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RESEARCH ARTICLE

A Wizard of Oz Study to Explore How the Young Population Perceives Brain-Computer Interfaces

José Rouillard* [*], Marie-Hélène Bekaert, Jean-Marc Vannobel

CRIStAL Laboratory, University of Lille, Villeneuve-d'Ascq 59650, France

ABSTRACT

This paper describes a wizard-of-oz (Woz) study that was performed to gather insights on how 44 teenagers perceive Brain-Computer Interfaces and how they imagine interacting with this technology in the domain of home automation. Ten questions were asked before users tested a fake BCI supposed to allow a mental control on a lamp, a fan and a radio. Three other questions were asked after the Woz experiment to gather users' feelings. Our study showed that young people were influenced in their perception of their own abilities to control connected objects (lamp, fan, radio) with a BCI, thanks to the Wizard of Oz technique. Thirty participants (68.2%) strongly believe they can control an object using their brain waves after the Woz experiment, whereas there were only eight (18.2%) strongly agree with this assertion before the WOz experiment. All participants, except two, changed their minds favorably after the experiment. A science fiction approach to the question of a subject's ability to interact with a BCI, and his or her ability to interact with a computer by means of thought, is a way of influencing the subject's perception of the possibility of implementing such an interface not in a fictional way, but in a very real one. This feeling may be reinforced by the fact that the BCI seems to behave as expected by the subject. However, we are not making any assumptions about how a fake BCI might be used by an uninitiated audience, or how it might be interpreted by them.

Keywords: Brain-Computer Interface; Wizard of Oz; Multimodal Interaction; Internet of Things; MQTT

*CORRESPONDING AUTHOR:
José Rouillard, CRIStAL Laboratory, University of Lille, Villeneuve-d'Ascq 59650, France; Email: jose.rouillard@univ-lille.fr

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1. Introduction

Current research in the field of Information Technology (IT) and computer sciences tends to integrate more and more artificial intelligence into systems designed to meet user needs. We know that artificial intelligence (AI) focuses on developing machines (software and hardware) that can replicate human abilities such as reasoning, learning, and decision-making. The emergence of advanced chatbots capable of generating coherent and well-structured texts is now drawing significant global attention [1]. Indeed, AI has become an integral part of numerous sectors in society, finding applications in fields such as data sensing and interpretation, big data processing, security monitoring, strategic planning, education, healthcare, robotics, autonomous vehicles, and more. Young people and adolescents, constantly connected to the Internet and social networks, are potential users of these technologies. In a few years, they will be potential users of new interfaces that are currently under development, like Brain-computer interfaces (BCIs), for instance.

This term "Brain-Computer Interface" was first used in 1973 by Jacques. J. Vidal [2]. Brain-Computer Interfaces (BCIs) establish direct communication between a human and a computer: from the man to the machine by analyzing the user's brain activity [3] and/or from the machine to the man by stimulating his channels sensory [4]. A year earlier in 1972, Michael Crichton [5] published his novel "The Terminal Man". In this work of science fiction, a neural implant connected to a computer must allow the main character to control his violent behavior. A decade later, in 1984, William Gibson [6] published "Neuromancer", describing a transhumanist future where implants and mechanical prostheses of all kinds augment the bodies of different characters. In the real world, it was not until 1998 that the first totally paralyzed patient received a neural implant allowing him to control a cursor on a computer [7].

From "Star Trek" to "The Peripheral", "Black Mirror", "X-Men" and many others, science fiction works (books, films or series) showing BCIs are now profuse. Called BCI-fi [8] they are widely documented in the Neurafutures project, a large explorative project about the representation of BCIs in science fiction media [9]. However, these works are far from the reality of research laboratories. Non-invasive BCIs based on EEG signals collected from the skull are being tested mainly for the palliation of severe disability but are complex to implement. Invasive BCIs with neural implants tested on humans are relatively recent, very few [10, 11] and raise important ethical questions [12] which are now leading states to legislate on neurotechnology regulation [13].

Between fiction and reality, hopes and fears, we conducted a study to determine the feelings of young adolescents regarding the possibility of controlling everyday objects using their brain.

Section 2 of this paper presents the coupling of Wizard of Oz principles and Internet of everything. Section 3 describes our research methodology (design, participants). Then, the results obtained are presented in section 4 before a conclusion and some perspectives.

2. Coupling Wizard of Oz and Internet of Everything

In this section we present the well-known Wizard-of-Oz methodology brought up to date thanks to numerous advances made possible via new technologies and in particular IoT (Internet of things) and IoE (Internet of Everything).

2.1. The Wizard of Oz Principles

In the field of human-computer interaction and computer ergonomics, the Wizard-of-Oz method (Woz) is used in experiments in which subjects interact with a computerized system that they believe to be autonomous, but which is totally or partially controlled by a human. This method can be used in the incremental design phase or when evaluating user acceptance of supposed capabilities of a computer system not yet available. Indeed, "*With this technique, the designers can develop a limited functionality prototype and enhance its functionality in evaluation by providing the missing functionality through human intervention.*" [14].

This Woz approach is used for example to explore strategies of persuasion via a computer-mediated dialogue without the need to develop a real complete dialogue system [15]. This type of studies reveals important elements about the perception of humans regarding systems that are not yet completely functional, such as when researchers are simulating the ability of an assistance robot to dialogue with humans [16].

