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TESI DOCTORAL

Low-cost methodologies and devices applied to measure, model and self-regulate emotions for Human-Computer Interaction

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Resum:

En aquesta tesi s'exploren les diferents metodologies d'anàlisi de l'experiència UX des d'una visió centrada en usuari. Aquestes metodologies clàssiques i fonamentades només permeten extreure dades cognitives, és a dir les dades que l'usuari és capaç de comunicar de manera conscient. L'objectiu de la tesi és proposar un model basat en l'extracció de dades biomètriques per complementar amb dades emotives (i formals) la informació cognitiva abans esmentada. Aquesta tesi no és només teòrica, ja que juntament amb el model proposat (i la seva evolució) es mostren les diferents proves, validacions i investigacions en què s'han aplicat, sovint en conjunt amb grups de recerca d'altres àrees amb èxit.

Resumen:

En esta tesis se exploran las diferentes metodologías de análisis de la experiencia UX desde una visión centrada en usuario. Estas metodologías clásicas y fundamentadas solamente permiten extraer datos cognitivos, es decir los datos que el usuario es capaz de comunicar de manera consciente. El objetivo de la tesis es proponer un modelo basado en la extracción de datos biométricos para complementar con datos emotivos (y formales) la información cognitiva antes mencionada.

Esta tesis no es solamente teórica, ya que junto con el modelo propuesto (y su evolución) se muestran las diferentes pruebas, validaciones e investigaciones en la que se han aplicado, a menudo en conjunto con grupos de investigación de otras áreas con éxito.

Abstract:

In this thesis, the different methodologies for analyzing the UX experience are explored from a user-centered perspective. These classical and well-founded methodologies only allow the extraction of cognitive data, that is, the data that the user is capable of consciously communicating. The objective of this thesis is to propose a methodology that uses the extraction of biometric data to complement the aforementioned cognitive information with emotional (and formal) data.

This thesis is not only theoretical, since the proposed model (and its evolution) is complemented with the different tests, validations, and investigations in which they have been applied, often in conjunction with research groups from other areas with success.

Acknowledgements

I have always said that when you do not speak in your mother tongue, you are not speaking sincerely, but this time I will make an exception to not break the written style.

I am a lucky person, because when thinking about the people I want to say thanks for this achievement, the list is huge. For this reason, I will name them in reverse chronological order:

I've to thank my advisors, Rosa and Roberto, whose knowledge made possible this document (and all the experiments in it). I've to thank them too to introduce a hardware-oriented student to the UX world and guiding him through the *emotional rollercoaster* that a PhD thesis is with success. All that is right in this document is theirs, all the mistakes are mine.

I would like to acknowledge Fran for opening me the gates of research outside the University of Lleida and counting with me in their projects as technological advisor. The same way thanks to all the medical specialists who assisted in the myriad of experiments and research with patients, students and specialists like them. This synergy is the reason why studied computer sciences.

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Thanks to the members of the GRIHO for all the wise counsel and willingness to help, always in every topic. And thanks to all the interns that shared with me the UsabiliLab (the only place in Catalonia where voters from the CUP, CIU and ERC worked together to get something done).

But this thesis started more than 25 years ago, maybe 29 or 30, and that is the main reason why I am lucky. Maybe started with me asking to my father to taught me reading with 2 years, because he read a lot and I know inside books there were information! Or maybe started when I learned assembler sitting next to him and looking how he was coding at 5. Or maybe started during a theoretical discussion with him about how to properly copy a human brain without loose humanity when I was 8. Or modding games together at 15. Or discussing the news in the newspaper before going to class at 20. All the years of discussions over a great variety of technical topics. My father, apart from being my best friend, have always pushed me to think on the next step, beyond my own limits. Everything said supported by my mother, who has always listened with interest (not always understanding us) and has given me advice and support with her feet on the ground without taking away my confidence. This thesis, along with who am I, could not be possible without my parents.

And finally, a special thanks to Sandra, who accompanied me in the final steps of the thesis (that proverbial *emotional rollercoaster* last loop) with supportiveness and patience, flattening my way and understanding why someone is writing a technical document at 3 AM.

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Chapter 1

1.0 Introduction

In the last 20 years, technological advances made it possible to apply computer-science tech into the affective computing area, from methodologies to physical machinery including our case: Affective Computing. This usually tends to come at a high cost in time, resources, trained staff and money due to the specificity of the technology needed.

But in the last 10 years, things have changed in one important way: new companies and open-source projects drastically reduced the prices as well as created new devices that can serve multiple purposes. Now almost any research group in the world, public or private, can afford cutting-edge technologies at a reasonable price. Many of the new technologies applied to UX are related to biometry, which is analysing biological data of the user’s body. The difference between those data sources is that, differently from the classical ones, they do not rely on the cognitive capacities of the user (to simplify it, the user doesn't need to answer questions actively), but they measure the automatic reactions of their body. These reactions could be part of the subconscious mind or an automatic body reaction in response to one external or internal stimuli. The internal stimuli are the most interesting part: what kind of things can cause measurable body reactions? Thoughts and emotions. For the first time, we have at our disposal devices to measure the (until now) “intangible” world.

Should be noted that the opposite of cognitive, is noncognitive[1] by definition:

''NOT BASED ON OR CAPABLE OF BEING REDUCED TO EMPIRICAL FACTUAL KNOWLEDGE''

So by definition, non-cognitive things are those that cannot be empirically measured. This definition dates from the year 1864, and many things have changed, as those devices can empirically measure the effects of those noncognitive traits over the human body. And by measuring its effects on the body, their values and their intensity can be extrapolated. So we are on the lead to empirically measure the world of senses, using noncognitive metrics as complementary data with cognitive ones, allowing us to know both how the user interacts with the system, and how the system interacts with the user at a level never seen before.

These new technologies opened a wide range of possibilities in many different fields such as education (to help students know how to perform better), medical treatments (to assist patients more humanely), new interaction devices (to help people with disabilities to overcome them), and many others. All those possibilities will be possible by the viability of affective computing, or those complex systems that can recognize and interpret human emotions.

In addition, the world has experienced a shift due to the first world pandemic of our times. Even when it will be finished at some point, it will have caused changes in the behavior of an important part of the population, not yet investigated or assumed. Those systems should be used in remote contexts to not lose the synergy between the society and the research groups all over the world. How many UX experiments have been performed during 2020? Many, due to the high adaptation of the collective of researchers. Now it is more important than ever that those devices become cheap and accessible to everyone, so that not only do we not go backwards in UX, but we continue further and further.

[1] https://www.merriam-webster.com/dictionary/noncognitive

This research has been conducted as a member of GRIHO[2], a research group that explores Human-Computer Interfaces and Data Integration, assigned to the Computer Science and Industrial Engineering Department of the Universitat de Lleida. Our goal is not only to research but to teach our students and transfer our vision of the technology to society in an emotive way, to make them understand how people are the center of the technology. This spirit of unity is reflected in the institution's logo, showing that we fill the gap that may exist between a user and the system they use, applying our knowledge to their benefit.

Figure 1: GRIHO Logo. Source: official GRIHO Webpage

This group was one of the first Spanish research groups that wanted to learn about the most forgotten technological trait: the people that use the technology and the way they do it. Following the path started by Jesús Lorés, they became founder members of AIPO[3] (*Asociación Interacción Persona-Ordenador*), they coordinated the publication of the first HCI bibliography written in Spanish (Lorés et al., 2001), developed their own User-Centered Design Methodology (MPIu+a) and started the first Human-Computer Interaction master in Spanish.

But most importantly, they have shown me the importance of usability and accessibility from the end-user point of view, and how that affects their day-to-day life.

[2] http://griho.udl.cat

[3] https://aipo.es

1.1 Thesis statements

This thesis defines four hypotheses to be verified along the research presented in this document.

We have the hypothesis that if users know how an emotion is affecting their behaviour, they can affect the subjective appreciation of that feeling, and by that change the way they feel it to improve their overall experience.

Emotional self-regulation is widely applied in psychology and educational areas with excellent results and precisely the relation of those areas to UX (in a computer engineering context) is what encourages us to focus our research on it. But prior to achieving that self-knowing, the main issue is how to detect which emotions are feeling users in a given moment.

As even with introspection it's difficult to know your own feeling, we believe that emotion measuring in UX fails if it's limited to classical-modelled written tests. For this reason, we want to propose a hybrid method, measuring and analysing biosignals and using existing questionnaires as validation of the results, with the objective of achieving a biosignal model at least as reliable as the questionnaires used until now.

Applying this new methodology will improve various common issues when interacting with a user in an experiment, such as Pygmalion Effect (Rubovits & Maehr, 1971) and the self-confirmation bias (Quattrone & Tversky, 1984). The first implies that the researcher is interfering with the result of the users; the second that the answers are not real because of a self-deception component in user cognition. This doesn't mean that those effects are completely pass-through, but their effects are less direct as we are measuring a sensitive-passive response (biosignal) instead of an active-cognitive one (reasoning and answering a direct question).

In the same way, we think that applying those methodologies in an educational environment together with gamification techniques can improve the interest of the students to consume the subject contents.

And finally, the last statement is that we can do it by using *low-cost* devices, services and methodologies, so it's affordable for everyone.

1.2 Thesis Overview

This document is structured in 5 different Chapters, each chapter presents a question in the opening to guide the reading and provides a section called **summary** at their end to show a short answer to that question.

· In Chapter 1, we have presented our four thesis statements:

1. If someone knows how an emotion is affecting its behaviour, that person can affect the subjective appreciation of that feeling, and by that change the way it feels to improve their overall experience.
2. We propose a hybrid method, measuring and analysing biosignals and using the user-written test as validation of the results, with the objective of achieving a biosignal model at least as reliable as the test used until now.

3. Various studies have suggested that web-based educational interventions can have a positive impact on user attitudes and conduct, we believe that our methodologies can contribute to that field.
4. All the above can be achieved by using *low-cost* devices, services and methodologies, so it can be affordable for everyone.

In addition, you can find the structure of the document (you are reading it).

· In Chapter 2, we present a question: **"What type of cognitive and sensitive measurements are collected by UX nowadays? And how?"** It describes the state of the art related to the technologies (including devices and tools) we used so far, and the workarounds to adapt them to fit our needs.

· In Chapter 3, we address a specific question **"How should an experiment be performed?"** where common problems of the mentioned technologies are discussed. It describes how to prepare the testing environment based on our previous experiences. 3 different contexts are discussed (Each with its own positive and negative traits):

1. Controlled lab
2. Non-research-oriented room (usually a classroom)
3. online experiment

· In Chapter 4, we describe the experiments conducted so far. This chapter will be a series of experiments that will allow us to answer our research questions. Each one will have those sections: **Objectives**, **Materials used**, **Design**, **Execution** and **Results**. It's an application of the previous question and they can be used as a guide to know the steps that allowed us to resolve the questions raised. Specially designed for those researchers only interested in one specific type of experiment.

At the end of every experience, a detailed summary is provided in the Results section. In the following chapter, an integrated version of all the results will be provided.

· In Chapter 5 we present our contributions and conclusions by answering the aforementioned research questions and thesis statements as well as discussing future applications and advances.

1.3 Considerations

The differences between UX and Usability are usually blurry due to companies and academic papers using them interchangeably, without knowing their exact meaning or even seeing them as synonyms. For this reason, multiple academics have tried to search and define a common nomenclature and usage as (Petrie & Bevan, 2009) or the newer (Cruz et al., 2015). It is a difficult topic, and this thesis will get the ISO 9241 official definitions for each one:

- Usability is defined at ISO 9241 (ISO/TC 159/SC 4, 2018) as "*The extent to which a product can be used by specific users to achieve specific goals with effectiveness, efficiency and satisfaction in a specific context of use.*"
- UX is defined in the ISO 9241-210 (ISO/TC 159/SC 4, 2019) as *"A person's perceptions and responses that result from the use or anticipated use of a product, system or service."*

This two can be joined if the usability is seen as a way to add to the user experience a satisfaction layer by taking into account the emotions of the user and how it relates to the way those specific goals are achieved as it is said in (Bevan, 2008). This work pursues the goal of explore new methods to provide a better insight into the user emotional response, by obtaining objective data.

Chapter 2 - State of the art

UX techniques and methodologies cover a wide pool of terms. To narrow down the range of technologies and devices that can be used we will answer the question **"What type of cognitive and sensitive measurements are collected by UX nowadays?"**.

2.1 UX Cognitive data - Techniques

Common UX research techniques appeal to the cognitive part of the interaction, meaning that as a researcher you are relying on the users who tell a story about why and what they did and how they feel. This methodology has been used for so long that has been validated by countless scientific articles. This is due to the fact that instead of being related to computers, they are focused on the study of human behaviour, an area of interest studied for more than 2000 years. The items described here had been selected because we think they had equivalents in emotive data extraction, note that in UX there are many, many more. Combining them (Cognitive and emotive data extraction) can bring us the most complete set of information about a given aspect.

One important aspect of UX is that we have two different kinds of measures (Bevan, 2008): Summative (or quantitative) and Formative (or qualitative). The basic difference is that formative assessments are focused on the detailed exploration of features to obtain a better understanding of needs, while summative ones are focused on the overall experience and product requirements.

Summative measurements are commonly obtained from quantitative metrics of user performance in controlled tests, but they can also be obtained from questionnaires (Hassenzahl, 2007; Lavie & Tractinsky, 2004) or from expert evaluation, such as the degree of conformance with usability guidelines (Jokela et al., 2006) and often require larger groups as their conclusions have to be statistically meaningful. It answers the questions regarding how many users are behaving in a given way. This type of test is usually performed when the product or experiment is completed to see its effectiveness. For example, the test method in ISO 20282-2 points out that to obtain 95% confidence that 80% of users could successfully complete a task would, for example, require 28 out of 30 users tested to be successful.

Formative measurements are extracted from qualitative data, tested for a smaller number of users. That's why the data obtained is considered entirely observational, and it's mainly used to detect flaws in design and discover new ways to present the information. For this reason, it answers questions regarding how users are behaving or why are they doing something in a given way. This type of test is usually performed during the initial stages of the product or experiment.

These techniques include (but are not limited to):

· **User Screening**, it's not a usability test *per se*. But it's a mandatory part to obtain a significant statistical analysis from our results. Choosing the right participants for a research study can be a challenge as the target audience will not be a homogeneous group. Instead, the user list will have different behaviours and previous knowledge. If as scientists we don't take it into account, there are many statistical paradoxes that can affect us as the Yule-Simpson effect (Blyth, 1972), ruining the meaning of the carefully analyzed data.

So, it’s important to obtain not only a good user set but some good groups of user sets. Usually, this is solved by dividing the users in the experiment using screening surveys. Those surveys must be crafted carefully as too specific questions can lead to people guessing what is the study about, with the risk of people providing exaggerated answers to participate and receive the incentive (As those type of tests usually provide one or another).

To avoid this there exists two options: using pre-validated screening questionnaires (as each field of knowledge has its own surveys, especially in medical-related areas, with their usage rules and sometimes prices) or making your own survey.

If the selected option is the second one, hand-crafting a survey specially oriented to one given project, the goal can be conflictive: the survey must ask about specific information about users, but it also should avoid revealing specific information about the study. To achieve this, open-ended questions and distractors are often used (Nielsen Norman Group, 2019). Open-ended questions need more effort to interpret the result, as it’s difficult to automate the evaluation of the meaning. Distractors are questions that are not going to be evaluated but they are present as a camouflage for the answers we’re validating.

