Hack of an Office Gadget for Sonification of Air Pollution

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ABSTRACT

The air quality inside an office can constitute an issue: a too high concentration of carbon dioxyde in a closed environment can harm the wellness of an office worker. This study's aim is finding a way to prevent this unpleasant situation, using, as a mean to make a user realise such air pollution condition, the sonification. For better suit this idea in an office-y context, it was chosen to hack an object which could be part of an office. For this study's sake, the chosen office gadget is a hourglass, firstly since it is an object whose user interaction constitutes a compromise between the typical one of the constantly used office device and the one which is had with a mere office ornament, and, secondly, due to practical issues in terms of creation of the object itself and of implementing the sonifying elements from the scratch.

KEYWORDS

sonification, air pollution, office environment, interaction

INTRODUCTION AND BACKGROUND

The air quality is one of the most relevant features in every human activity; oxygen is what keeps humans alive, and a lack of it, contemporarily with a too high concentration of other harming gases, can cause severe damages. The scope of this project is to provide an innovative way of preventing such damages, with the help of sound, and inserting this help in a typical indoor environment, where workers are supposed to spend much time.

Air pollution and carbon dioxyde role

Air pollution has been demonstrated to be a problem both on a worldwide scale, being it a cause of the global warming, and on an individual one, being able to harm one's physical health. Specifically speaking, one of the most harmful pollutor is carbon dioxyde, or CO_2, and its contribution to the so called "greenhouse effect" has famously been recognized as the largest among all polluting gases' [4]. In addition, carbon dioxyde has been demonstrated to have effects on human nutrition, since, corresponding to a higher concentration of CO_2 in the atmosphere, it has detected a diminuition of zinc, iron and proteins' in cereals; this elements' lack in human body has been noticed to increase more and more, as described by Myers et al.[10], hence outlining a correlation between these two phenomena.

In terms of anatomical harm to a human body, CO_2 has been recognized to cause several severe pathologies, which range from hypercapnia to hypoxia, which collaterally causes damages to other human body parts, no longer furnished with oxygen; these and other consequences were collected by Permentier et al. [11], focusing especially on what happened in the emergency departments of hospitals, which, due to the nature of the used materials, were the most exposed to such pollution and intoxication. In general, carbon dioxyde in high concentrations in the air environment has both long- and short-term harming effects on the human organism. In order to prevent such effects, it is necessary to keep the concentration of CO_2 below a safety threshold; Calvin et al. [5], in particular fixed such treshold, expressed in CO_2 equivalent, at around 450 ppm.

For the sake of this project, it was decided to consider a more common environment than an emergency department, where the CO_2 concentration can have consequences similar to the so called "Sick Building Sindrome" [2]; so, considering, for instance, a general purpose office in a firm, a university or another public place: the concentration of CO_2 in such environment is more subtle to be kept track of, since, differently from a chemical district or an emergency division, there are no reagents producing high amounts of CO_2 in a short time, whereas only the normal human breathe is a CO_2 source; if the place has no air exchange with the outside environment, the carbon dioxyde concentration can easily rise above the safety treshold, without being detected, and it has been shown how a bad indoor air quality can affect productivity in a workplace [12]. In a certain way, it is a subtler pollution than the example proposed by Permentier et al., consisting in dry ice sublimating and releasing CO_2 in high quantities; yet, it has to be prevented as well.

Sonification

In the beginning, it is reasonable to assume, it was silence. Then, when everything started, vibrations, hence sound came along. Sound, in all its declinations, has always been one of *the* information conveying means; it makes languages, music, signals, everything possible to be interpreted and addressed a meaning or a significance.

The sonification process' aim is to convey information without using direct verbal communication, or too explicit sound references [8]. This means that no explicit sound should be used, rather something more subtle: for instance, using an alarm sound for giving a sensation of danger is indeed in the sonification field, but it is too "immediate", in a certain way. In the case of an alarm-y information to be conveyed, a subtler variation in the soundscape (e.g. adding a noise component, or altering the harmonics or the pitch of it) is more suitable for the sonification's sake.