Figure 1 presents an example of a Woz experiment conducted in our laboratory. A user comfortably seated in an armchair wears a BCI headset on her head and attempts to control some objects present in the experimental room (lamp, radio, fan). This headset is not connected to the home automation system. A supervisor (the Wizard), behind a one-way glass, interacts with a classic computer (keyboard/mouse) to pilot those objects in place of the user, who believes that she is controlling those objects thanks to her brain activity.

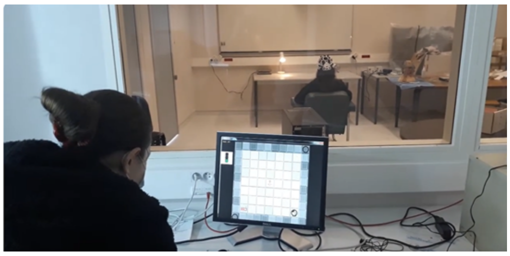

Figure 1. BCI Wizard of Oz Experiment in our laboratory.

Figure 1 shows in the foreground the Wizard of Oz, interacting with a computer (here a Unity 3D interface) to choose a connected object, among lamp, fan, radio, and a command to apply (switch on/off). In the background, the user tries to switch off the lamp thanks to her cerebral activity. The command chosen by the Woz (here "switch off lamp") will be sent from one room to the other and the user will think that she is really controlling the device.

2.2. IoE to Manage WoZ

Human behavior is complex. The present study seeks to understand how adolescents perceive the possibilities of interaction thanks to brain-computer interfaces. To carry out this experiment using the Wizard of Oz technique, we have designed and developed tools to actually pilot objects from one room to another, near or far. To do this, we relied on IoT and IoE.

The term "IoT" for "Internet of Things" is attributed to Kevin Ashton [17] and describes a system where the Internet is connected to the physical world via ubiquitous sensors. IoT supports machine-to-machine (M2M) communication and aims to develop an ecosystem where physical objects are connected to each other. In other words, IoT is about physical devices that communicate without human intervention. A typical example of an IoT solution can be described with a home automation system based on a weather API (Application Programming Interface), capable of automatically adjusting the temperature of a house, without any human intervention.

The term "IoE" for "Internet of Everything" was attributed to Cisco Systems, Inc. and describes an advanced version of IoT that is not limited to physical devices but extends to an intelligent network connection between people, things, data, and processes [18]. IoE can be considered as a superset of IoT that provides general intelligence and enhanced cognition in the networked environment [19]. IoE supports not only machine-to-machine (M2M) communication, but also machine-to-person (M2P) and person-to-person (P2P), using technology. A typical example of an IoE solution can be described with a system involving data acquisition coming from various sensors merged by an intelligent environment combined with the willingness of different users (touch, voice, brain-computer interface, etc.) according to their physical and cognitive capabilities. Some researchers have already shown that it is possible and interesting to use IoE for BCI management [20]. In this study, we are also using IoE to indirectly manage connected devices. Instead of receiving real signals directly from the user's brain activity, the devices are directly driven by a human supervisor.

In a typical sequence, the Woz first sends the command "Please turn on the radio". An audio message is generated using voice synthesis and broadcast in the experimental room in order to be heard by the user wearing a BCI headset. The user tries to mentally carry out the proposed command. After a few seconds the Woz decides to send a command propagated in the electrical circuit (X10 protocol), to "Turn on the radio". This last high-level command is interpreted by our system to physically trigger the correct action, for example "Switch On A3" corresponding to the number assigned to the X10 receiver plugged into the electrical outlet.

3. Research Methodology

This section describes the necessary flows to solicit the users (displayed messages on screens, voice synthesis to be broadcasted on the Internet network, etc.) and commands sent from the control room to objects situated in the experimentation room, supposed to be controlled by the users' thoughts. MQTT and X10 protocols were used as well as the Node-RED platform to manage inputs and outputs in a flexible and configurable manner.

In an earlier study [21], we introduced BIOFEE (Biomedical Framework for Enhanced Experimentation), a system leveraging Firebase Real-Time Database to develop web and mobile applications for individuals with progressive illnesses. This framework facilitates interaction with objects and robots, enabling the testing of multimodal solutions such as touch, voice, gestures, and eye gaze, tailored to the specific needs of each patient's condition [22].

Figure 2 describes the architecture used in our current Woz study, based on the BIOFEE framework. Classical experimenters explain to users how to interact with the pretended BCI interface to supposedly pilot one of the three connected objects: a lamp, a fan and a radio. A special experimenter, the Wizard of Oz, is hidden behind a one-way glass, and is really in charge of controlling the devices by injecting commands transmitted thanks to the MQTT protocol, across Node-RED.

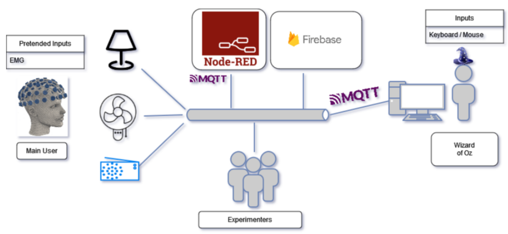

Figure 2. Architecture of our Woz experiment.