Related to the timing to be applied, this technique should be used after the development of the test as it’s basic to avoid outliers and define user groups in case wider demography is needed.

· **Interviews**, The easiest way of discovering a feature is simply asking it. Interviews are a meeting of people, with the purpose of consultation (Oxford Languages, 2020). During an interview, many of the listed techniques in this section can be applied as a part of the inquiring process (for example using during the session card sorting, surveys, etc.). The data extracted from the interviews are always qualitative (formative), as the important is not the numbers but the initial insights of the user and the project. Those interviews are usually structured but can vary, for example, the user can answer a question before we ask it (by developing one of their previous answers for example). This is why it’s said that an interview is more a conversation than an interrogation (Portugal, 2013). The and the questions can be ordered by the expected answer:

· open: the interviewed user can develop their response, with next questions varying depending on their answer.

· closed: short answers, including yes/no questions although they are not usually recommended.

The question in an interview can be classified by their objective too:

· Demographical: To better understand the user profile.

· Acclarative: To ask for more details over a topic.

· Opinion: Useful to define user-profiles and discover new querying topics to add in other interviews.

· Wrap up: non-important data to make the user feel more comfortable and imply the user, like a normal conversation.

Usually, the interview session takes less than one hour and is carried by two persons, the observer and the moderator. The moderator and the observer can be the same person as the session is recorded, but this implies re-reviewing the session to take notes and analyze the interview details after finished.

After the interviews, it is recommended that each one is synthesized in a summary with the key points of each one to aggregate the most important information. With the resume of each session, we can look for patterns, generate insights and make the interview report with the conclusions.

Basically, information is gathered during and after the experiment:

· *During*: As the sessions are driven, the moderator or the observer can add or change the questions if they see that something has not been taken into account.

· *After*: The global results must be analyzed to improve the knowledge of the topic and the users.

· **Satisfaction questionnaires** (also known as **surveys**), the stats of "satisfaction" usually implies a wide range of emotions, and as emotions are part of our inner world each user will feel it in a different way with a different intensity. In psychological terms, the levels of "engagement" and "arousal" or "disengagement" and "quietude" won't be the same for two satisfied users (Oliver, 1997).

Arousal is the psychological state of being focused on a point of attention, and it's responsible for regulating alertness and information processing. Arousal seems to influence the retrieval of information, as it participates in "memory encoding" in a way that people tend to keep more information about the subject causing the arousal to increase than others (Mickley Steinmetz et al., 2012). But it has to be taken into account that arousal is related to long-term memory, so short-term experiences are not so benefited by that circumstance (Revelle & Loftus, 1992).

This usually makes surveys difficult to understand as we have to deal with users in a varying emotional state. As extracted from (Oliver, 1997):

"It appears that emotional extremes including delight, excitement, and distress are naturally occurring emotions in satisfaction…. If a consumer responds that he or she is satisfied, does it mean that this consumer is in a state of contentment, or of pleasure, or of delight?"

if you're really interested in something, being satisfied with it might fall somewhere between being pleased and delighted; but if you're not, being satisfied probably puts you somewhere between being pleased and relaxed.

- *Richard L. Oliver*

One of the flaws in the surveys is that "Satisfaction" is more related to comparison over past experiences or future expectations than a "formal measurement". This is well reflected in the study "*When Less Is More: Counterfactual Thinking and Satisfaction Among Olympic Medalists.*" (Medvec et al., 1995). Where it was proved that the satisfaction is not linear dependent on the resulting position in an Olympic competition (The example is extracted from the 1992 olympiads in Barcelona, where all bronze medalists were significantly more satisfied than the ones with a silver medal).

To solve this and to become the most neutral possible, depending on the subject we want to ask for we have a lot of official surveys (some of them are quite expensive and kept it's content as "secret" to not lose effectiveness) that have been validated for a particular environment and objective (or to be applied in a generic context). A special note must be made to emotional subjective evaluation surveys as PrEmo (Desmet & Laurans, 2017), where a set of 14 cartoons are used to let users express their emotions without using words in a more accurate way.

Figure 2: PrEmo Emotions. Source: www.premotool.com

Related to the timing to be applied, this technique should be used after the development of the test. Can be used too prior to it to extract information about past experiences:

· *Prior*: This can be performed in case our study needs information about expectations or previous similar experiences.

· *After*: This will provide useful information, especially if we're following an iterative methodology.

· **Card Sorting**, used in psychology long before used in UX to discover the Information Architecture of a person, even described as early in *Practical Suggestions on the equipment of a Psychological Laboratory* (Sanford, 1893).

It's based on the active grouping and naming of objects and concepts. Applied to Computer Science, it allows defining a common terminology, relationships between entities and categories. This information can be used to decide what items display and where; how to organize menu contents, and, most important, the words to describe the objects so the user can understand what they are.

It is performed by giving users a set of cards. A set of concepts or categories can be provided (closed card sorting) or not (open card sorting). The objective of the test in both cases is that the users order the content as they think makes more sense.

Early uses were related to establishing characteristics of a given subject and the measured metric was the speed of sorting (Jastrow, 1898) but this implied that there is a "correct answer". Lately, the technique evolved into a "not correct answer" used to create groups of people with similar mental ordering patterns. In computer science, it was used to design the menus for an operating system in the early '90s, starting with (Tullis, 1985).

This methodology is cheap and easy to understand for everyone so a huge experienced team is not really needed.

Related to the timing to be applied, this technique can be used prior to the development of the test, during it or after. Each phase should be used for different purposes:

· *Prior*: as a validation of the screening process to determine the clustering of a given use into a group. Should be analyzed before the experiment begins, as a validation of the groups (or to split the users into smaller groups, in case we detect that it is too heterogeneous). Important to analyze this before the experiment starts if the researcher can.

· *During*: As part of the hierarchy of ideas that needs to be discovered during the experiment. Card sorting helps the user to explain their organization in an indirect way, representing hidden mental processes difficult to be explained by the user. This information must be analyzed when the experiment has finished.

· *After*: To see if there are better ways to order the elements as are shown in the experiment. This should be used always once an experiment has finished, as maybe the experience itself has been a "training" for them, waking new ideas about how it should work. This will provide useful information, especially if we're following an iterative methodology.

· **Tree Testing**, although it is a technique eminently used in website analysis, it can be used to evaluate the ease to find elements in a hierarchical tree of concepts. It is known too as Reverse Card Sorting because it's in a way the opposite: it is analyzed how the user behaves with a given set of categorized concepts (Spencer, 2003). Card sorting assists in the definition of a common hierarchy of ideas (taxonomy), but those final normalized taxonomies must be tested to ensure full understandability for all users. Tree testing is the answer to how to implement this test.

It is usually carried out on paper instead of a computer to avoid the typical aids in navigation in web pages but nowadays is used too online. The important thing is to not have visual distractions, so it always will be plain text.

According to Donna Spencer, who names it "*Card-Based Classification Evaluation*" this methodology only needs a proposed taxonomy and a set of scenarios with multiple and different user-tasks seeking information. Each level of the taxonomy will be written into a card, and the path through the cards (with the options selected) will define the user interaction. The overall idea is to minimize the number of times users must go back to an upper level, meaning they didn't find the information they are searching for.

Related to the timing to be applied, this technique can be used prior to the development of the test, or after it for validation purposes.:

· *Prior*: This can be done prior to developing a prototype to full test the interaction, as it's a cheap and fast way to validate your taxonomy.

· *after*: In case it's needed to validate a change triggered by detecting a flaw during an experiment.

A/B Testing, or split testing (if more than two versions are taken into account) consists in comparing different versions of the same instance, as it can be a web page, an application, a marketing campaign or an experiment (King et al., 2017). In UX usability it's usually related to the process of comparing two taxonomies (for example before and after a change proposed in a card-sorting, or detected during a tree test) or two prototypes.

In A/B tests two versions of the same thing are compared only to analyze one element at a time, so the results are only attached to the variable observed and the intention that observation had. For example, a hypothetical experiment modelled focusing on which mail subject improves the results of a test between students. Two types of messages are sent, each one to 50% of the classroom, one as the control group and another as the experimental group. The message subjects are "Remember that next week a test about this month's subject will be performed" and "This month's test will be really difficult! Study hard!". Then after the test, the score mean of each group should be analyzed to see which message was more effective, because only this is the intended result. If another variable wants to be extracted from there, it has to be reanalyzed as it can even change its sign. For example, how in the percentage of the students that have received each one has opened the mail or let it unread.

A/B Testing must be realized after the experiments:

· *after*: To validate the improvements over a previous instance or version.

· **Experts Review/Peer Review** that only involves a single, well trained professional with similar competencies as the producers of a given work. That review is highly dependent on the professional that conducts the analysis, as better results are obtained not only if the professional has a deep knowledge of test practices but a large amount of past experience in other projects. It is recommended that the expert has not been involved in the development of the analysis subject, and mandatory that the involved personnel is not present to avoid priming or bias among the test users. In technical areas, it is a well-defined process pointed at finding defects in each workflow present in the material being reviewed (Hirshorn et al., 2017).

This methodology can be expensive as experienced professionals come at a high cost, but it's usually a fast step as it implies a small team specialized in this sort of things. The cost to analyze the results is lower too, as the expert usually provides the data obtained fully digested.

Related to the timing to be applied, this technique can be used during the test:

· *During*: all the tests are conducted by an external team, as the analysis of the resulting data.

· **Field Studies,** Similar to the previous one, but the expert is analysing how the user is behaving. This is the most used methodology as it helps to understand how the final user will use the final product. That method is especially useful as the activities are developed in the user's context rather than in a laboratory. It's greatly used as a part of Agile development for the iterative reviewing (Recker et al., 2017).

The related activities are very wide, depending on if the researcher is interacting with the users or not and the objective. Studies can be Observational (look at how users are behaving in an environment), Querying (asking users questions and becoming more specific as the researcher gains knowledge over the topic) or Guided Prototyping Exploration (to detect issues before working on the final version).

Depending on the purpose, this technique can be used before during or after the experiment, with the results needed to be analyzed before progressing to the next phase:

· *Prior*: To gain knowledge about a given topic, a test can be conducted prior to the experiment design.

· *During*: The experiment is conducted in the environment the user is going to be in when using the final product. If this is not possible, the conditions must be as similar as they could be.

· *After*: To validate results or detect errors. This is usually related to an iterative process or Agile methodology.

All the previous ones are based on qualitative data (maybe not in the formal sense of the word), as even if we can assign points to the answers, those are always based on the subjective experience of the user, and thus difficult to extrapolate among them. It means you can only get the justified reason their brain processed, not the sensitive one, and humans are sensitive beings. This fact has a direct impact on a UX field test, as every person that interacts with an interface (and this applies, too, to the real world) brings their state of mind with them.

Usually, all written UX tests are pointed to an emotionally neutral user, who is asked if they feel frustrated after that interaction. Not many ask if they feel frustrated before it, as it's difficult to measure and even more difficult to establish a common context for all users. They don't take into account the daily circumstances that affect the interaction with the products they use. Curiously, everyone thinks that an angry driver is more dangerous than a calm one, but in a lot of research, it's supposed that in UX experiments an angry user will be as neutral in his opinion as a happy one.

For this reason, it is important to achieve a certain baseline before starting the experiment. The easiest way to deal with a person is to listen to them for a few minutes, and then try to induce them with the spirit of the experiment he/she is going to participate in.

2.2 UX Emotive Data - Biometry

Actually, there are multiple UX experiments that add emotive data to the cognitive data extracted by classical means. This increases the number of information researchers has about an experience by adding a layer of emotion, as classical methods try to gain insights from the answers of the users. That heavily implies that the user is currently understanding their experience and behaving and in an ideal case, objectively describe it. This includes being aware of their feelings and properly describing them. That is absolutely impossible as every experience is subjective. With the biometric data gathering a new area of study in UX has been opened, as now insights over the automatic body responses, including the unconscious ones, provides a peek about what the users are feeling before they even process it consciously.

In this state of the art for biometric devices review, only devices and technologies that do not need direct contact with the user are seen. This is because as the plan is to measure the body response, the minimum number of devices should be directly touching them (only EEG and EDA). In addition, only three devices are described for each technology, each one being the most representative for a price range (low cost, medium cost, and high-cost research-oriented devices).

Note that two of the most used biometric technologies are not seen in this compilation: face emotion recognition and voice recognition. This is because although used, they are not used in this thesis.

2.2.1 Eye Tracker

On the other hand, the passive data collecting of biometric information in a user interaction started in the 1950s with the first eye trackers. They were based on beams of light reflected on the eye and recorded on film. The first serious research was conducted in 1967 (Yarbus). In those experiments, it was shown that the fixations have more relation with the interest of the user at that point than with the image observed. He was the first to establish that the eye movement reflects the user's thought processes and monitoring it can give access (at least to some extent) to those thoughts without the need of the user to rationalize it.

This technique was developed during the ’70s mostly focused on reading research and was later applied to human-computer interaction during the ´80s decade. Applying those to computer-related fields improved the real-time results acquisition and led to new knowledge. Even with the theory of the Strong eye-mind hypothesis (Just and Carpenter, 1980) where is said that there is no appreciable lag between what is seen and what is processed (that theory has been often questioned and criticized due to the covert attention problem), and if it’s accepted that the user is thinking in what it’s attention is focused, only with eye-tracking information we cannot infer any cognitive process (as for example a fixation in a face may be for recognition, likeness or dislike). For this reason, eye-tracking technologies are usually mixed with Artificial Intelligence to complete eye-tracking analysis.

Name	Range	Technology	Price
Gazerecorder	Low-Cost	Software	Free (Webcam required)
Tobii Gaming ET	Medium-cost	Hardware	150-200€
Tobii T-60	High Cost	Hardware	14000€

Table 1: Eye trackers studied in this thesis.

2.2.1.1 GazeRecorder

Besides modern hardware solutions, “recently” appeared software solutions that use the hardware usually provided by a laptop, as “GazeRecorder 1.9” (GazeRecorder, 2018). It is basically a desktop eye-tracking application, that comes with a simple interface to design your experiments and integrate user inputs (like mouse and keyboard use). They use multiple state-of-the-art tracking algorithms to identify the face, eyes, iris and head movement to obtain the most accurate tracking possible.

This application comes too with an online webcam-based application, adding an API that allows integrating the gaze recording capabilities directly into an app or web page. As a web application, if a test platform can be made there’s no need to use a laboratory to perform the session. It works fine on a computer and on an android phone.

Its advantages are obvious, as every screenable representation can be analyzed using their very low-cost method, letting researchers track users in any laboratory or in their own environments (even home) bypassing the problems related to lab sessions.

In addition, it is completely free for non-commercial use, so it can be used for research without a budget.

As their weak points, it is obvious that using home equipment for webcam eye-tracking technologies has less precision than a lab-purposed infrared tracker. This means that the resulting data will suffer, especially with lower webcam resolutions and poor lighting conditions. Lower resolutions mean that not many of the webcams in the market provide HD (1920 x 1080 pixels), being the normal 480px. This implies that the eye will appear as one group, being incapable of differentiating pupil and iris (as infrared cameras do). In the same way, as webcams do not come with their light source, they will need a proper external light that provides the contrast needed to detect eye position against the rest of the face.