Barrass and Kramer [3] gave a valuable overview on the possibilities that sonification allows, and on which tasks are performable with its techniques: for instance, a sonification-based setup allowed a group of pilots to learn how to conduct a plane quicker than a video based interface. Related to the aim of this project, a previous research [9] showed how sonification can suitably be applied to gas patterns; such research showed extremely defined and precise relations within nitrogen n-oxydes and ozone and sound patterns, making a whole dataset to be explorable in a sonified way. This project's ambition is still on a slightly lower scale, being at its first stage; though, some valuable hints about sonification of gases were taken.

Pollution and sonification

As stated above, the aim of this project is to find a way for combining air pollution and sonification, for inserting this setup in an opportunely hacked office gadget. The best way for pursuing such scope is then to develop a slightly interactive device, which shall provide most of the feedback in terms of sound.

METHOD

Given the background premises, many possible office gadget were taken in considerations: ranging from the most common and used, such as laptops, printers and coffee mugs, to the most decorative and less used, such as ornaments, paperweights and so on. Eventually, a hourglass was chosen; it is an object endowed with an intrinsecal utility (that is, measuring time), and it is an item with which a user can interact not too deeply, which would happen, for instance, with a laptop, more and more constantly used in office work; on the other hand, it needs some kind of interaction, even just for being turned upside-down every time the bottom side fills up. Besides, it is easily buildable from the scratch, also using second hand materials, bypassing many availability and hacking problems.

Physical support

On two cardboard basis, thickened with wood squares, two opportunely cut plastic bottles were inserted, and linked with a small paper cylinder, that is, the hole in which the sand flows from one side to the other one. The side sticks are recycled wood chopsticks, and the sand was fetched from an open beach close to Stora Lappkärrsberget, Stockholm, Sweden, and oven-dried.

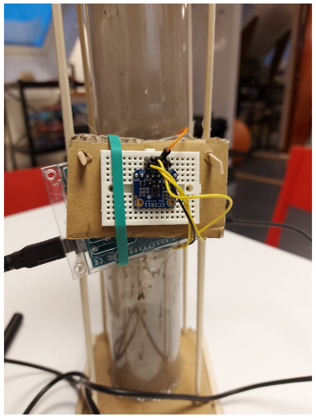

Figure 1: A picture of the CCS811 CO_2 detector, tucked onto a cardboard surface and held together with its Arduino board with a rubberband.

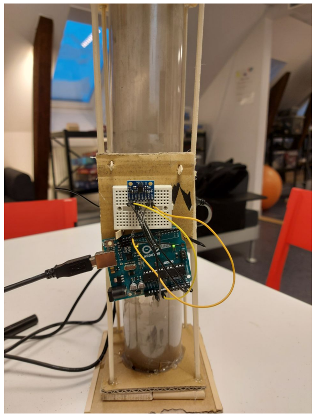

Figure 2: A picture of the MPU6050 GY-251 accelerometer and gyroscope, tucked onto a cardboard surface as well.

Hardware

The hardware used consists of two Arduino UNO boards, two breadboards, jumper wires and USB B cables, plus one laptop on which to run Arduino and PD, and two sensors: the first sensor is a CO_2 concentration detector, the second is an accelerometer/gyroscope. The CO_2 detector is an Adafruit CCS811 sensor, while the accelerometer and gyroscope is an MPU6050 GY-251 sensor. These are connected to the respective Arduino boards via a breadboard each and the suitable number of jumper wires.

Software

Two main coding languages and environment were used: Arduino, for the physical interaction, and Pure Data, for the sound synthesis; the sample of wind synthesis used in the Pure Data patch included in the setup is based on a patch included in "Designing sound" by A. Farnell [7]. The not trivial communication between these two enviroments works through the serial ports used by the Arduino environment for sending the sketches to the boards; the "comport" object in Pure Data intercepts and interpret this data flow, making it usable in a Pd patch. Said "comport" object is not included in the common Pd Vanilla distribution, thus making it necessary to get the Pd Extended distribution; this distribution is available at [1].

Sound design

As specified above, the sound design is an elaboration of a pre-existing wind sound synthesis. It was chosen since a wind background can represent a suitable sonification for an air environment. Two elements of variations were then added: a slider capable of controlling the pitch/speed of the wind, and a noise element, recalling the sand flowing in a sandstorm. The loudness of such noise was linked to the value of the windspeed, hence growing proportionally to it. The concept behind this design is that a "dirtening" element like the noise, in an air-recalling soundscape, is supposed to make the user aware that something is not correct in the air's situation.