MQTT (Message Queuing Telemetry Transport) is a compact and dependable protocol designed for Machine-to-Machine (M2M) communication. Recognized as an open OASIS standard [23] and an ISO recommendation (ISO/IEC 20922), MQTT is described by the MQTT organization [24] as 'the standard for IoT messaging. Its simplicity, cross-platform compatibility, and low bandwidth requirements have made it a popular choice for IoT applications, whether used locally or remotely.

MQTT's widespread adoption stems from its simplicity, as it eliminates the need for traditional client/server architecture. Utilizing a communication model based on topic subscriptions and publications, MQTT streamlines interactions between microprocessor-driven devices. Each device operates autonomously, performing tasks based on real-time information it receives, while also sharing updates with other system participants as needed.

MQTT's popularity is further bolstered by its extensive community of developers and users. MQTT brokers, which facilitate communication between clients, along with numerous clients themselves, are available for virtually any operating system and cloud platform. Additionally, a wide range of software stacks and libraries exist to support development in various environments.

MQTT appeals to a broad audience, including enthusiasts of DIY projects and home automation. Originally developed by IBM to monitor oil pipeline sensors in conjunction with existing Supervisory Control and Data Acquisition (SCADA) systems [25], MQTT operates differently from OPC-UA data servers commonly used in industrial settings. While both protocols provide secure communication, OPC UA [26] emphasizes a semantic data representation model to promote system interoperability, whereas MQTT primarily transmits data as strings.

Figure 3 shows an Implementation of a Wizard of Oz experiment carried out in our laboratory. In the background, in the experiment room, the user, alone, is asked by a speech synthesis to perform some mental actions. In the foreground, the Wizard of Oz, hidden behind a one-way glass, controls all the devices remotely thanks to MQTT and Node-RED.

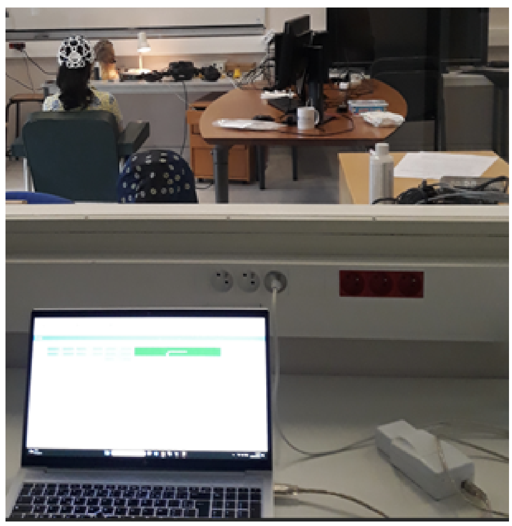

Figure 3. Implementation of a Wizard of Oz experiment carried out in our laboratory with MQTT.

This Web interface possibly allows control by several people through multiple devices (desktop PC, laptop, smartphone, etc.). **Figure 4** shows the OpenBCI headset used during our experiments. This is a truly effective BCI headset, but in the context of this study, it was not connected via Bluetooth. Thus, the brain waves emitted by the participants had no possibility of being captured by this equipment. This simulated interaction was credible because participants were asked to sit in an armchair, and then listen to the instructions given by the instructor, who then put the headset on their head and left the room. They therefore did not have the opportunity to handle or see the headset in detail.

Figure 4. OpenBCI headset.

Figure 5 presents the Node-RED workflow created to manage the inputs and outputs for the interface. This workflow is connected to a dashboard available in a Web browser (see **Figure 6**). If a valid sequence of three elements is detected (example: "Think Switch off Fan"), then the corresponding MQTT command is sent on the Internet, to be received by the computer in charge of the X10 protocol management. This textual trigger activates an X10 command (example: "sendplc M5 off") and the user perceives in the experiment room the corresponding physical result.

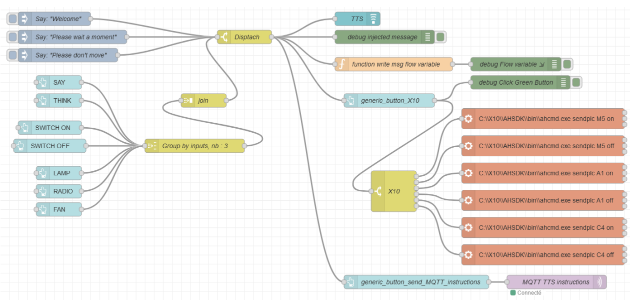

Figure 5. Node-RED workflow.

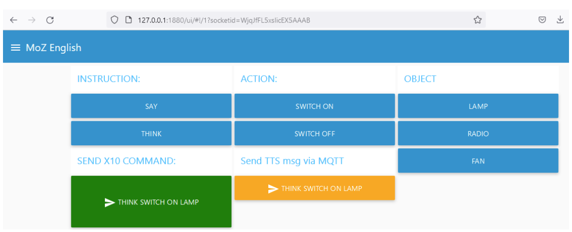

Figure 6. The Wizard of Oz Node-RED dashboard used in our laboratory.

3.1. Research Design

Figure 6 shows the dashboard used by the Woz to interact with the experiment room and the participants. For a typical example, the wizard clicks successively on the buttons "Think", "Switch on" and "Lamp", so this command is ready to be sent for an oral instruction (orange button) and/or an effective MQTT + X10 trigger (green button).