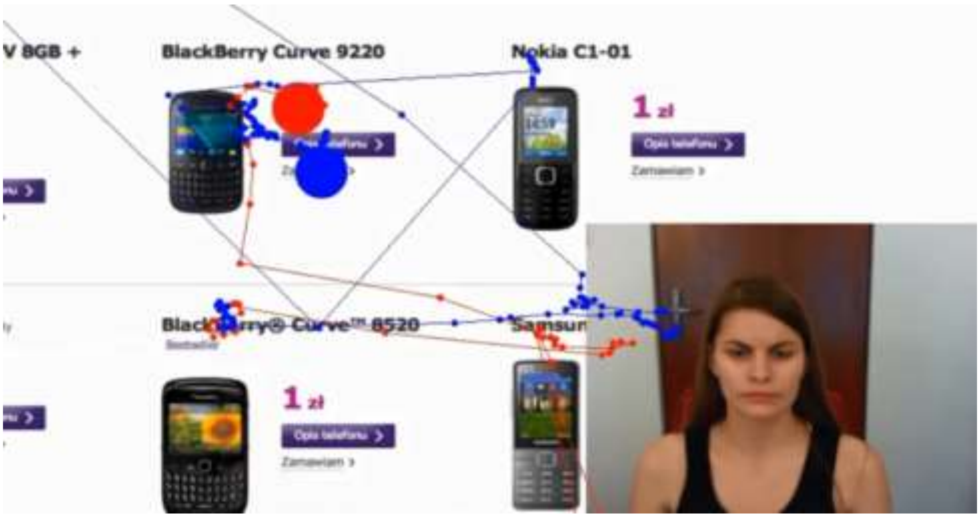


Figure 3: SMI Red 250 (BLUE); GazeFlow (RED). Source: GazeRecorder inc.[4]

These technologies are perfect for market studies, but as usual, the paper approval depends on the quality of the data extracted and the used tools, it would be difficult to use them for a scientific publication. Anyways it seems that with optimal conditions, the result can be comparable to a device using infrared light as an SMI Eye tracker (GazeRecorder, 2019).

2.2.1.2 Tobii Gaming Eye Trackers

Recently, and mostly thanks to their partnership with SteelSeries (a company that develops and sells competition-grade peripherals for video games) a lot of games (especially mentioning Ubisoft ones) added support for Tobii consumer devices.

Figure 4: Tobii EyeX1. Source: Tobii official page

[4] https://youtu.be/Y7q1frqhZdA

This led to new hardware, software, and business path for Tobii with their motto "you play, we analyze" to provide metrics to help e-sporters train and improve skills. Along with this, the new super-budget trackers **EyeX1**, **Tobii 4C** and the newest **Tobii 5** (all roughly 150€) allow the consumer to access this kind of technology.

Figure 5: Tobii 4C. Source: Tobii official page

Figure 6: Tobii 5. Source: Tobii official page

Although not as precise as the Tobii T-60, it is good enough to perform research with it and multiple publications had been developed using them (Elliott et al., 2019; Barresi et al., 2016) with the set of official software provided to extract the data, both in real-time or to be analyzed after the experiment.

Tobii Ghost allows you to see in a second computer the gaze captured from a gaming Tobii eye tracker in real-time and record it. Or if the desired result is having something similar as the research Tobii Studio, "Streaming Gaze Overlay" and "OBS Studio" can work together to develop a sort of "basic" Tobii Pro SDK.

Legally, reading Tobii 3.6 section of User Conditions:

3.6) Not for Analytical Use. Unless Licensee enters into a separate agreement with Tobii, the SDK may not be used to develop and distribute software that (a) store Tobii Data; or (b) transfer Tobii Data to another computing device or network; in both cases where the intent is to use or make it possible to use Tobii Data to analyze, record, visualize or interpret behaviour or attention ("Analytical Use"). To clarify; storing, using or transferring Tobii Data for the sole purpose of implementing software that uses Tobii Data for Gaze Interaction Use does not constitute Analytical Use.

Seems that this use is not legal without owning a pro SDK license, but it is a polemic fact as the data can be extracted from the screen directly, where (legally again) stops being Tobii Data. So, some groups used that this way. This makes it acceptable for students who want to be introduced to the topic, but not suitable for research groups if they don't buy an official research license.

2.2.1.3 Tobii T-60

This eye tracker was built integrated into a 17" TFT monitor that was shown to be ideal for all forms of eye-tracking studies in a static environment. That means that is limited only to stimuli that can be presented on a screen.

The T60 consists of a special display equipped with infrared sensors and cameras (integrated and hidden onto the display chassis so it's not seen by the user) to analyze the eyes and a webcam to record the user during the session. As it is a research version, image processing software is provided to locate and identify features of the eye.

It requires a 2-5 minutes calibration session with every user before starting (sometimes that calibration must be repeated) to guarantee precise measurements. The device performs really poorly when the users are wearing glasses, so if they don't need it at that distance, it is recommended that they don't use it.

Its work is centered on the monitoring of the foveal region, where most of the visual data is recorded and transmitted to the brain, despite being less than 10% of the visual field.

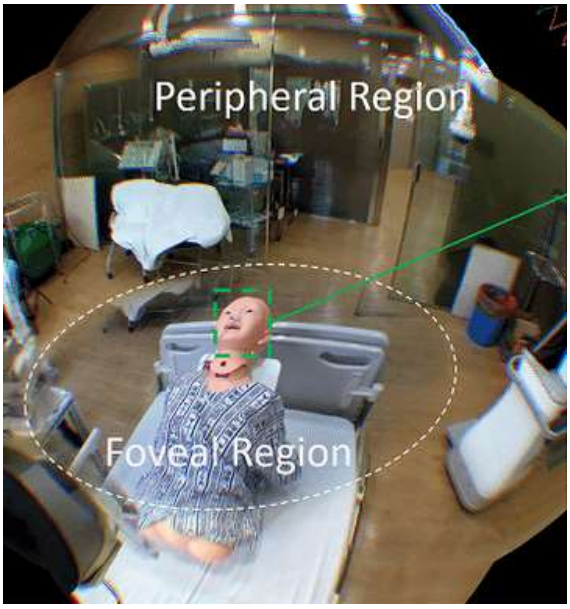


Figure 7: Foveal region view. Source: (Syawaludin et al., 2020)

The fovea is surrounded by the parafoveal region and the human eye attends to both areas at the same time, without the need to move the eyes. That peripheral vision has very poor precision, so it's mainly used to collect movements and contrasts.

Infrared light is projected into the eye causing reflections that will allow eye tracking. When light enters the retina causes two different reflections:

- Ocular bright, or brightness of the pupil.
- Glint or corneal reflex.

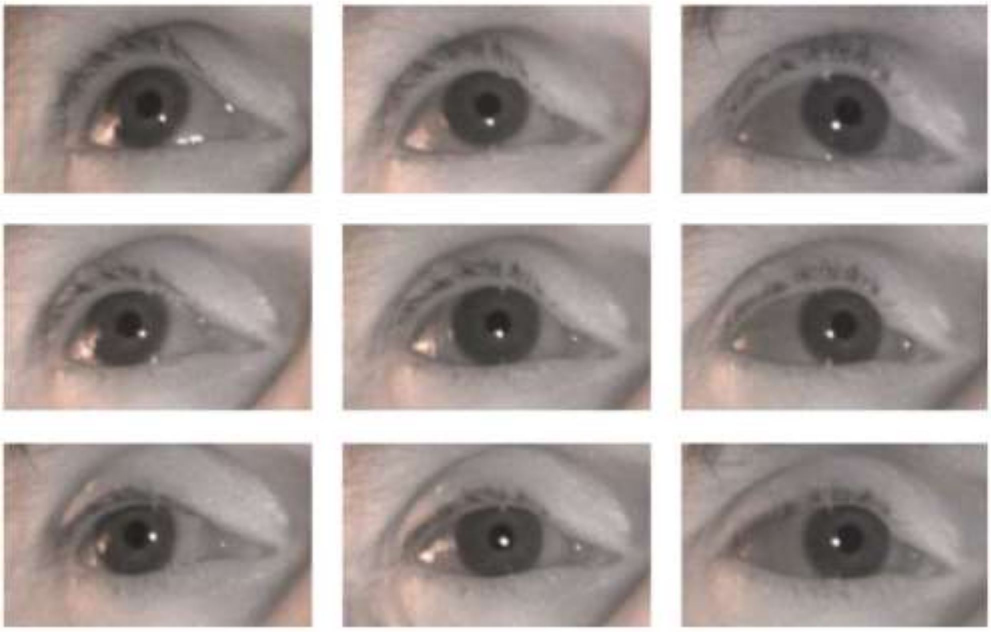


Figure 8: Corneal reflection at various gaze positions. Source: (Blignaut, 2014)

Once both parameters have been measured, using image processing algorithms, the fixation point and corresponding screen coordinates are obtained, regardless of head movements.

This device provides meaningful data on visual attention: which areas and elements of the screen are users focusing on (fixation points), for how long (heat maps) and what order they follow in their visual exploration (saccadic routes). The inverse of the heat maps are the “blind areas” that have been unnoticed by the user.

Figure 9: Saccadic route, heat map and attention zones, respectively. Source: Griho docent material

Although it is not a low-end device (in fact it’s quite expensive), that device was the Crown of the king in the research group while most of the tests were conducted, so we used it instead of other solutions. Unfortunately (or not), this model has been discontinued.

2.2.2 EEG (electroencephalogram)

Electroencephalography (EEG) is a neurophysiological probe upon brain bioelectrical activity in baseline conditions of rest, wakefulness or sleep, and during various activations using a device. It is mostly a non-invasive procedure, with electrodes (wet or dry) placed along the scalp (In UX research it is always non-invasive).

It is based on the measurement of differentials of voltage caused by the brain by the activation of different regions. Two main features are measured with the recorded data: Spectral content and event-related potentials. The first of them analyze the type of brain waves that can be observed in each frequency, the second observe fluctuations caused by a specific event as a trigger.

The waves that can be observed in an EEG are:

Band name	Band range	Associated with
Delta	0.5 - 4 Hz	Sleep, dreaming
Theta	4 - 8 Hz	sleepiness
Alpha	8 - 13 Hz	Introspective, restful
Beta	14 - 25 Hz	Active
Gamma	> 25 Hz	Concentration

Table 2: Brain wave types

It is a known technology for more than 100 years, as Richard Birmick presented in 1875 his findings on bioelectric phenomena in the cerebral hemispheres of mice and monkeys (by that time a craniectomy was needed). Hans Berger (1873-1941) began his studies on electroencephalography in humans in 1920. But it was not until early 2010 that a new generation of cheap devices opened the research for UX related experiences. It provides a resolution by far lower than newer methodologies like MRI (Magnetic resonance Imaging), but its mobile capabilities and better temporal resolution than other technologies make them ideal for UX labs.

Actually, we have different options in the market in the range of budget EEG headsets, each one with its own strong and weak points.

Name	Range	Sensors	Battery duration	Price
Mindwave	Low-Cost	1	8 h	70 €
MUSE	Medium-cost	4	5 h	250 €
EPOC	High Cost	14 + 2 Ref.	4 h	700 € (HW) + 7000€ (License)
OPENBCI	Open-source, Variable cost	Up to 16 per shield	25 h	Starting from 1000€ (HW)

Table 3: EEG Headsets used in this thesis.

2.2.2.1 Neurosky Mindwave Mobile

The Mindwave Mobile (Neurosky, n.d.) version was produced by the company Neurosky and it is the cheapest EEG headset that can be found in the market (100€ or less). This device is composed of a single channel dry sensor (it is said that in this region there are two sensors, anyways this is unconfirmed and acts like one) that measures the electrical signals in the FPz brain region (between FP1 and FP2 regions). With a sampling rate of 512 Hz and using 12 bits to represent the readed values, it is easy to disassemble the device to build more complex machinery. At the same time, the integrated hardware present in the headset processes the signal and removes the artifacts generated by the musculature and electrical interferences. The secondary sensor (the ear clip) is a ground reference, so it allows the measuring of the differential power between the two analyzed regions (Vourvopoulos & Liarokapis, 2014).

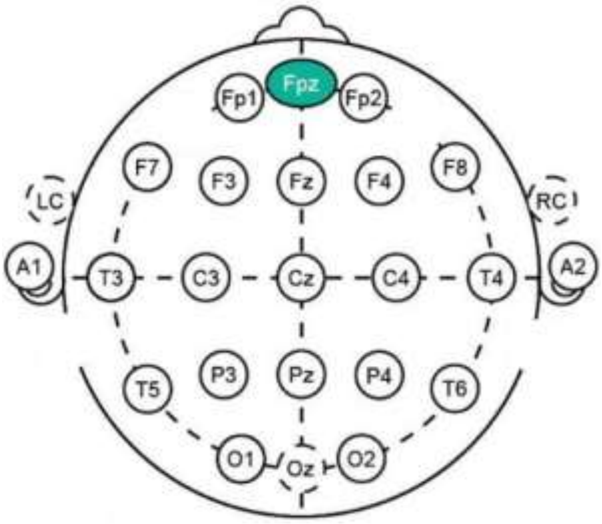


Figure 10: Neurosky FPz Placement. source: (Abujelala et al., 2016)

Its main flaw is that with only one sensor (in the frontal region) the resulting experiments are very limited, as it’s impossible to, for example, measure the difference between left-right brain hemispheres.

This is the only commercial EEG that works with a single AAA battery, but there is no affectation in its operativity.

It comes with some handy tools with their free SDK to extract data from virtually all platforms (pc and mobile) and the typical user-oriented tools for meditation (present in all the following products except OpenBCI), that measures Relaxation and Concentration levels. No data about the effectiveness of these “Emotional” measurements had been found, but it is supposed that it was as bad as other brand attempts.

It seems that data can be extracted without a lot of interferences (Wojciech, 2014) and has a good quality for being a dry-sensor even compared with a medical-grade (Rieiro et al., 2019) except for the fact that blinking needs to be removed by post-processing. It seems that with one sensor, the blinking-detection feature cannot be discarded automatically as the product owner says.

2.2.2.2 MUSE Headband

Muse is a device that provides real-time information about the brain activity of its wearer. Shaped like a headband with a hook-shaped end at both ends, designed to rest on the ears, it doesn't rely on wet sensors (unlike Emotiv EPOC). Throughout its structure, multiple sensors are incorporated, which collect electroencephalography data of its wearer, as well as some facial gestures. The four sensors are set on the positions TP9, FP1, FP2 and TP10 positions from the 10-10 Subset, providing values in microvolts up to 1682.815 uV. These sensors come with an in-built selectable notch frequency filter that erases all signals above 50 or 60 Hz alternatively (Muse Developers, 2018). In addition, a Driven-Right-Leg (DRL) circuit is added to reduce signal artifacts amplified by the skin itself (Winter & Webster, 1983).

It also comes with two accelerometers, a device that provides data on the attraction of the device in relation to the Earth's gravitational force used by positioning the device in space (basically to detect heads tilting). Although the EEG sampling frequency is around 3520Hz, the output is provided at 220 Hz with a width of 10 bytes, but by default is downsampled by 16 times to shrink the packet size (this can be changed).

