the light status, without using a specific device for light detection. The other blind users suggested deducing the status from the switch position. However, this would require having to learn and remember the position of the switches and on/off positions for all the rooms, thus requiring a considerable cognitive effort. In the living room instead, all the blind participants stated that it would be very difficult to deduce the light status from learning the position of the switch, given there were multiple switches. However, with the sound emitted by the installed device when any of the switches were turned on or off, all the users had the opportunity to perceive the light status. Similarly, in the bathroom all the users were able to quickly check the light status just by pressing the single switch and hearing the sound. The device was particularly liked by the participants as they appreciated the fact of not having to carry any specific tools in their hand in order to carry out the task. The users provided positive comments. Five users particularly highlighted the usefulness of this device, especially when the switches do not offer an on/off position from which the light status can be figured out, and particularly when the lights can be switched on from multiple positions. One user expressed an interest in the opportunity to have such a support already integrated into common light bulbs, or into the housings where light bulbs are installed. Four people suggested using the same approach for LED available in appliances in order to obtain information about the status. One participant reported some difficulties in hearing the tone used for the auditory feedback clearly. However, he was 77 years old and said he does usually have some difficulty in perceiving high frequencies. Three out of seven users expressed a preference for having two different sounds to indicate the status: two beeps when the light is on, and a single sound a little longer to indicate the light is off. They had noticed this kind of auditory feedback in other appliances, such as an air-conditioner. Using this system would allow the user to be immediately sure about the light status after pressing the switch. The minimal effort involved was favorably compared to the mobile apps previously installed by four participants, who in fact rarely use them.

With regard to the usefulness of the prototype, the users gave very positive feedback: 70% expressed '5/5' and 30% '4/5' (with an average a=4.71 and a standard deviation sd=0.49). Concerning the appropriateness of the sound, the response was overall positive (a=3.43; sd=0.98) with a preference for '3/5' expressed by 43% and '4/5' by 30%. Nevertheless, the aural feedback needs to be improved, as suggested by the users. In relation to the installation type, the majority of users would prefer to have the tool integrated with the light bulb and the other 29% directly in the switch. In particular, the two users who preferred the configuration with the tool in the switch explained this preference as the opportunity to have the aural sound closer to the user.

The five sighted people were just asked to turn on/off the lights in the three rooms. They had no previous knowledge of the device. In the kitchen none of the users noticed anything unusual when carrying out the task. In the bathroom instead, four people were immediately surprised to hear a sound when using the switch. One user did not initially notice the aural feedback and had to switch the light on/off twice before associating the sound with turning on the light. At first all the sighted users found that the sound associated to the light status was slightly strange, but after turning the light in the living room on/off a number of times, they said they did not consider it significant in terms of having a negative impact on the procedure. Regarding this aspect, all the users indicated either '4/5' or '5/5' on the scale where '1' was "very bothered" and '5' "not at all bothered" by the sound (a=4.4; sd=0.55). Concerning the installation type, 60% of users would prefer an integration of the tool with the light bulb, 20% in the chandelier and the other 20% did not mind which. No preference was expressed for the installation in the switch. Nearly 60% of the users would prefer the tool in the light bulbs.

7 Conclusions

Everyday activities and tasks, especially those which are repetitive, should be able to be carried out with a minimal amount of effort. In this work we consider a specific task from the point of view of people who are totally blind: how to check the lighting status. A potential stand-alone aural tool to alert the user when switching on a light in a room is presented to support the discussion in the field. Our prototype has been conceived as a low cost solution easily replicable for any light at home, in hospitals, hotels, or in buildings with no wireless connection able to support a Home Automation device. The concept of giving auditory feedback on status can be extended to appliances which have a series of LEDs e.g. a coffee machine, through the use of sounds at different pitches. The evaluation conducted by involving 7 blind and 5 sighted people confirmed the utility of our tool: all the blind users indicated a positive value for the usefulness of the tool and the sighted people expressed positive feedback with regard to the potential negative impact of sound associated to the light being switched off or on.

The contribution of this work is to introduce a very simple tool based just on an electronic circuit with the aim to propose an idea for a basic accessibility level in many products, such as light bulbs or LED, which draws attention to the potential for commercial exploitation, via inbuilt or add-on devices.

Further work would include a study comparing the device with other support options available, as well as further exploration into the feasibility of integrating the use to include a wider range of LEDs.

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