3.2. Participants

The Lille University (France) regularly offers mediation activities for middle and high school students. In this context, CRIStAL (Lille Computer Science, Signal and Automation Research Center) welcomed a group of 44 high school students to introduce them to research careers. The BCI team conducted a Wizard of Oz (WOz) study on this adolescent population.

The participants were welcomed into our laboratory for a week of immersion at the university and discovery of the scientific research activities of our laboratory. In a common room the program for the day was presented and four groups of around ten participants were established. Each group was placed in a room adjacent to the interaction room, and each participant completed a questionnaire before entering, one by one, the interaction room. After spending the experiment for a few minutes, each participant was placed in a third room, so as not to be able to communicate with the other participants. They then completed the questionnaire after the Woz experiment. Finally, a debrief period with all the participants was carried out in a common room. We explained how and why Wizard of Oz experiments are used. So, they understood that they had no real direct control over the connected objects allegedly controlled by their brain waves.

The data were studied with the RStudio 2024.04.0+735 "Chocolate Cosmos" Release version for windows.

Figure 7 shows the age distribution and proportion of the participants, which were counted 4, 10, 1, 13, 15 and 1 for the ages 13, 14, 15, 16, 17 and 18 years old, with mean 15.63, median 16 and standard deviation 1.44.

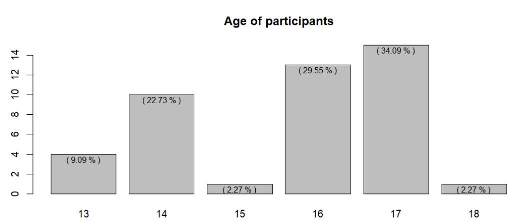

Figure 7. Age of survey participants.

Figure 8 shows the gender of the survey participants: 56.82% were female, 36.36% were male and 6.82% preferred not to say.

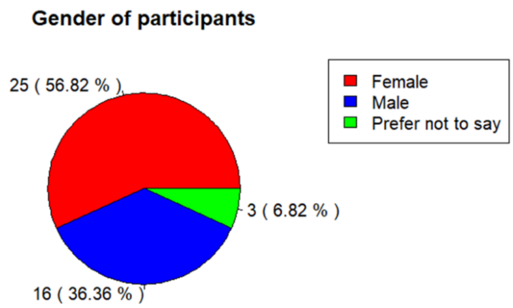

Figure 8. Gender of survey participants.

4. Results and Discussion

Figure 9 represents the participant's answers for the question "Are you a fan of science fiction?" with a 5 levels Likert scale, corresponding to "1: Strongly agree, 2: Agree, 3: Neither agree nor disagree, 4: Disagree, 5: Strongly disagree". The same Likert scale was used during all the study. The results show that 59.09% agree or strongly agree with this assertion, while 29.54% disagree or strongly disagree, and 11.36% are neutral. This question was asked, notably, to remind the participants that certain phenomena are explainable by science, while others are not yet.

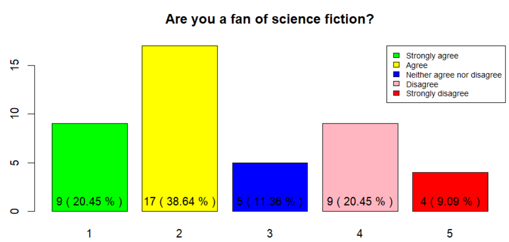

Figure 9. "Are you a fan of science fiction?"

Figure 10 represents the participant's answers for the question "Do you have home automation equipment at home?": 84.09% of participants answered "Yes". This question was asked to remind them that we can easily control different connected devices thanks to home automation using gestures or voice as modalities of interaction.

Figure 11 represents the participant's answers for the question "Do you consider yourself familiar with technologies?". A very large majority (86.37%) agree or strongly agree with this statement and therefore consider themselves familiar with the use of technologies such as smartphones, connected objects, wifi networks, etc.

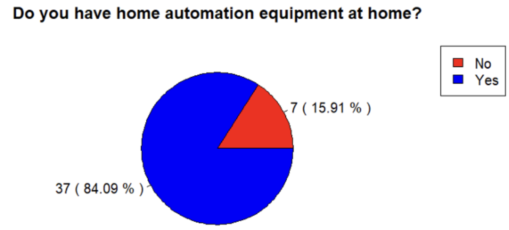

Figure 10. "Do you have home automation equipment at home (bulb, connected socket, automatic roller shutter, intelligent heating, etc.)?"

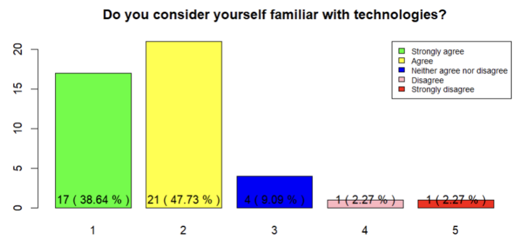

Figure 11. "Do you consider yourself familiar with technologies (smartphones, connected objects, WIFI networks, etc.)?"

Figure 12 represents the participant's answers to the question "Do you have the feeling that computers can communicate with humans through our 5 senses?". The notion of multimodality lies behind this question. The first part (38.64%) remains neutral on this question. A second part (36.37%) agrees or strongly agrees, and a last part (25%) disagrees or strongly disagrees.