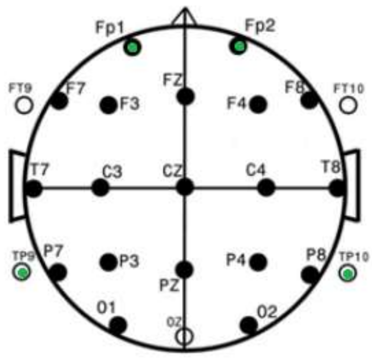


Figure 11: Muse headband location. source: (Muse Developers, 2018)

It provides a wide range of processed, muscular and experimental features apart from the raw measures. Among the raw measurements it can be found:

- Battery data.
- Voltage detected in sensors in microvolts.
- Accelerometer three-axis acceleration values in milli-g units.
- The number of packets lost (as packets are numbered).
- Contact indicator. To show if all the sensors are keeping proper contact with the skin.

Among the processed ones:

- FFTs (Fast Fourier Transform) of each raw sensor. This is the most important processed measurement as it computes the power spectral density of each frequency on each channel. Basically, it shows how much of a frequency there is over the total of the signal. The output is a 129-element array with values from -40 to 20 dB, for a frequency range divided from 0 to 110 Hz. These values are calculated each 10 Hz with a 90% overlap from one element to the next.

- Absolute power band (in Bels) for each frequency range (alpha, beta, theta, delta and gamma). This is the logarithm of the sum of the FFTs for the data over a frequency range.
- Relative Power Band. Similar to the previous but showing the percentage of the signal is composed by that frequency range.
- Band power session scores. A custom metric that increases the importance of the FFT value if it is outside the mean value provided during the session.

Among the muscular features:

- Blink detector. Represented by a Boolean, useful to remove artifacts.
- Jaw clenches, same as the previous, useful to detect and remove or discard during speech.

And the experimental features, note that even Muse developers point at those features as unreliable in most cases:

- Concentration, showing higher values when the user is thinking intensely. Based on the gamma signals, usually a lot of artifacts coming from the muscular features are shown.
- Mellow, showing higher values when the user is relaxing.

The original goal which Muse was created for was to give feedback from meditation sessions in order to know its performance. The feedback in the commercial version was auditive and was presented to the user through a mobile application.

Muse-lab is a Java application created by the developers of MUSE Headset designed to allow interaction with the device to programmers and/or researchers who want to use its sensors. The application is able to receive all signals from the Muse device through UDP/TCP ports once the helmet is paired with the computer. With the headset synchronized, the application is able to display the information in the form of a time graph showing the oscillations in the values of the signals in real-time and export them to a file to be analyzed in a second pass.

Museum-lab therefore, serves as a gateway for data being possible to use the output generated by the program for all kinds of different purposes.

2.2.2.3 EMOTIV EPOC

One of the first budget EEG devices oriented to the general public that appeared on the market, with a heavy amount of “do it yourself projects” made by different communities. One of those devices (and the most used one) is the Emotiv EPOC, in its non-EEG version. This means that the purchased license was user-oriented, and therefore does not give access to the raw data of the 14 EEG channels or the two accelerometers available in the device (Figure 1).

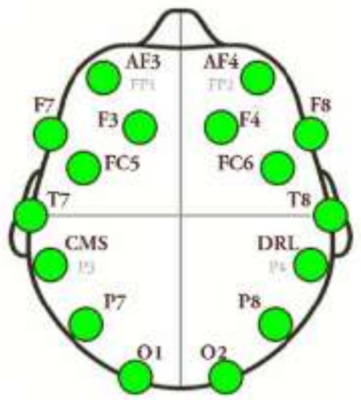


Figure 12: Epoc sensor location. source: (Muse Developers, 2018)

The characteristics of the sensors in this model are the following: 14 channels plus CMS/DRL references (located in the P3 and P4 regions) to filter artifacts, each one with 14-bit resolution (although the value of the last two is discarded automatically to compensate for the instrumental electrical noise) communicating with the computer via an encrypted USB with wireless technology (2.4 GHz). The acquisition rate is 2048 Hz although is downsampled to 256 Hz when transmitted to the pc. This USB ensures that the RAW signals cannot be obtained in an easy way. In addition, it compensates standard electrical noise by hardware filtering of "fast waves", keeping only waves between 0.2 and 45 Hz as valid. That sensor is monopolar, it means that the set of electrodes registers the potential difference compared to another electrode that is considered neutral instead showing the potential differences between pairs of electrodes (bipolar). This way the offset is common within all electrodes. Those 14 sensors (that provide EEG signals) must be wet with a saline solution to provide a good signal. It's not as comfortable as other devices, but its data is a lot more reliable. It's demonstrated that this device is statistically equivalent to traditional research-grade devices (Badcock et al., 2013).

Their Emotiv control panel allows you to view the three "Suites" that the User SDK incorporates: Expressive, Emotive and Cognitive.

· Expressiv performs a mapping of facial expressions (previous configuration). Its sensitivity and accuracy are surprising in the first instance (the helmet must be placed correctly), but there are many open-source projects that can perform better using a cam in a way extremely cheaper and non-invasive, so it's discarded for research purposes.

· Emotiv performs EEG data processing and shows emotional levels. The success of this suite leaves much to be desired (especially with further testing) in addition to the fact that there are values, such as the level of frustration, which can in no way correspond to the actual stage of the individual. It seemed to be a WIP or a "playground" for users.

· Cognitiv, through training, maps a few seconds of neural activity to a specific action. Trained actions can be visualized on a cube that simulates movement. This alone does not allow you to assign keys to thoughts, but in the settings section, you can access the Mouse Emulator tool (a bit hidden) that uses the gyroscopes of the helmet as a mouse and there the patterns saved in cognitive can be used to click buttons.

Emotiv had available a set of public tools (most of the free utilities by 2015 are paid versions by 2020) that interact with the signals treated in order to perform tasks. They had two main functions:

Interaction: Mouse Emulator and EmoKey are tools that synchronize with the different suites and allows the assignment of head movement, facial expressions and thoughts to mouse and keyboard actions. Both tools were free and sufficient for any user with neck mobility.

Data acquisition: If the experiment is related to user activation of external devices, data from the official SDK (Emotional, Cognitive, and Expressive Suites) can be shared with other programs through Mind Your OSCs, a program that converts the outputs of the processed signal to OSC network packet format. This data can be retrieved with Processing2's oscP5 library, an environment that can be processed with an Arduino to activate real-world devices (tchnmncr, 2011).

In addition, there can be found free programs to get the whole system up and running for research sessions.

The raw data (in case you don't have the research SDK substantially more expensive), can be extracted using the EMOKit project, which incorporates a series of scripts (in C and Python) to extract and decrypt this data, regardless of the SDK and operating system.

EmoKit (Brocious & Machulis, 2011/2016) libraries were a set of python code so the users can access raw stream data from Emotiv headsets built previously to the year 2016 (When Emotiv added an extra encryption key unique for each headset that must be decrypted somehow online, to finally remove any attempt to decrypt data). Later they published a C version called Emokit-c (Lemaignan, 2016/2016) that changes the technologies used, but provides the same data for the same headsets with a slightly different format.

The version was very Linux-focused but in Windows, the script works just as well if the correct equivalent libraries are installed on the system, noting that these dependencies are not shown in the Github repositories.

For Windows, copying these scripts requires the following dependencies (assuming a 64-bit Windows 7): gevent-1.0.1.win-amd64-py2.7, greenlet-0.4.2.win-amd64- py2.7, pycrypto-2.6.win-amd64-py2.7 and pygame-1.9.2a0.win-amd64-py2.7; obviously Python is also needed (version 2.7). Keep in mind that it uses python 2.7 as python3 isn't going to work. It should be noted that in order to work properly in Windows OS, python scripts must be modified by adding the includes from the socket or _socket library, even though they are not used (this seems to be a dependency problem).

Once running, the Render.py script shows a screen displaying the gyroscope sensors, using a white box that moves across the screen left, right, up and down following the head movement. Emotiv.py shows the decrypted packet sent by the headset.

2.2.2.4 OpenBCI

This is not a company that sells a product to make a profit with. OpenBCI stands for open-source brain-computer interface (BCI), created by Joel Murphy and Conor Russomanno from a KickStarter Project. As they claim in their official webpage[5], they provide the tools necessary to sample the electrical activity of a body with their affordable biosensing systems. Actually, they can be used to sample

[5] www.openbci.com

electrical brain activity (EEG), muscle activity (EMG), heart rate (ECG), body movement, among other uses. The truth is that it's affordable, but maybe not so for today's standards.

All their software is completely free and can be downloaded from their official webpage (OpenBCI, 2013) and it's written in Processing. There are ports of their code for NodeJS and Python.

They offer two versions of their hardware: Downloadable schemas (all their models are prepared to work with standard electrodes) and pre-mounted buyable systems. It is usually recommended that you buy an OpenBCI 32bit Official Board as it uses the ADS1299 Chipset specially designed by Texas Instruments for biopotential measurements. The use of this chipset provides highly correlated EEG features when compared to a high-end device (Frey, 2016) suggesting that it can be a feasible alternative to really expensive hardware. The first versions used an Arduino-compatible ATmega328P.

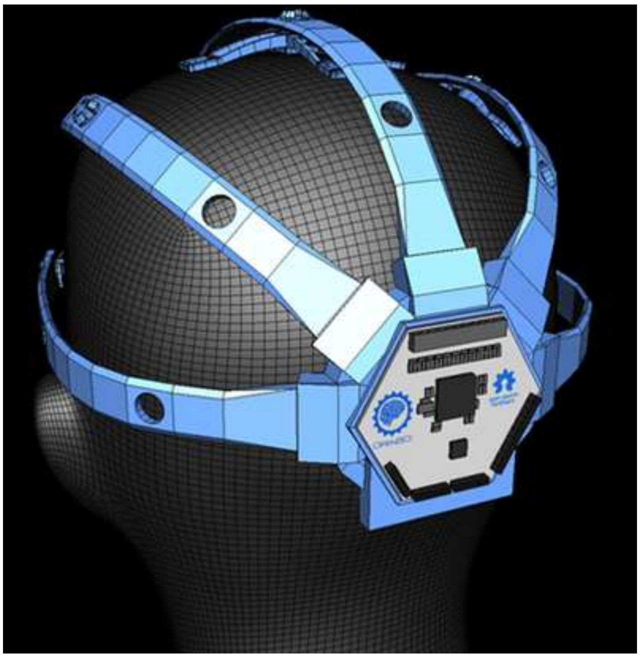


Figure 13: OpenBCI headband. source: (Muse Developers, 2018)

The mainboard can be connected up to 8 channels (can be expanded to infinite by stacking boards) each for one sensor, recording the data with 256 Hz sample rate and using up to 24 bits. Those sensors can be of any kind (wet, dry, silicone, etc) and can be easily adapted to the head using the 3D-printed models provided in their website. But while the extreme customizability of their devices is perfect for any occasion, it comes at a cost, as most of their bundled kits are comparatively expensive.

So its main flaws are their expensiveness, and to reduce it the experiment has to be focused on only one feature (Frontal asymmetry, for example) if you don't want it to escalate quickly.

2.2.3 Electrodermal Activity (EDA)

Named GSR (Galvanic Skin Response) in the past, as the history of research in this field by different approaches in different areas has ended up with a lot of different nomenclatures for the same feature, today standardized to EDA.

Electrodermal activity presents a set of features the most important are SC (Skin Conductance) and SP (skin potential), being skin conductance the most used.

The SC (Skin Conductance) of the skin changes its electrical conductance depending on its circumstances. This method uses the electric concept of conductance (which is the inverse of resistance) and implies applying a low current (0.5 volts): as skin conductance goes up the electrical current flows easier by the skin. This is the most used method for being considered more reliable.

SP (skin potential) measures the potential difference between two electrodes without applying current. Those electrodes must be placed in different places, as if two are situated on similar active places the differential would be lower. It is a not so used method as it's more difficult to interpret and requires larger devices to measure it, placed in further points than SC. However responses are often similar (Tronstad et al., 2013) being sometimes different by an unknown cause (it is theorized that it's due to the hydraulic capacity of the sweat glands of the monitored zone at that given moment).

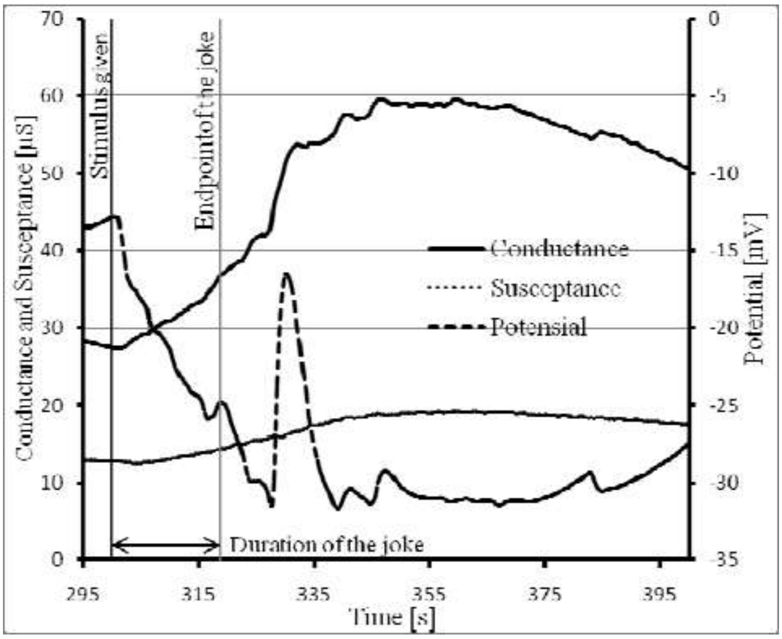


Figure 14: SC and SP comparison in an experiment. Source: (Jabbari et al., 2010)

It is a measurement that is influenced by the sympathetic nervous system resulting from a stimulus (that can be both internal or external). This means that it is an involuntary response based on the control of the sweat glands in the skin. The electrical skin resistance values are varying depending on the state of the sweat glands, which are controlled by the sympathetic nervous system (Martini & Bartholomew, 2003). Moreover, there is a direct correlation between the psychological and the physiological arousals, meaning that in an aroused mental state, caused for example by a presaged activity (going to the dentist) the sweat glands increase their activity too, varying skin conductivity. This is measured in microsiemens (µS) and the normal levels are a stable line between 2 and 20 µS.

This is the reason why EDA is used to measure emotional automatic body responses.

To record it, two electrodes apply a constant (very low) voltage to the user's fingers, and convert the current flow to conductance, measuring the resultant current conducted by the skin. The reason the electrodermal activity is measured in the fingertips is that in the hands there are more sweat glands than in other usually exposed parts of our bodies (the soles of the feet have many too) and they are more responsive to psychological stimulation rather than thermal sensations, being minimally responsible in thermoregulation processes (Dawson et al., 1990). Those sweat glands act as a set of resistors in parallel when filled with water (the main component in sweat) in a manner that when more "activated" glands, lower is the impedance in the circuit conformed by them. The changes in the glands array produce rapid variations in the measured signal.

Means and SEs for the three responsiveness measures, the mean skin conductance level (SCL), the number of skin conductance responses per minute (SCRs) and the sum of skin conductance response amplitudes per minute (S-AMPL), for each of the 16 positions. The positions are sorted on the mean SCL.