In terms of links to the code, the sonified elements are the sand flow in the hourglass and the already quoted air pollution: as far as it concerns the sand flow, the accelerometer is set in order to start a countdown every time the z-axis acceleration changes sign, that is, whenever the hourglass is turned upside-down; this countdown returns an increasing value in the Pd patch, which is thrown in the slider, increasing windspeed; on the air pollution side, the Pd patch is set in order to play the noise element every time the CO_2 concentration goes above the 450 ppm treshold.

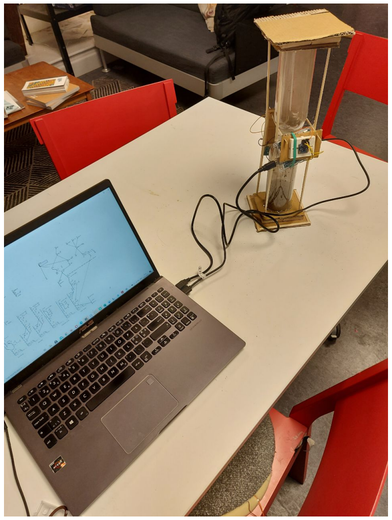

Figure 3: The temporary setup of the device. A cabled connection to the computer is still needed, otherwise the serial connection with Pure Data would no longer work

Final setup

After glueing together the two sides of the hourglass, the electronics were tucked onto two opposite sides with cardboard and glue, and the whole structure was strengthened with wooden chopsticks. At this stage of the device, in order to keep the serial connection between Arduino and Pure Data opened, it is still necessary to keep the Arduino boards cabled to the computer running the Arduino sketches and the Pure Data patches, as seen in Figure 3.

TESTING AND DISCUSSION

Testing method

The testing method combined a first think-aloud experience, followed by a questionnaire. In total, five participants tested the device; out of them, three were told beforehand which was the scope of the device, and everyone was afterwards explained in the details the mechanics and the expected sonification outcomes.

Testing results

The first question in the questionnaire was directed essentially towards the ones who had no previous explanation about the device's function, and regarded the intuitiveness of the sonification choices: for one of the involved participants, it was clearly deductible; another one could just guess the sonification's meaning. In general, the main suggestion is that, once being explained the setup, its characteristics and what are the expected outcomes, then it is clearly understandable.

The second, third and fourth question regarded the sonification itself, asking whether the sound element were linked correctly to the good/bad air quality, if the sand flow and hourglass' filling up sonification sounded fine, and if there were suggestion for improving/modifying them. In terms of the suitability of the sound designs, is general positive, with a specific approval for the wind-blowing background; among the remarks, the need of improving the characterization of each sonification, perhaps diversifying them more among themselves, giving a particular highlight on the pollution sonification; also, the sand flow sonification link to the interaction with the device seemed a bit "unnatural" to one participant, who also suggested to make the pollution detector start with the turning of the hourglass.

On a technical side, the highest pitch of the sand flow sound should not be that high, because it turned out to be fastidious for some participants; also, one participant found the volume distracting, if too high; lastly, the plastic bottles used for building up the hourglass became dirty, not clearly allowing one to see inside of it, which represented a problem, since not seeing the sand flowing did not help in associating it to a sound design. Eventually, the sonifications were considered pretty easy to be understood after the final detailed explanation.

The last three questions were more focused on a usability evaluation, asking whether the device was easy to use and understand, and if it would have been suitable in an office or other work environment; a valuable hint was to extend the hourglass duration, in order not to make it too big of a distraction; this represented a problem for another tester, who claimed that another setup, different from an hourglass, could be better, something with even less possible interaction, for avoiding completely the distraction element. Generally speaking, the device was easy to use and not in need of further features to be added; however, it was not that easy to understand without an explanation, as stated above.