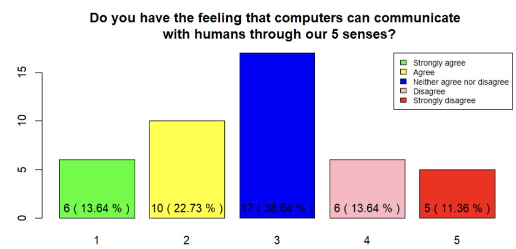

Figure 12. "Do you have the feeling that computers can communicate with humans through our 5 senses (sight, hearing, touch, smell, taste)?"

Figure 13 represents the participant's answers for the question "Have you ever heard of Brain-Computer Interface (BCI) before today?".

More than 70% of the participants had never heard about BCI before the experiment.

Figure 14 represents the participant's answers for the question "Do you think it is possible to control a device using thought without special equipment?".

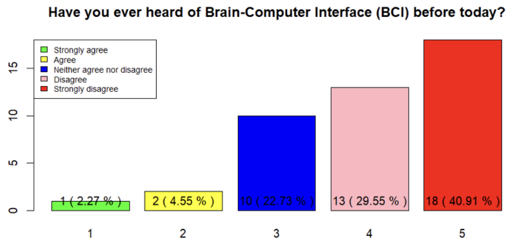

Figure 13. "Have you ever heard of Brain-Computer Interface (BCI) before today?"

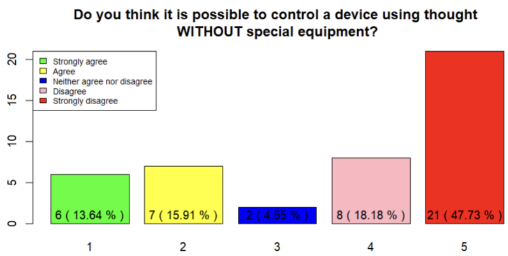

Figure 14. "Do you think it is possible to control a device using thought WITHOUT special equipment (electrode headset, etc.)?"

Around 65% of the participants think that it is not possible to control devices using thought without special equipment. But 29.55% agree or strongly agree that it is possible.

Figure 15 represents the participant's answers for the question "Do you think it is possible to control a device using thought with special equipment?

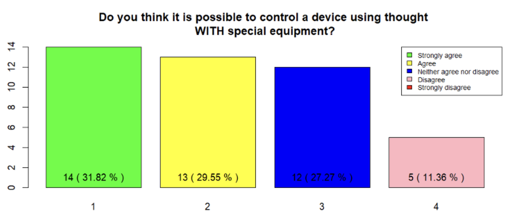

Figure 15. "Do you think it is possible to control a device using thought WITH special equipment (electrode headset, etc.)?"

Around 61% of the participants ("Strongly agree" and "Agree") think that it is possible to control devices using thought with special equipment such as an electrode headset; 11.36% disagree with this assertion and none strongly disagree.

Figure 16 represents the participant's answers for the question "Do you think you are capable of controlling an object using your brain waves?". The results are balanced between participants who think they can do it (36.36%), those who do not think so (31.82%) and those who stay neutral (31.82%).

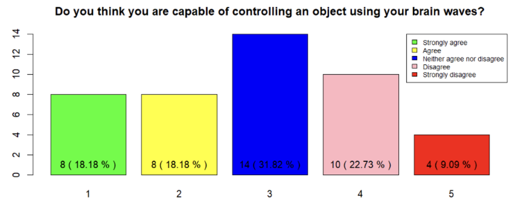

Figure 16. "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves (with an electrode headset placed on your head)?"

Figure 17 represents the participant's answers for the question "After carrying out the experiment, do you think you are capable of controlling an object using your brain waves?". 95.45% agree or completely agree.

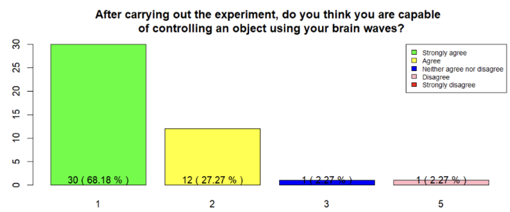

Figure 17. "After carrying out the experiment, do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves (with an electrode headset placed on your head)?"

Figure 18 represents the participant's answers for the question "Would you say that controlling an object using your brain waves was easy?". The results show that 72.73% agree or strongly agree, 18.18% stay neutral and 9.09% disagree or strongly disagree.

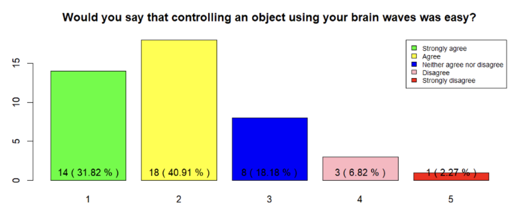

Figure 18. "Would you say that controlling an object (lamp, radio, fan, etc.) using your brain waves was easy?"

Figure 19 represents the participant's answers for the question "Do you think you will be able to use such technology in your daily life in a few years?". The results show that 61.36% agree or strongly agree, 25% stay neutral and 13.63% disagree or strongly disagree.

Figure 20 represents the results of the Gender crossed by the answer to the question "Are you a fan of science fiction?".