Position	SCL [μS]		SCRs [1/min]		S-AMPL [μS/min]	
	M	SE	M	SE	M	SE
Forehead	8.72	0.72	2.97	0.54	0.32	0.07
Foot (instep)	8.50	0.88	4.88	0.76	0.92	0.18
Finger	6.50	0.53	3.80	0.64	0.53	0.13
Shoulders	5.96	0.94	2.41	0.69	0.43	0.12
Neck	5.38	0.84	1.57	0.42	0.19	0.07
Abdomen	5.15	0.91	1.26	0.63	0.29	0.14
Calf (sock)	4.70	0.95	1.63	0.47	0.28	0.09
Wrist (vertical)	4.65	0.73	2.10	0.62	0.44	0.15
Buttock	4.33	0.59	0.98	0.35	0.19	0.07
Wrist (distal)	4.23	0.89	1.43	0.42	0.31	0.11
Chest	4.20	0.69	1.57	0.50	0.35	0.10
Wrist (central)	4.18	0.72	1.77	0.57	0.44	0.14
Thighbone	3.72	0.58	0.90	0.33	0.18	0.07
Arm	3.04	0.52	0.62	0.23	0.13	0.05
Back	2.18	0.60	1.21	0.43	0.26	0.09
Armpit	1.61	0.34	0.71	0.27	0.10	0.05

Figure 15: Responsiveness measures depending on the location. Source: (van Dooren et al., 2012)

The "single effector model" is generally accepted and used to extract information from EDA. There are two components measured in this model: the abrupt increases and decreases present in the signal performing peaks (Phasic) and the overall slow-changing baseline level (tonic). Those components have not "normal values" as it can be different for each user in the experiment, but usually tonic amplitudes increments or decrements slowly in the range of 2-3uS on average… with fear responses showing phasic peaks increasing them up to 8 uS over the offset (Braithwaite et al., 2015).

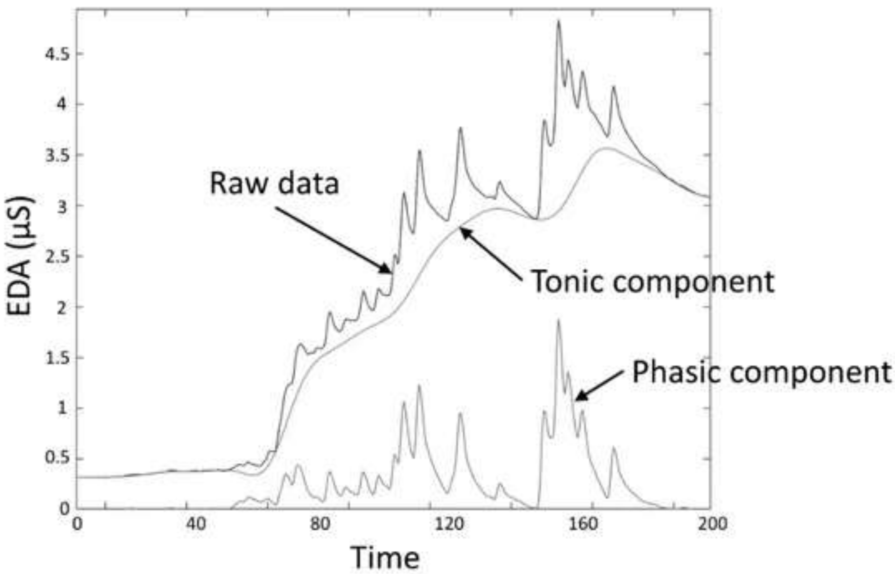


Figure 16: Different components of an EDA signal. Source: (Posada-Quintero & Chon, 2020)

It is difficult to measure tonic arousal, although when observed increases in the tonic signal it is usually an indicator of background arousal. For this reason it is not considered directly informative or easy to derive from. The same way phasic peaks in signals can be related to a given stimulus or not related to any peaks at all. If changes are not detected in a range between 1 to 4 seconds from a stimulus they are considered nonspecific, else they are listed as SCR (Skin Conductance Responses). SCR has a pattern consisting in a rise from the initial baseline onto a peak, with a decline after that generally finishes in a more elevated baseline than the pre-SCR levels. The amplitude in the peak is related to the intensity of the feeling (repeating stimuli would cause the peak to show less amplitude due to a process of habituation, this is commented in the following chapter), and a minimum of 0.05 µS of threshold is established to avoid false positives (Boucsein et al., 2012)

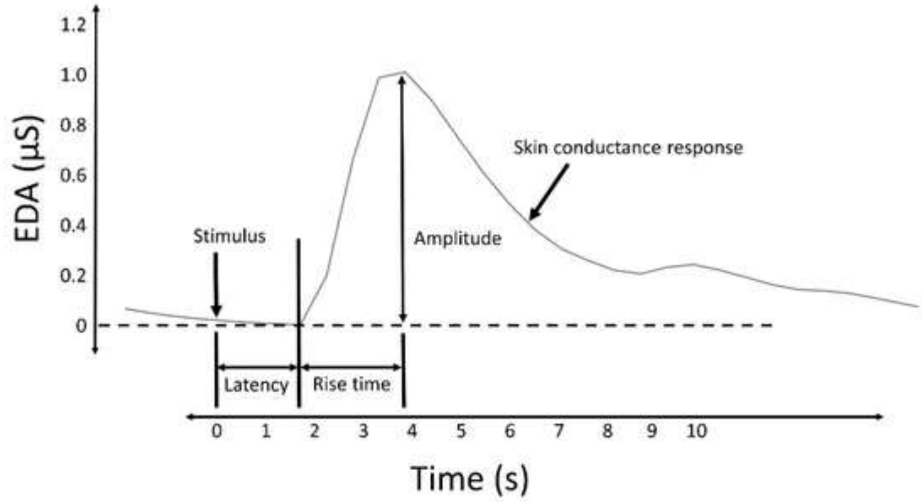


Figure 17: SCR from stimulus rise to signal decline. Source: (Posada-Quintero & Chon, 2020)

It is suggested emotion arousal increases peaks (Tomaka et al., 1993) and even specific cognitions may trigger the evoking of a specific skin conductance response (Nikula, 1991), but EDA only can show emotional intensity, not valence (if the emotion is positive or negative).

The devices studied in this thesis represent one instance of each economic range: low, medium and high research-grade cost.

Name	Range	Precision	Price
Arduino-Based	Low-Cost	Low	150 €
Empatica E4	Medium-cost	Medium	1500 €
BioPac hardware	High-Cost	High	3000 €

Table 4: EDA devices studied in this thesis.

2.2.3.1 Bitalino

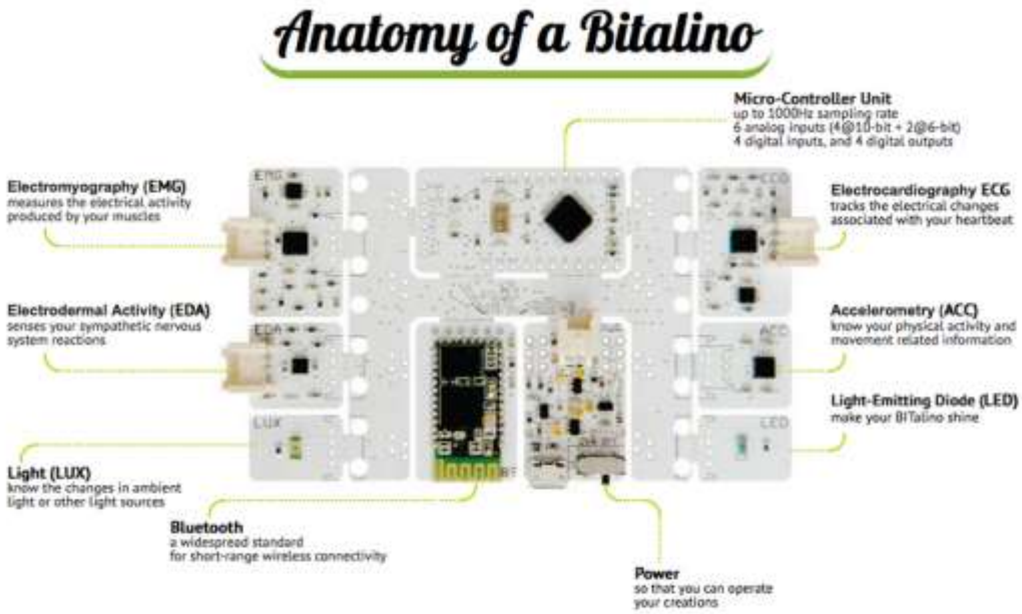
Bitalino is an open-source board based platform that uses the same processor as the Arduino Uno, focused on biometric data acquisition. It began in 2017 as a university project in the Institute of Electrical Communication in Lisbon distributed by a company named Plux-Wireless Biosignals. Its central unit can be connected to a myriad of sub-shields that monitor different aspects of biometry (EDA, heart rate, etc). Their hardware is low cost (Its *starter development kit* with all the peripherals costs roughly 150€) coming from two series: BITalino and BITalino (r), where the r stands for

Revolution. The only difference is that the r model sensors are 60% smaller (actually in 2021, the classic board is discontinued).

Its OpenHardware policy means that everything is customizable, and its parts can be interchanged with devices from different brands without affectation: The main board can be reprogrammed or changed by a normal Arduino, the boards for connecting sensor can be expanded with third-party sensors, or the opposite using the sensor of a Bitalino into another system (as long they can provide 3v and deal with analogue outputs).

The shields that pre-process sensor signals come pre-connected to the main board, but they can be split and rewired to match the required shape (for example to build a wristband).

The sensors come with a high sampling rate of about 1Khz per channel providing a digital value between 1 and 1023 by its analogue-to-digital signal converter (Bitalino provides a table for each sensor to convert those values to physical ones). Per board limitations, all sensors must acquire the signal at the same refresh rate. Unfortunately, the sensors are for general use, so they don't come filtered in any manner, it's the job of the technician to implement the physical filters or to filter the given signal.



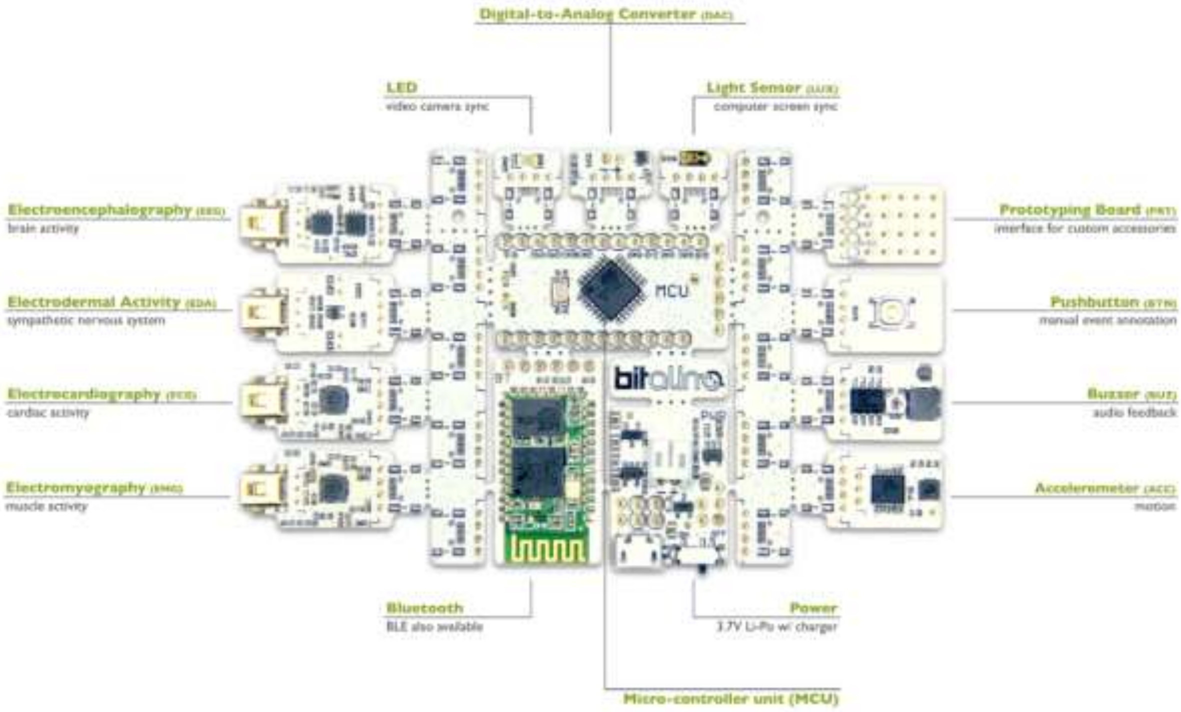


Figure 18: Bitalino and Bitalino(r) connected shield versions. Source: official webpage

The application development is really fast as they promote its software OpenSignals (a python-powered free framework to visualize data) and a large number of programming APIs to link the device with a program written in one of the provided languages.

The low-cost multimodal platform BITalino is being increasingly used for educational and research purposes in areas as health monitoring (Virgili, 2016) and sports enhancement (Morouço et al., 2020) as it has a high correlation with results obtained by reference-gold equipment (Batista et al., 2019) in EDA and ECG measurements; not so good for EEG measurements as in delta band the differences between devices are noticeable. Another of it’s advantages is that all their sensors are dry ones.

2.2.3.2 Empatica E4

EMPATICA is a spinoff of the world recognized MIT Media Lab focused on human data analytics and affective computing (Empatica Inc., 2013). They developed the first non-EEG based seizure monitor system approved by the American FDA (Food and Drug Administration) for use in epilepsy among the pediatric population, named Embrace. This is a smartwatch that captures physiological data in real-time and processes them with the objective to notify epileptic attacks (especially a condition called SUDEP, that leads to death) to a caregiver so the user can be helped (Picard, 2018).

The E4 Wristband is the research-oriented evolution of the Embrace providing extra information about heart rate, blood volume pressure, temperature and EDA. It collects real-time data from a PPG (photoplethysmography, which gives data about the heart rate and blood volume pressure) sensor, EDA dry sensor, 3-axis accelerometer and temperature sensor to stream it to a computer or mobile device. After that researchers can conduct in-depth analysis with a stored session.

Figure 19: Empatica E4 Specs. Source: official web page

Its use in research is focused on measuring arousal effects to study the emotions of a user. However, there are not many studies validating the quality of those measures, and those who try it seems that the quality obtained by the EDA sensor when the user is in motion is low (Milstein & Gordon, 2020). Even in those cases, it seems that the overall physiological changes (tonic response) between different situations and interests are reflected in the data obtained by the EDA sensor, even in motion (Shoval et al., 2018).

Figure 20: Empatica E4 Collected data. Source: empatica support page

Those validation issues will be solved by the next instance of their product: EmbracePlus which combines the Embrace comfort and the sensors present in E4, improved and this time officially validated.

The high number of sensors incorporated in this device makes it a great deal for its relatively low price (around 1400€) and as the UX related projects tend to be stationary, we think that the official specifications for the product can be trusted if the measurements are obtained in optimal conditions, meaning with the user not moving their arms in a desktop environment the phasic signals can be recorded without problems.