FURTHER DEVELOPMENT

As far as it concerns the hardware part, the first setup draft was supposed to include a Bela board instead of Arduinos. This is indeed a possible further development, or better: the natural prosecution of the project; the Bela technology, developed in London from 2014 [6], is particularly suitable for this scope, being it more intrinsecally sound-oriented than Arduino; it is possible to directly implement a Pure Data patch in its web based coding environment; also, the Bela board has a built-in speaker, which allows to position the sound output directly on the device, instead of using computer speakers for it. Also, a more realistic way to implement the sand flow and the filling up of the lower hourglass' sonification could the usage of load cells instead of an accelerometer, which appears to be more "artificial"; in this sense, two load cells should be placed at the bottom of each of the two ends of the hourglass, transmitting an increasing data according to the increase of sand weight they bear as long as the sand drops on them.

In terms of polluting agent, during the testing one of the users suggested to try the device close to a soldering station, individuating an obvious source of air pollution in there. This device is not completely suitable for that setup, since CO_2 is not the only polluting agent produced in a lead-based soldering operation; it may be interesting to investigate such environment with other sensors, capable of fetching other polluting agents, different from carbon dioxyde.

On a mere stylistic side, for better suiting an office environment, the hourglass should show on the outside the least wiring possible, and be a bit littler in terms of height; the duration can be compensated with widening the basis.

CONCLUSION

This attempt to find a suitable sonification way for air pollution got a partial success. Features as like as the wind blowing background and the sand flowing sonification have got positive feedback; nevertheless, other elements, such as loudness of the audio, potential distraction and the need of a detailed explanation constituted some cons on which it will be important to operate for improving the device more and more.

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REFERENCES

[1] 2013. http://puredata.info/downloads/pd-extended. [accessed December 28, 2020].

[2] Zahra Aghalari, Abdoliman Amouei, Ahmad Zarei, Mojtaba Afsharnia, Zahra Graili, and Mehdi Qasemi. 2019. Relationship between CO2 Concentration and Environmental Parameters with Sick Building Syndrome in School and House Settings in Babol, Iran. *Journal of Mazandaran University of Medical Sciences* 29, 171 (2019), 31–44.

[3] Stephen Barrass and Gregory Kramer. 1999. Using sonification. *Multimedia systems* 7, 1 (1999), 23–31.

[4] B Bolin and B R Doos. [n.d.]. Greenhouse effect. ([n. d.]). https://www.osti.gov/biblio/6761224

[5] Katherine Calvin, James Edmonds, Ben Bond-Lamberty, Leon Clarke, Son H. Kim, Page Kyle, Steven J. Smith, Allison Thomson, and Marshall Wise. 2009. 2.6: Limiting climate change to 450 ppm CO2 equivalent in the 21st century. *Energy Economics* 31 (2009), S107 – S120. https://doi.org/10.1016/j.eneco.2009.06.006 International, U.S. and E.U. Climate Change Control Scenarios: Results from EMF 22.

[6] Augmented Instruments Laboratory c/o Centre for Digital Music at Queen Mary University. 2014. www.bela.io/. [accessed October, 25, 2020].

[7] Andy Farnell. 2010. *Designing sound*. Mit Press.

[8] Gregory Kramer, Bruce Walker, Terri Bonebright, Perry Cook, John H Flowers, Nadine Miner, and John Neuhoff. 2010. Sonification report: Status of the field and research agenda. (2010).

[9] Joshua L Laughner and Elliot Kermit Canfield-Dafilou. 2017. Illustrating Trends in Nitrogen Oxides Across the United States Using Sonification. Georgia Institute of Technology.

[10] Samuel S Myers, Antonella Zanobetti, Itai Kloog, Peter Huybers, Andrew DB Leakey, Arnold J Bloom, Eli Carlisle, Lee H Dietterich, Glenn Fitzgerald, Toshihiro Hasegawa, et al. 2014. Increasing CO 2 threatens human nutrition. *Nature* 510, 7503 (2014), 139–142.

[11] Kris Permentier, Steven Vercammen, Sylvia Soetaert, and Christian Schellemans. 2017. Carbon dioxide poisoning: a literature review of an often forgotten cause of intoxication in the emergency department. *International journal of emergency medicine* 10, 1 (2017), 14.

[12] David P Wyon. 2004. The effects of indoor air quality on performance and productivity. *Indoor air* 14, 1 (2004), 92–101.