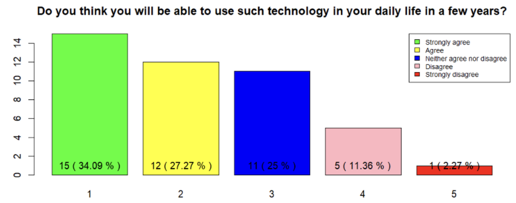

Figure 19. "Do you think you will be able to use such technology in your daily life in a few years?"

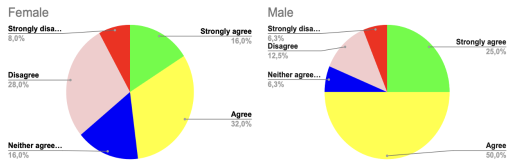

Figure 20. "Are you a fan of science fiction?" by gender.

Men are mainly fans of SF (75%) while women are more divided. Science fiction has the reputation of being a fairly sexist literary genre mainly dedicated to a male audience[27]. Researchers from the University of Cambridge[28] find that "just 8% of all depictions of AI professionals from 100 years of film are women and half of these are shown as subordinate to men". This would explain the low interest of young women in scientific studies and careers.

Figure 21 represents the results of the crossed question "Do you think it is possible to control a device using thought without special equipment?" by "Are you a fan of science fiction?".

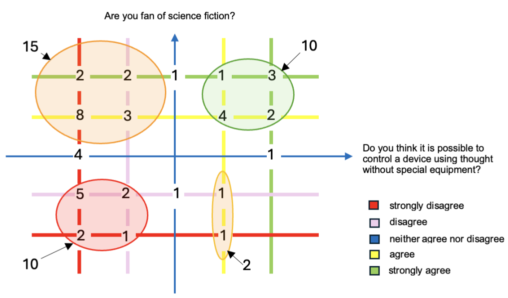

Figure 21. "Do you think it is possible to control a device using thought without special equipment?" * "Are you a fan of science-fiction?"

The data obtained in reply to the first question (here "Do you think it is possible to control a device using thought without special equipment?") are represented on the horizontal axis, those obtained in reply to the second question (here "Are you a fan of science fiction?") are represented on the vertical axis.

The axes in blue correspond to the neutral response (neither agree nor disagree). The red lines correspond to the strongly disagree response, the pink lines to the disagree response, the yellow lines to the agree response, and the green lines to the strongly agree response. The number at the intersection of a vertical line and a horizontal line is the number of responses obtained to the cross-questions (strongly disagree * strongly disagree, strongly disagree * disagree, strongly disagree * neither agree nor disagree, etc. For example, 8 participants strongly disagree with the question "Do you think it is possible to control a device using thought without special equipment?" but agree with the question "Are you a fan of science fiction?" (intersection of the vertical red line and the horizontal yellow line).

The majority (29 participants out of 44, on the left of the vertical axis) don't think it is possible to control a machine by thought without special equipment, whether they are fans of science fiction (15 participants, top left of vertical axis) or not (10 participants, bottom left of vertical axis).

Among those who think the opposite are 10 science fiction fans (top left of vertical axis). Telepathy being one of the themes of science fiction, this result presents a certain coherence.

Figure 22 represents the results of the crossed question "Do you think it is possible to control a device using thought without special equipment?" by "Are you a fan of science fiction?" by gender.

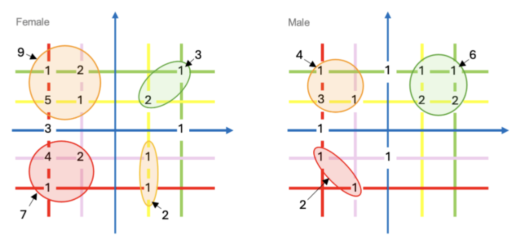

Figure 22. "Do you think it is possible to control a device using thought without special equipment?" * "Are you a fan of science-fiction?" by gender.

The majority of female fans of science fiction think that it is not possible to control a machine by thought without special equipment, unlike the majority of male fans of science fiction who think it is possible.

Figure 23 represents the results of the crossed question "Do you think it is possible to control a device using thought with special equipment?" by "Are you a fan of science fiction?".

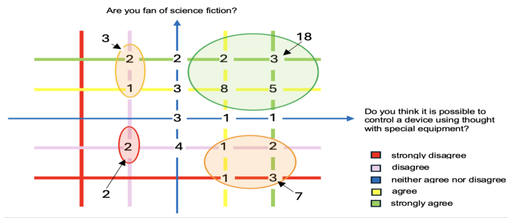

Figure 23. " Do you think it is possible to control a device using thought with special equipment?" * "Are you a fan of science fiction?"

The majority (27 participants out of 44) think it is possible to control a machine by thought with special equipment, whether they are fans of science fiction (18 students) or not (7 students). Only 5 participants think it is not possible and 12 participants did not comment. Among the 18 participants who are science fiction fans, 10 responded favorably to the two questions "Do you think it is possible to control a device using thought without special equipment?" and "Do you think it is possible to control a device using thought with special equipment?" and 8 only responded favorably to the question "Do you think it is possible to control a device using thought with special equipment?".

Figure 24 represents the results of the crossed question "Do you think it is possible to control a device using thought with special equipment?" by "Are you a fan of science fiction?" by gender. 81% of male participants (13 out of 16) think it is possible to control a machine by thought with special equipment (69% strongly think so). 48% of female participants (12 out of 25) think that it is possible to control a machine by thought with special equipment (24% strongly think so).