2.2.3.3 BioPac Student Lab

These elder teaching devices introduced in 1995 are among the most used data acquisition systems in undergraduate teaching labs. The system is so widely used (in undergraduate labs) that it has been adopted into the curriculum materials. The system comes with a generic universal data acquisition hardware with amplifiers to make it sensible to biometric data. This way the microvolts produced by muscles and even the brain can be identified by the central unit. The software comes with pre-defined scenarios that guide the researcher through all the process, from choosing the sensors and placing them, to analysing the obtained results.

Figure 21: MP41. Source: www.biopac.com

The most common version in the classrooms is the MP41, a single channel hardware for basic teaching. But that device doesn't fit into the research-oriented needs.

Figure 22: MP36R. Source: www.biopac.com

Among the researcher's community the most common are the MP36R, a 4-channel system approved for human and animal research. This is widely used in psychophysiological studies related to EDA activations and has been used and validated multiple times against research-oriented devices (Silva Moreira et al., 2019, Wu et al., 2016). Its official software *AcqKnowledge* includes automated analysis routines for ECG, HRV, EEG, EMG and EGG, which makes the researcher's actions post-experiment a lot easier.

A great choice if a research team doesn't have computer engineers in the crew, but more expensive than other solutions and less versatile, as the researcher is limited to a limited set of scenarios.

2.3 Self-modulation response

In the cases pointed by this thesis, all the metrics and data extracted using the previous technologies and methods are oriented to return processed feedback to the users with the objective to empower them in health-related areas. This thesis postulates that if people understand the physiological effects they are experiencing as a result of a given stimulus, they have the choice to improve their automatic response by a process called self-modulation.

This thesis follows the theories and tries to evaluate the model of "*The influence of a web-based biopsychosocial pain education intervention on pain, disability, and pain cognition in patients with chronic low back pain in primary care: a mixed methods approach*" (Valenzuela-Pascual et al., 2015). The main theory considered is that educational interventions can improve the knowledge of patients with chronic pain and thus having a positive impact on their attitudes, behaviours and life in general. The measured metrics were "pain intensity" as the main outcome, and "fear-avoidance beliefs", "kinesiophobia" and "disability" as secondary outcomes. The scores in those items were assigned using validated surveys (see the need for a face-to-face validation equivalence to performing a proper "Internet intervention" in section 2.3.2.2 of this thesis) and were measured before and after the two weeks that lasted the experiment.

The conclusions reported was that the Education Intervention kept the disability scores post-test stable in the experimental group, while in the control group keeps worsening by each iteration. As an extreme healthcare case, this is viewed as a success as there is no proper treatment for nonspecific low-back pain. In the other areas, the web intervention was trying to evaluate didn't obtain a statistically significant improvement over the face-to-face intervention.

These improvements are achieved by affecting nociception mechanisms. In the neurophysiology of pain, the nociception is the neural mechanism by which a stimulus potentially harmful is detected with awareness or without it by the central nervous system. This is said because dangerous situations (or those situations the user fears) trigger a subconscious detection of danger. This means that an experience can be harmful even before it really becomes harmful, as it can start hurting when the fear of the consequence is perceived (Holdcroft & Jaggar, 2005). For example, when someone feels pain when seeing a syringe. The phases of nociception are transduction, transmission, modulation, and perception (Fig Next):

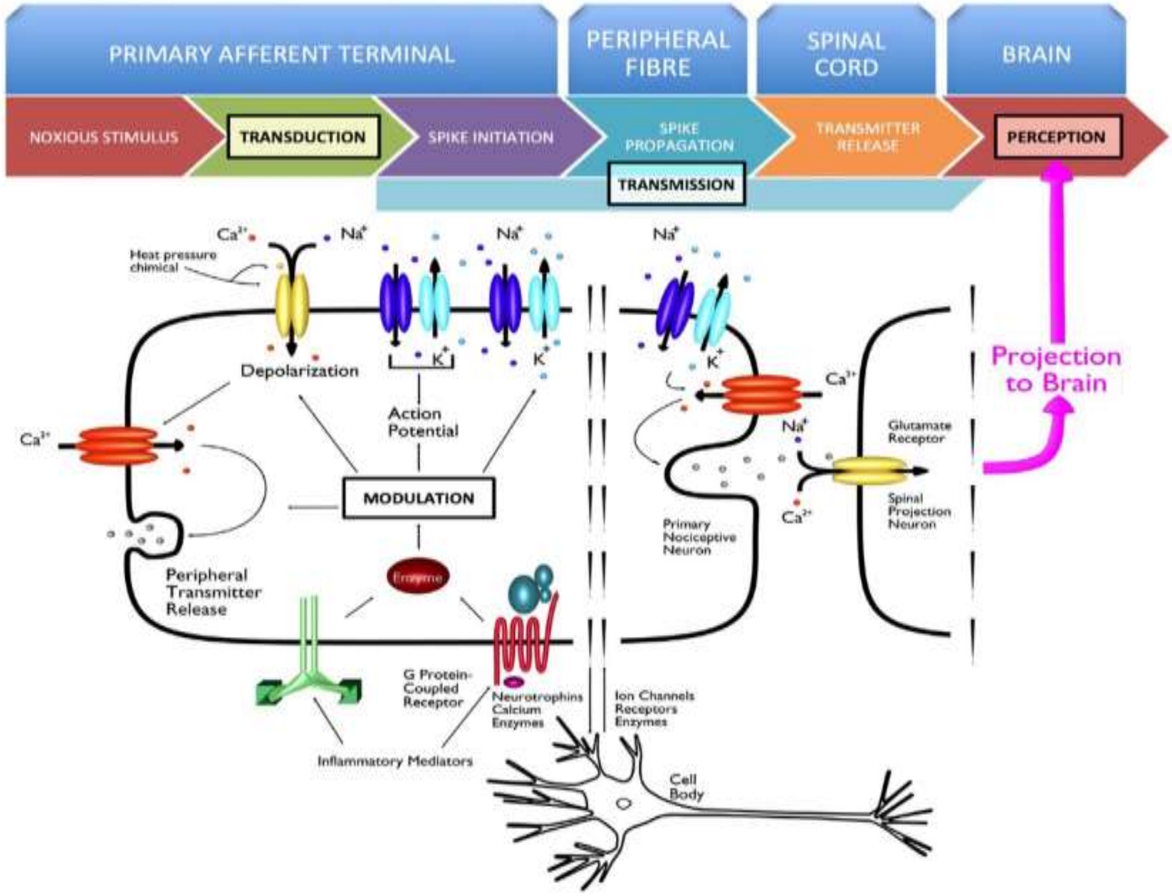


Figure 23: Nociception phases. Source: (Mertens et al., 2015)

Those stimuli are regulated at every stage before being transmitted to the brain with the result of increasing the stimulation or inhibiting it to a certain point (Tobaldini et al., 2019). The areas of the brain where that stimuli are processed are involved in other aspects related to emotion and cognition, meaning that there is some kind of correlation between the experience and the emotions felt during it (Ossipov et al., 2014).

2.3.1 Emotion Regulation

Following the same approach, emotion regulation has similar automatic mechanisms and it has a cognitive component even more important in the modulation phase (Gross, 2014). The awareness of the mental process of the phenomenon inevitably modifies the process itself by providing recursive feedback. Taking a cognitive-based attitude towards an automatic response has a direct effect over the experience and wellness of that person (Nielsen & Kaszniak, 2006) and it can be again, positive or negative.

This type of self-regulation is related to the activation of a group of areas in the prefrontal brain regions involved in cognitive processes and known to be developed later during the maturing process. This means that is a quality that is developed during the growth of a human being and, usually, it improves with ageing (Martin & Ochsner, 2016). It's a process that heavily implies previous experiences, but can be shaped externally during a session[6]. This is one of the parts most important to this thesis, as it's known that how a user thinks is shaped partially by how it feels in that moment.

[6] In this thesis, a session will be defined as a data acquisition from a user in a given context.

For instance the effects of stress are associated with both memory impairments and reduced hippocampal volumes (Lupien et al., 2009) while a deepening learning capacity has been shown for positive emotions (Yiend, 2010). This has exceptions for example with moderate punctual stress, which can improve learning by the increase in attention (Wang et al., 2015).

There are many emotion regulation techniques, one of the most common to be used and studied in neurophysiology is “reappraisal” (Gyurak et al., 2011). By definition, reappraisal is “an assessment of something or someone again or in a different way” (Oxford Languages, 2020). It is especially useful if more information about the stimulus that has caused the emotional response can be given as feedback, so the users can reevaluate their experience applying additional information gathered from their measured response. Providing external information is a good way to intensify any experience, especially bad or stressful ones.

But one thing to be taken into account is that this is an iterative process (Yih et al., 2019): during the appraisal of an experience, there is a cognitive and automatic component that it’s reevaluating itself during it. In (Uusberg et al., 2019) it is described how this varies depending on the moment that reappraisal begins relative to the emotion generation, splitting them into reactive or proactive instances. Proactive is when the objective of changing the emotion is set earlier than it. For example, a student can enter into proactive reappraisal when studying for a test in advance to not getting nervous during it. Reactive is the opposite, and the objective of changing the emotion is set during or even past it. For example, a couple after breaking up that rethinks how they felt in the past. Both examples are re-evaluating something that had been evaluated before adding new information, sometimes changing the emotion. This is why it is said to be an iterative process.

2.3.1.1 Negative Regulation

There are a series of negative regulation techniques that have to be avoided generally through both the processes of reappraisal and appraisal (meaning that they can happen before, during and after the experiment). We will talk about those most related to UX, the avoidant and the passive techniques.

Avoidant regulation is focused on the negation of the overall experience. The experience was not positive and the user tries to forget it as soon as possible so it does not feel anymore badly about it. Maybe they think it's their fault that they didn't achieve the test objective, or that they don’t have the knowledge to do the requested task, or are simply displeased with their interaction with the session conductor. This can even influence the likeness of the user to participate in future similar experiments, making it difficult to obtain additional feedback about what was the issue.

It is important that the researchers don’t provide anything but positive interactions, putting emphasis on the fact that this is exactly the reason why the test is performed, to address all the difficulties the user is experiencing because those issues will be experienced by other users in the future. As some studies demonstrate, the presence of support during a risky decision can have a buffering effect reducing emotional response to a negative stimulus (Callaghan & Tottenham, 2016). Similar results were obtained during one of our experiments, presented in Chapter 4, involving medicine students. In our case, we observed how those users were regulating (or at least trying to) their physical responses to lower their affectation.

Passive regulation represents the other face of the coin, with users focusing on what is their fault and they lack the knowledge needed to use the tool, so they don’t even try it. This kind of user often points at things like “I am bad with [insert the experiment subject]” or “I’m a disaster”, sometimes even from the start as if they were justifying themselves. This will almost inevitably lead to a bad experience. These kinds of users should be explained that they are an important part of the experiment and be slightly positively reinforced to avoid a bad experience from the beginning. There exists an automatic body response that affects EDA signal when dealing with threats (stress) and rewards (altered perception), even when it's a mental-dimension issue (Löw et al., 2008).

2.3.1.2 Positive Regulation

The objective of every positive regulation technique is to achieve mindfulness, a state of full attention towards the current activity, in a neutral emotional state. It is often applied as a meditation technique to decrease stress and it's the objective of most of the non-research oriented budget headsets, as it has been proven moderately effective in reducing stress and anxiety (Khoury et al., 2013). Various studies relate the improvement of those techniques when applying EEG feedback, where higher levels of emotion regulation have been achieved by a variety of methods such as lower amygdala activity (Herwig et al., 2019).

In the same way, it is important to be aware to not abuse the external positive regulation, especially when applying the use of rewards. There are two types of rewards, extrinsic and intrinsic. The first has a quantitative value and is usually given by a second person for having achieved a goal. Intrinsic rewards do not have a quantitative amount, as it's a psychological result of performing something difficult, usually giving it to yourself as an inner feeling. This is what usually leads to a mindful state.

Extrinsic rewards are great positive feedback, but their risk is that this kind of reward (and specifically the reward expectation) can interfere with the physiological response that is trying to be measured. A good example (and a bit extreme, but we believe that in the extreme experiments, extreme results can be observed) is the demonstration that using an economic reward in combination with other techniques can lead to an attenuation of tonic EDA signal caused by the expectations of reward (Delgado et al., 2008).

As the typical reward that is usually provided for being part of an experiment can lead to changes in the signals acquired, it is not recommended that the reward is informed before the experiment has finished, unless the experiment objective is just that, to evaluate how the rewards are affecting users.

Another important thing is that the feedback provided can be important *per se* to the point of becoming a reward by itself. This type of reward is usually intrinsic but can be enhanced with external feedback. In this direction, one of our first experiments (described in Chapter 4) involved patients from a fibromyalgia association. We found that most of the people suffering from this illness were affected by social unacceptance too. When their illness is finally diagnosed, and other diseases are thus discarded due to the difficulty of diagnosing, some of the patients suffer from the stigma of having "invented an imaginary illness" (textual words) to take profit from it.

As a theoretical experiment, we could not validate the data obtained because they were moving and performing different activities during the recording session, but we could detect some signals related to their brain feeling pain. This fact, by itself, provided them with great joy and was totally unexpected by the researchers. When asked about it, they explained the problem and put a lot of interest in the fact that what they really need is not relief (most of them had got used to the symptoms) but recognition as they are not lying about their condition. Personally, it was shocking when it became clear that their reward was more intrinsic, such as the recognition of others or getting their attention.

This is seen in multiple studies with this kind of patients, where adding the users in the development of the intervention improved the effectiveness of it (Camerini et al., 2013).

2.3.2 User Knowledge

Emotion regulation is not always an automatic response as explained before, but the lack of regulation or the conscious act of rejecting to perform a reappraisal can be present too. We've seen in some of the experiments (expanded in Chapter 4) where some users wanted actively to be centred only on the idea they wanted to project about them, and when asked directly they confirmed that they only wanted to show their attention at that point, ignoring the other focus. This was prominently seen in a neuromarketing experiment, related to political parties, where some of the users show a strong polarization even refusing to look at their "opponents". Cognitive regulation is always a choice.

This leads to another important point that is studied by this thesis: users sometimes need to be trained with an educational intervention to perform an action of reappraisal by themselves. This is needed when some of their beliefs do not match with reality or they have been reduced to a point that they cannot go on by themselves. Some of the cases are quite extreme, for example with chronic pain patients that cannot live in "normal" conditions. However, with this re-learning process, they can find new connections to change their perception through proper feedback. This may be due to things that they interiorized in past experiences or during reappraisal with negative feedback. For instance, the patient that started to believe she is imagining her illness because her environment is telling her so; the voter of a given political party that refuses to even look at the opponent flag; the student that has received bad feedback from a teacher and thinks that she cannot deal with certain types of situations.

It is known that patient education in medical environments can modify their cognition about the condition they are suffering from, allowing them to reduce apprehension and return to their activities (Engers et al., 2008). In collaborative learning activities, this can be applied too, as group-level regulation methodologies are often activated in order to face challenges with success (Järvenoja et al., 2019). Without a proper guide, those automatic group responses are not always successful, but almost always improve the overall experience of the group compared to the individual experiences of the members (Mänty et al., 2020).

Following these theories to a lesser extent, we can say that any experience can be improved by the means of educational intervention, in UX environments to enhance the experience, empowering the users to make them participants of their own experience. This leads unavoidably to an enhanced experience.