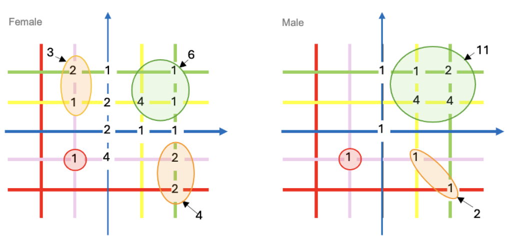

Figure 24. "Do you think it is possible to control a device using thought with special equipment?" * "Are you a fan of science fiction?" by gender.

Figure 25 represents the results of the crossed question "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" by "Are you a fan of science fiction?".

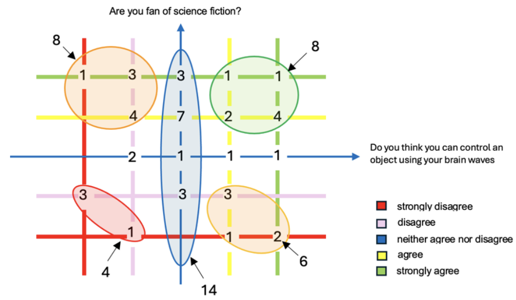

Figure 25. "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" * "Are you a fan of science fiction?"

Opinions on this question are very divided: 16 participants think they can control an object with their brain waves, 14 participants do not comment, and 14 students think the opposite.

30.7% of science fiction fans think they can control an object with their brain waves, 30.7% think they cannot and 38.6% do not comment. 46% of science fiction not fans think they can control an object with their brain waves, 31% think they cannot and 23% do not comment.

Figure 26 represents the results of the crossed question "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" by "Are you a fan of science fiction?" by gender.

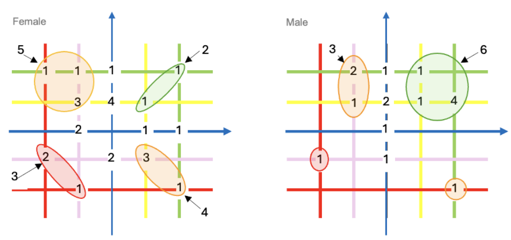

Figure 26. "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" * "Are you a fan of science fiction?" by gender.

32% of female participants think they can control an object with their brain waves, 40% think they cannot and 28% do not comment. 44% of male participants think they can control an object with their brain waves, 25% think they cannot and 31% do not comment.

Figure 27 represents the results of the crossed question "Do you think it is possible to control a device using thought with special equipment?" by "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?".

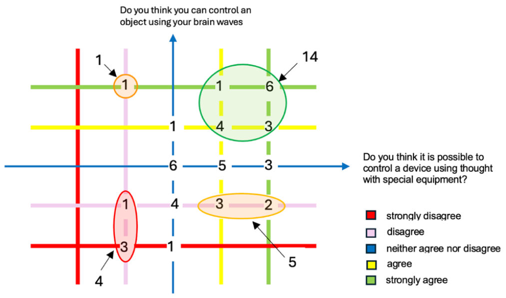

Figure 27. "Do you think it is possible to control a device using thought with special equipment?" * "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?"

Logically, 4 participants believe they cannot control an object neither with their brain waves or by thought using specific equipment and 14 participants believe they can control an object with their brain waves and by thought using specific equipment.

Oddly, 5 participants think they can control an object by thought using specific equipment but not with their brain waves and 1 participant believes he can control an object with his brain waves but not by thought using specific equipment.

Finally, 20 participants do not comment on one or the other of the statements. Which suggests that they do not necessarily associate brain waves and specific material.

Figure 28 represents the results of the crossed question "Do you think it is possible to control a device using thought with special equipment?" by "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" by gender.

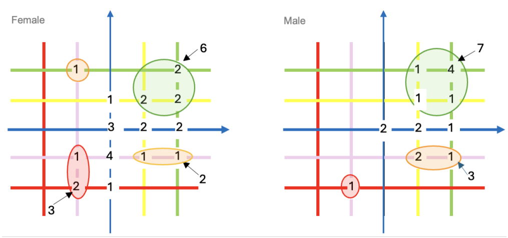

Figure 28. "Do you think it is possible to control a device using thought with special equipment?" * "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" by gender.

Figure 29 represents the results of the crossed question "Do you think it is possible to control a device using thought with special equipment?" by "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" by fan/not fan of science fiction.

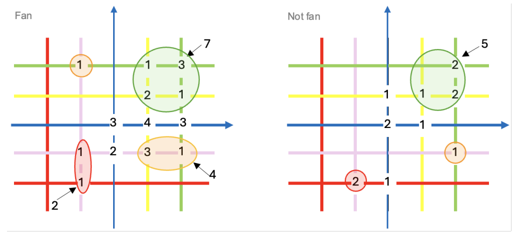

Figure 29. "Do you think it is possible to control a device using thought with special equipment?" * "Do you think you are capable of controlling an object (lamp, radio, fan, etc.) using your brain waves?" by fan/not fan of science fiction.

The gender and the fact of being or not a fan of science fiction do not seem to be significant here.

Figure 30 represents the results of the question "Do you think you are capable of controlling an object using your brain waves?" before and after the WOz experiment.