2.3.2.1 Information technologies

The objective of those technologies is to provide information to the users who are exposed to them, in a voluntary or involuntary way. This process can also be involuntary as users are going to unconsciously process all the information that is shown, including but not being limited to the point their gaze is fixed on the screen (Yoo, 2008).

As the data extracted from the Eurostat statistics in 2013 (Eurostat Report, 2013) shows compared to similar reports in 2019 (Eurostat Report, 2019) and 2020 (Eurostat Report, 2020) the percentage of people using the internet weekly have raised from 72% to 84% (77% on a daily basis plus 7% at least once a week as it is said in the last report, which can be added up) with peaks in some countries over 95%. In 2013, more than 60% of users in the 16-24 age range were searching for information about education (they stopped to ask this question after that year), while online courses have doubled in percentage over that time span (around 6% mean in 2013 vs. more than 10% mean in 2019).

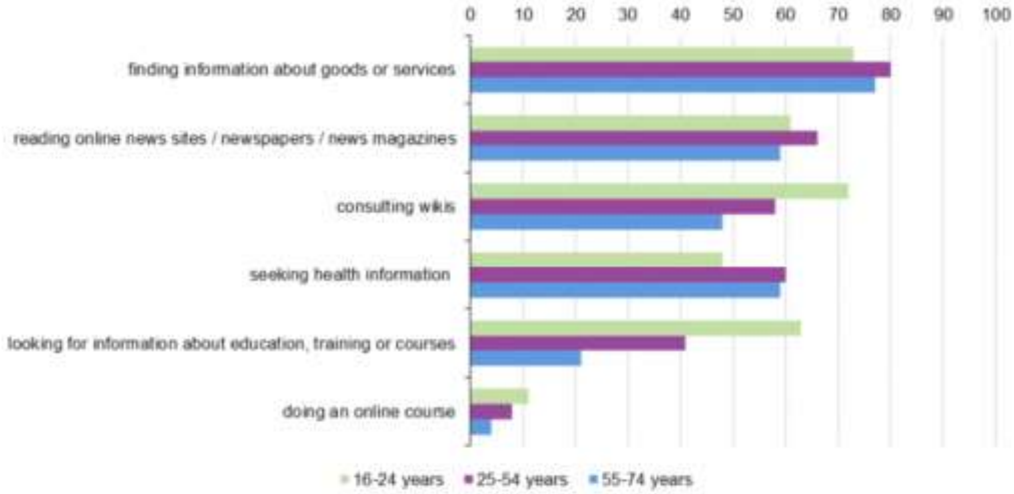


Figure 24: Use of internet for access to information and learning purposes, by age group, EU-28, 2013. Source: (Eurostat Report, 2013)

This is the mean in all European countries, so it covers a heterogeneous group of different cultures, traditions and economic levels. In any case, and due to these high degrees of use, the internet, and particularly the World Wide Web, is considered an extremely convenient tool to serve information to the users all over the world.

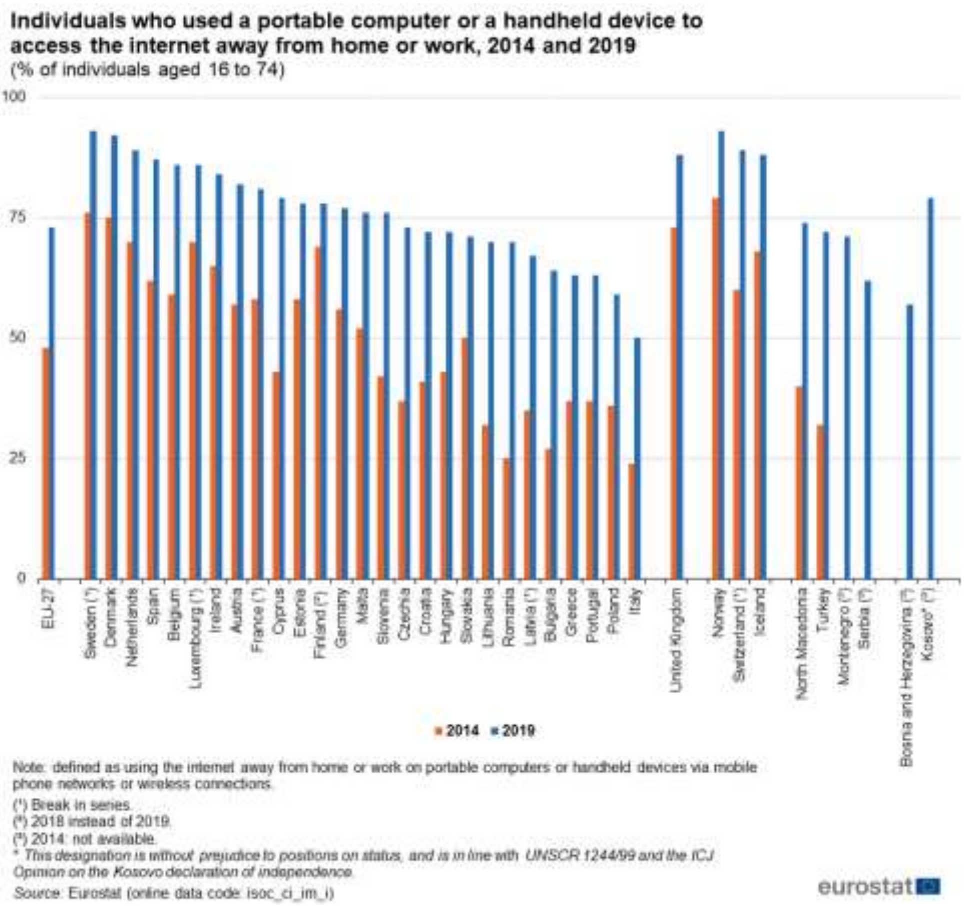


Figure 25: Handheld devices in Europe 2014-2019. Source: (Eurostat Report, 2019)

Most of them are accessing the World Wide Web using portable devices, as this trend has increased from 48% in 2014 to 73% in 2019. Note that for most studies, Eurostat has stopped making distinctions by age range and that this data is not referring only to smartphones. In any case, a ratio of three out of four using the internet regardless of user age is a quite impressive data.

This shows the importance of a high degree of responsiveness and usability of the interactive applications developed. They should be easy to use as they can be accessed (and will be) from anywhere, any kind of device and by almost any type of user belonging to any age range.

2.3.2.2 Educational interventions

Educative interventions over web platforms are a common methodology used in medical fields achieving extremely good results. (Poddar et al., 2010) and (Springvloet et al., 2015) are good examples of a successful web-based education intervention related to nutrition topics in young people and adults respectively, where medium-term effects on users are suggested.

On the other hand, it's difficult to find studies that are not related to health-related or applied knowledge areas. It can be due to the fact that it is difficult to not fall into unethical situations when applying adult learning theories to change the opinion of a sensitive being. This lack has been pointed by (Ritterband & Thorndike, 2006) where as an internet intervention developer criticizes the paper (Kerr et al., 2006). In that publication, Kerr tries to address quality criteria for "internet educational interventions" based on 10 examples, but it seems that all the analyzed experiments were "new" medical education interventions. The complaint states that internet interventions are cognitive and behavioural treatments adapted to be delivered via the web (Griffiths et al., 2006), and based on effective non-remote treatments. As the treatment, it must be customized to each user to fit their specific needs.

So formally, a new approach for an education intervention without a physical, face-to-face validation has the risk of not being considered proper "internet intervention" as described by Griffiths. Rittenband does not doubt about the effectiveness of the results but states that a new method must at least to be validated against another validated method, and proposes that there should be an authoritative body to deal with that process empirically.

The target users must be taken into account when designing the intervention, as it should fit the needs of a heterogeneous society with different kinds of strong points and disabilities. For this reason, the elements used in the intervention may be easy to use, favouring multimedia over text to make it more suitable for different degrees of reading capabilities (especially if our users are part of the population at risk), or interfaces they are already used to if users are teenagers.

2.3.2.3 Improving Motivation: Gamification

All the needs specified above can have an impact on the user interest and willingness to participate in the intervention. Gamification usually is introduced to add interest in those kinds of experiments to improve the willingness to participate by adding elements and dynamics from the games. Games are activities realized inside a determined set of rules, that usually finish in a goal state (wining).

It is not strange to use games for training purposes in almost every field as applying gaming in activities improves user engagement and learning capabilities. In addition, the gamified experience usually has implicit feedback, as the game score is usually based on user actions performance over a set of game rules. An interesting type of game is the one that is giving feedback to the user in real-time in a natural way, showing the logical consequences of their acts in-game. Some games provide both types of feedback, an “actual state” at any given point and a summary at the end of the game.

There are three typical game mechanics, depending on how the users interact between them:

- **Competitive** mechanics rely on users racing against them for positions in a leaderboard. Usually, they receive points for performing tasks successfully.
- **Non-competitive** mechanics present the experience as a solo path. Users get badges for completing a set of tasks. Sometimes to enhance the experience, those tasks are non-linear, dependent on other tasks performed or are not mandatory at all, meaning that every user will have a different and personalized experience at the end.
- **Cooperative** mechanics often present their objectives as “team quests” and the communication between members is essential. OKR methodology (Doerr, 2018) (an acronym for Objectives and Key Results) is an example of how results tracing can be gamified in a company.

Independently from the mechanics, there are common elements that are usually present in learning-oriented gamification (Jackson, s. f.). The most common are these (but are not limited to):

- **Points**. These can be used in different ways, but in the end, they are only a numeric field that increments when a task is performed successfully from an initial stats, usually zero. With the game finished, the amount of points shows the user performance. This way the player can repeat the game with the objective to improve that score, showing that the user had learned over the process.

  If the objective of the game is not only to improve good decisions but to penalize bad ones, they subtract points to the total score. An inverse point system is used sometimes as a separate variable: it starts from a given amount of points, and each wrong decision decreases that number. When it arrives at zero, the game finishes. This is the principle of “health bars” in most games.

  When the objective is to show the development of the user during the game, it’s frequent the usage of a level system. Each given amount of points increases the base level of the user, who is considered more experienced by that. This feature encourages the user to acquire more points.

- **Badges** are rewards in the form of trophies or achievements as a reconnaissance for performing a given action, or a set of actions, inside the game playthrough. Their advantage is that they exist “outside” of the game world, as you give them to the real users. They have a double purpose: increasing user implication (they may want to obtain more, and as a consequence play more) and persuade users to follow a certain path or set of actions. For example, when detected an unused feature of the game, giving a badge to those who use it may improve its usage rate.

  They are usually public and are strongly focused on community interaction, even private ones are usually shown between friends.

- **Certificates** are another type of rewards similar to badges.

They are a most “official” notification of having performed a task inside the game, and they are sometimes recognized across platforms (for example a certificate for Udemy is accepted by Linkedin).

- **Leaderboards** are a public section where the performance of the different users are listed in a competitive way. If the listed feature is their score, it is called scoreboard. In one game there can be multiple boards pointing at different features to motivate the different type of users (this will be seen later).

  This element can present some problems as all the users who participate in the game will be competing against them. That can turn the learning effect into a “score-at-all-cost” effect to win, diminishing the learning process and demotivating certain types of players.

- **Collectables** are bonus resources or items that are obtained in-game but that are not necessary to complete it. Most of the time they are not even influencing the final score, but it gives the user an excuse to explore the platform in-depth as they are hidden or difficult to obtain.
- **Pathways**. Not all users want to follow the same path when interacting with a game and each user must find their own way to participate in the experience. For that reason even when the gamified experience is linear (there is a defined series of actions that every player will have to perform) it will be an illusion that the user is deciding.

  Best gamifications will provide various ways of doing a task or even better: different tasks to perform that leads to different endings.

  Quests divided into **objectives** are a way of grouping a series of actions, involving a given complex objective. This is a way of making interesting a task perceived large in scale, by giving little rewards when finishing parts of that task. As an example, filling a survey with one hundred questions could be perceived as a time-consuming task, but if this is presented at a quest to “providing the needed information” divided into 5 objectives (filling five different forms with twenty questions, each one with a different topic) things changes by the user point of view

- **Countdowns**. They can be added to any gamification element to add time restrictions. This can be used to encourage users to do some kind of things or to add a control layer to the feature:

  Quests can come with a timing to complete all the objectives, when not completed all, the player needs to start from the beginning again.

  Leaderboards can be time-limited to avoid the same users getting too much advantage. This usually leads to weekly, monthly and all-time leaderboards.

- **Personalization**. As a part of the pathway, some players like to put their personal print on the experience, especially in the long-term experiences.

  If a user is going to put a lot of time and effort, these features will increase their own self-identification with the achievements.

- **Unexpected events** or **Microinteractions** are focused on surprising the user. This will help the user focus on the task, especially in those more boring and long. This can be sound, visual signals, anything that the player is not expecting.

Easter eggs are unexpected features included as a joke.

Those elements are usually used together as a combined gamification typology to meet the interests of different types of users at the same time, creating a complex behavioral ecosystem. From a classical gamification point of view, there are four types of user behavior in a game (Bartle, 1996). Bartle taxonomy defines two-axis and situates the user type in quadrants, depending on if they are more focused on the dichotomy's action/interaction and players/world:

Figure 26: Bartle's Taxonomy. Source: (Kumar et al., 2020)

- **Killer**: They are really competitive, and uses all the other qualities of the game (such as exploration) in finding new ways to have an advantage over the other players. The main difference between killers and explorers is that they want to see the others lose as a way of reaffirming their victory. Bartle findings suggest that a small number of users fit into that class, less than 1%. They become engaged with leaderboards, badges and ranks.
- **Socializer**: They enjoy the game by interacting with other players, seeing the game as a tool to build relations with the others. They are more prone to collaborative work and are happy to collaborate to achieve more things that they can do only by themselves. As the more common type of user, around 80% of the total users fit into this class. They became engaged in community-oriented items, like forums or chats.
- **Achiever**: users who like to reach goals by their personal development. They have in common with killers that they are also very competitive, but in a less direct way, as they see the competition about self-achieving over being better than the rest of the players. Badges are perfect for them as they like to show others how they are progressing. Around 10% of the total users fit into this class. They usually become engaged with badges.
- **Explorer**: users that are most interested in discovering what the game has to offer than by the game or the competition itself. For them, the discovery is the reward and usually are fine with repetitive tasks if they lead to new findings. They don't like experiences "on rails" or when the steps are scheduled, so they don't want to be bound to a predetermined path. Around 10% of the total users fit into this class. They usually become engaged in experiences with unlockable paths.

Categories are not rigid as users tend to present traits from more than one group, with one dominant predisposition. This is the reason why most gamification attempts should have elements of multiple classes to be attractive to multiple types of users. For example, running a Bartle online test[7] with 2 options for each question gives me a KAES (an abbreviation of the 4 user classes) percentage of 80% Killer, 67% Achiever, 33% Explorer and 20% Socialiser in collaborative gaming: A bit worrying result.

Bartle proposed an expanded model with a 3rd axis (about implicit/explicit attitude) that splits the 4-type model into 8 subtypes. Taking a 3D online Bartle test (mudhalla.net, n.d.) with a lot more questions (54) and a 1-to-5 (from totally agree to totally disagree) answer style is coherent with the first result, as the type is implicit Killer 87% (Griefer) with traits from implicit achiever 59% (opportunist), explicit explorer 50% (scientist), explicit achiever 47% (Architects), 41% explicit killer (Politician), explicit socializer 38% (Networker), implicit explorer 35% (hacker), and implicit socializer 28% (friendly). The more complex the test becomes, the more splitted traits are found.