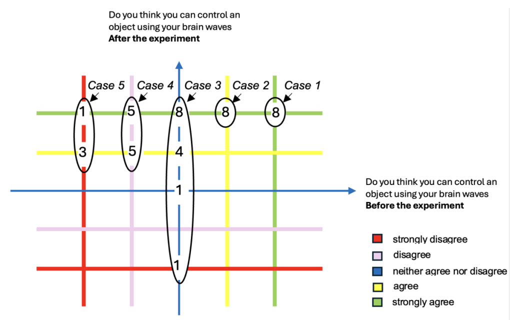

Figure 30. "Do you think you are capable of controlling an object using your brain waves?" before and after the Woz experiment.

30 participants (68.2%) strongly agree with this assertion after the Woz experiment, while only 8 (18.2%) of the participants strongly agree with this assertion before the Woz experiment.

Case 1: The 8 participants who strongly believed they could control an object with their brain waves before the experiment did not change their minds after the experiment.

Case 2: The 8 participants who thought they could control an object with their brain waves before the experiment changed their minds and strongly believed they could do so after the experiment.

Case 3: Of the 14 participants who had no opinion on the question before the experiment, 8 participants strongly believe they can control an object with their brain waves after the experiment, 4 students believe they are capable, 1 participant still has no opinion on the question and 1 participant strongly thinks he is not capable of doing so.

Case 4: Of the 10 participants who thought they would not be able to control an object with their brain waves before the experiment, 5 participants were strongly convinced otherwise after the experiment and the other 5 participants it was possible.

Case 5: Of the 4 participants who strongly believed they would not be able to control an object with their brain waves before the experiment, 1 participant was strongly convinced otherwise after the experiment and the other 3 thought it was possible.

Only 1 participant replied "Neither agree nor disagree" before and after the experiment and only 1 switched from "Neither agree nor disagree" to "Strongly disagree", after the WOz experiment. Except for these 2 participants, everyone changed their minds favourably after the experience.

5. Conclusions

With this article, we explored, through a Wizard of Oz study, how the young population perceives brain-computer interfaces. For this, we have developed an interactive system, based on MQTT and driven by Node-RED, to allow a Wizard of Oz experimenter to remotely control connected devices (lamp, fan, radio) in an experiment room. Participants answered questions just before and after passing an experience in which they felt like they were controlling devices using their brain waves. In reality, it was the Wizard of Oz who controlled said devices.

The static analysis carried out on the obtained results show that for this population of 44 teenagers, 59.09% consider themselves as fans of science fiction and 84.09% of them have home automation equipment at home. They are mostly comfortable with technology as 86.37% consider themselves as familiar with new technologies (devices, network, software…). The participants' opinions are quite divided regarding the possibility of computers communicating with humans through the five senses. The highest percentage (38.64%) are people with a neutral opinion, and the percentages of agreement and disagreement are quite close (36.37% and 25% respectively), which shows that there is no clear consensus on this question.

Our study focused on brain-computer interfaces, but more than 70% of the participants had never heard about BCI before the experiment. Even though they were mostly fans of science fiction, they did not think that it was possible to control devices entirely with thought and without equipment (like in certain science fiction movies or series). Indeed, around 65% of participants believed that it is not possible to control devices with thought without special equipment. Around 61% of the participants thought that it is possible to control devices by the means of brain activity detected across special equipment, such as EEG headsets.

Before the experiment, 36.36% of the participants thought they could control an object using their brain waves, while 31.82% did not think so and 31.82% remained neutral. After the Woz experiment, 95.45% agreed or completely agreed (68.18% + 27.27%) with the fact that they could control an object using their brain waves. 72.73% said it was easy to perform this (fake) BCI interaction (18.18% stayed neutral and 9.09% disagreed or strongly disagreed). Finally, 61.36% estimated they will be able to use such BCI technology in their daily life in a few years (25% stayed neutral and 13.63% disagree or strongly disagree).

Artificial intelligence (AI) is a field of science and technology focused on creating intelligent machines that mimic human capabilities such as perception, decision-making, interaction, learning, and reasoning. Today, AI is a widely discussed topic, with generative AI technologies like ChatGPT, Character.ai, Midjourney, and Gemini being at the forefront of the current excitement. Between September 2022 and August 2023, AI-related websites attracted 24 billion visits, with 14 billion of those visits directed to OpenAI's ChatGPT [29, 30].

Young people in particular have easy access to this kind of tools and technology, and it becomes very difficult for them to determine what a machine can or cannot do currently, compared to a human. Our study showed that young people were influenced in their perception of their own abilities to control connected objects (lamp, fan, radio) with a BCI, thanks to the Wizard of Oz technique. A futuristic headset and a few electrodes on their heads were enough to make them believe that they were really controlling connected objects. Even if this will undoubtedly be possible in the more or less short term, this study shows the real need to legislate on the development, marketing and use of neuro-technologies like the Chilean Senate which unanimously adopted in 2021 a draft law amending the Constitution to protect brain rights or "neuro-rights" [31].

Pending the emergence of a French and/or European neuro-ethical law, we plan to renew this Wizard of Oz study for a few years to follow the evolution of our high school cohorts.

Author Contributions

The data were collected by J.R. J.R. and J.-M.V. collaborated on the technical aspects of the research. The original draft preparation was initiated by J.R. J.R., M.-H.B. and J.-M.V. contributed to the literature review, and wrote the manuscript. All authors contributed to the article and approved the submitted version.

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Institutional Review Board Statement

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

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