In the following years, those classic groups had been expanded with the Octalysis Framework (Chou, 2015), which rearranged them and added a new dimension to the 3-D Bartle expanded version. This new version is the motivation, which can be extrinsic or intrinsic.

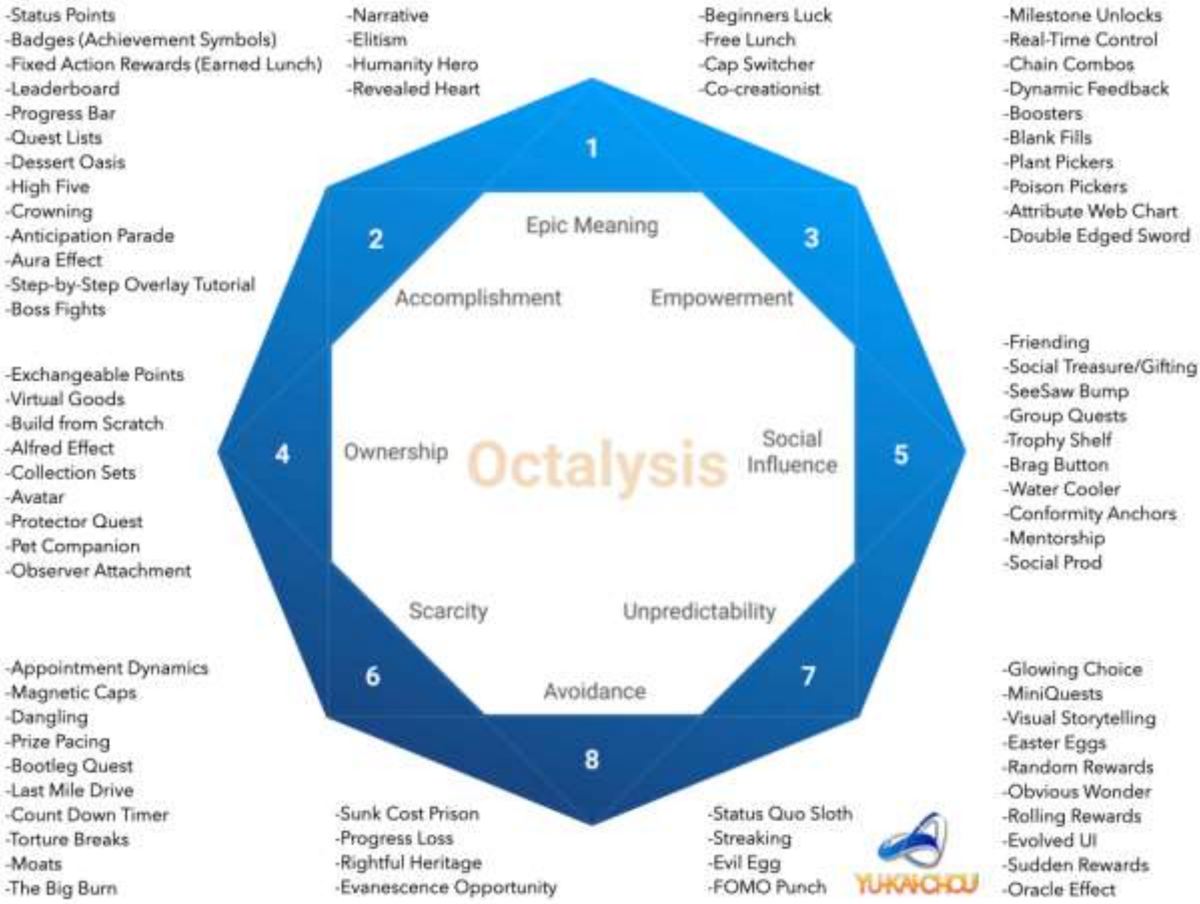


Figure 27:The 8 core drives of gamification. Source: (Chou, 2020)

Extrinsic motivators appeal over the user willingness to obtain something, it can be an item, a reward or even a goal by itself. Intrinsic motivators appeal to the inner world of the user, that wants to use their creativity or socialize, but they don't want any kind of reward, as the reward is the experience by itself. These kinds of motivations are related to a different "brain core area" each one, so with this distinction, a symbolic map about the active side in the brain of a user during a gamified experience is

[7] https://matthewbarr.co.uk/bartle/

defined. The left side of the brain is related to extrinsic motivators and the right side with intrinsic ones.

This new ordering recalling the intention of a user provides an interesting point of view, as it focuses on what players obtain from the gamification rather than how they behave. This takes into account that users are not like a clockwork machine, they have needs that they are trying to satisfy during the gameplay.

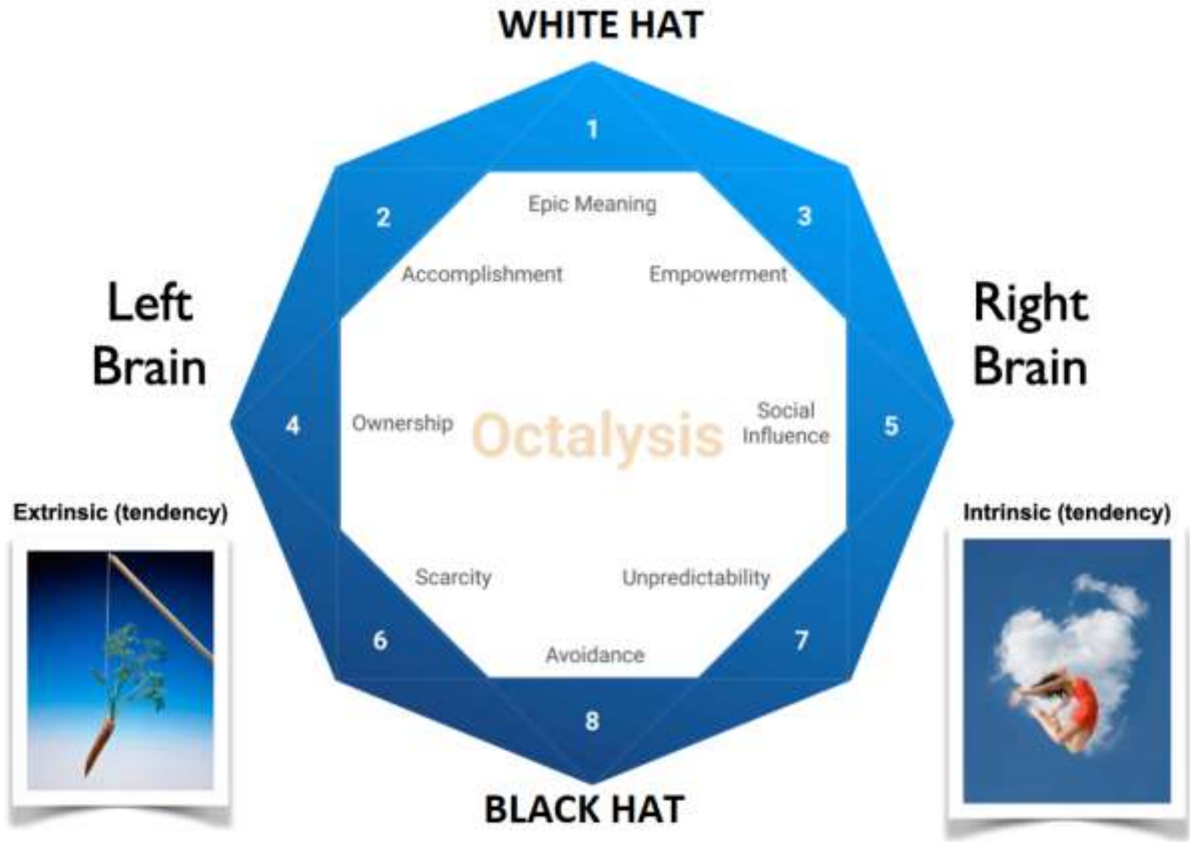


Figure 28: Extrinsic vs intrinsic: (Chou, 2020)

This model adds another point of view into the gamification experience, as this one adds negative (called Black Hat) and positive (White Hat) motivations. Bartle doesn't point to any of the profiles as having good or bad motivations, as all are focused on keeping the game ecosystem levelled. With this new classification, upper motivators (White Hat, positive) are those that let you express yourself making you feel successful, while bottom motivations (Black Hat, negative) appeals to the fear of losing and “leads to getting a bad taste”. It’s important to take into account that negative motivators are not intrinsically bad, all motivators are good if they are not used to obtain malicious results.

From this point of view, (Tondello et al., 2016) proposes a six-class types of users regarding if they are willing or not to play, and what each one obtains from the experience.

Figure 29: Willingness to play and user types - Intrinsic. Source: (Marczewski, 2015)

To add the intrinsic/extrinsic disruptor axis for each type of user, except the ones that they only want to play (as the game itself is the reward and they don't demand much more for it), the polygon is splitted into a 3D model with the three-axis pointing at if they are more prone to interact with the user or the system, acting or interacting, and if their reward will be intrinsic or extrinsic *(Marczewski, 2015)*. This 12-side model shows at 3 and 9 o'clock the disruptors type user, 12 and 6 o'clock the extrinsic type users, and at 2-7 4-10 axis the intrinsic user types. Each one is situated inside the quarter they fit if its final purpose is taken into account (marked in red).

The main difference between this model and Bartle's one is the decomposition of the killer/winner user into four different disruptor subsets. In Bartle's theory, killers are a type of player that gets its reward from dominating and humiliating other players, and this doesn't necessarily mean winning. In *(Marczewski, 2015)* it is assumed that dominant players are not inherently bad. Some players don't want to control their opponents to crush them (Griefer) but to help them (Influencer). And finally, the griefer is the classical killer type of Bartle. The same is applied to users who are trying to change the game to destroy it (Destroyer) or with the idea to improve it (Innovator).

Figure 30: Dodecad of user types. Source: (Marczewski, 2015)

As it's pointed out by the author too, all the different user types have traits from other types, and they are interacting with the other users. A healthy gamification is where all the types of users can live together in the same space. But what's interesting about this author's proposal is that he defines not only a static view, but also interactions that affect the evolution of user behaviours to the point they change their type.

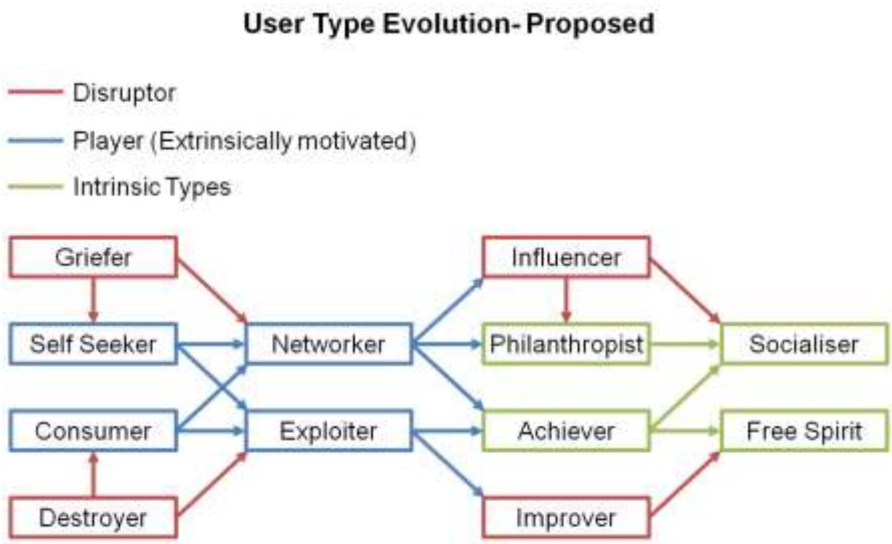


Figure 31: User evolution proposed. Source: (Marczewski, 2015)

2.4 Chapter summary

So we can say that the answer to the question **"What type of cognitive and sensitive measurements are collected by UX nowadays? And how?"** is:

- Qualitative measurements can be extracted using common UX methodologies, but more reliable emotive data can be extracted using biometric devices.
- The collected measures can be trained to be more inhibited or accentuated.
- Adding gamification components in the experiments and interventions increases engagement and motivation, especially for long-term interventions.

Chapter 3 - Methods

As the proposed methodology presents a series of issues that have to be faced in order to produce reliable data (see Chapter 2), we will discuss **"How should an experiment be performed?"**. First of all, we have to take into account the question **"What will be the objective of the study?".** After having the objectives defined we will ask ourselves **"What devices are we going to use?"** and **"In what context are we going to use those devices?"**. With this information, we can search for common known issues related to the devices and contexts to address them (or to take them into account in the experiment design), define how the interaction with the user must be performed depending on the context, and finally carry out the experiment.

3.1 Common issues

Some issues are present across all environments and if not always mandatory, addressing them usually reduces chances of failure and post-processing time in general. Common issues are related to things that are present independently from the context[8] like electric currents or electromagnetic emissions, test users psychological or physical limitations or issues caused when users interact with the researchers.

3.1.1 External interferences

The proposed methodology relies on electronic devices, so electrical and electromagnetic interferences are a reality, especially when speaking about low budget instruments. EMI is the general term used for electrical signals that interfere with the normal operation of electronic equipment. They can interfere with data acquisition systems based on measuring magnetic potentials like EEGs. A variation of EMI is RFI, this is when the band interferes on the radio spectrum. In this case, the main danger is to lose information in the communication between the devices and the data aggregator (that can be a PC, a tablet or a specialized device to store data) when wireless technologies are used (Sue, 1981). In addition, most of the devices causing interference produce an auditory vibration that can be identified as a "buzzing" and is usually perceived as unpleasant by people. For those reasons, tests should be conducted in laboratories adapted for this purpose whenever possible.

One method of detecting interference is using a Gauss Meter, a device that displays electromagnetic measurements. Even a cheap one, around 50€, would be an interesting addition to the laboratory equipment. If none is available, many smartphone apps simulate a Gauss Meter using the phone's built-in compass. It is not very precise, but enough to identify the EMI sources when close to them. With it, contexts (for example a laboratory) can be examined to find devices emitting interferences before the session begins. Switching off those devices producing interference or putting them away from the recording devices should be a priority.

With or without a gauss meter, an inspection of the room should always be performed during the design phase of any test looking for:

· **Old or cheap LED illumination**. As a LED is a diode (a valve that only allows electricity to flow in one direction) lamp that works on DC, it needs a driver that downgrades current and even converts it in case it is CC. A LED driver is a device that can usually be found integrated into the led bulb itself (can

[8] The location where the experiment is recorded: a laboratory, a classroom, a private room, etc.

be external too, depending on the purpose and installation size) that provides thermal protection and a stable current to the diode. The EMI interferences are not caused by the LED itself, but by their drivers. The bands where interferences are produced are high, from 30 MHz to 300 MHz, but depending on the device there can be multiple affectations. High-quality drivers are properly filtered and don't emit radiation, but usually cheap and low-quality ones do. The benchmarking devices webpage (ledbenchmark.com, 2021) performs a well-indexed test on hundreds of lightbulbs and if they cause interference. They make a special mention to a led lightbulb *Mirabella 5W MR16* that has been reported to cut radio signals and TV reception in an entire neighbourhood.

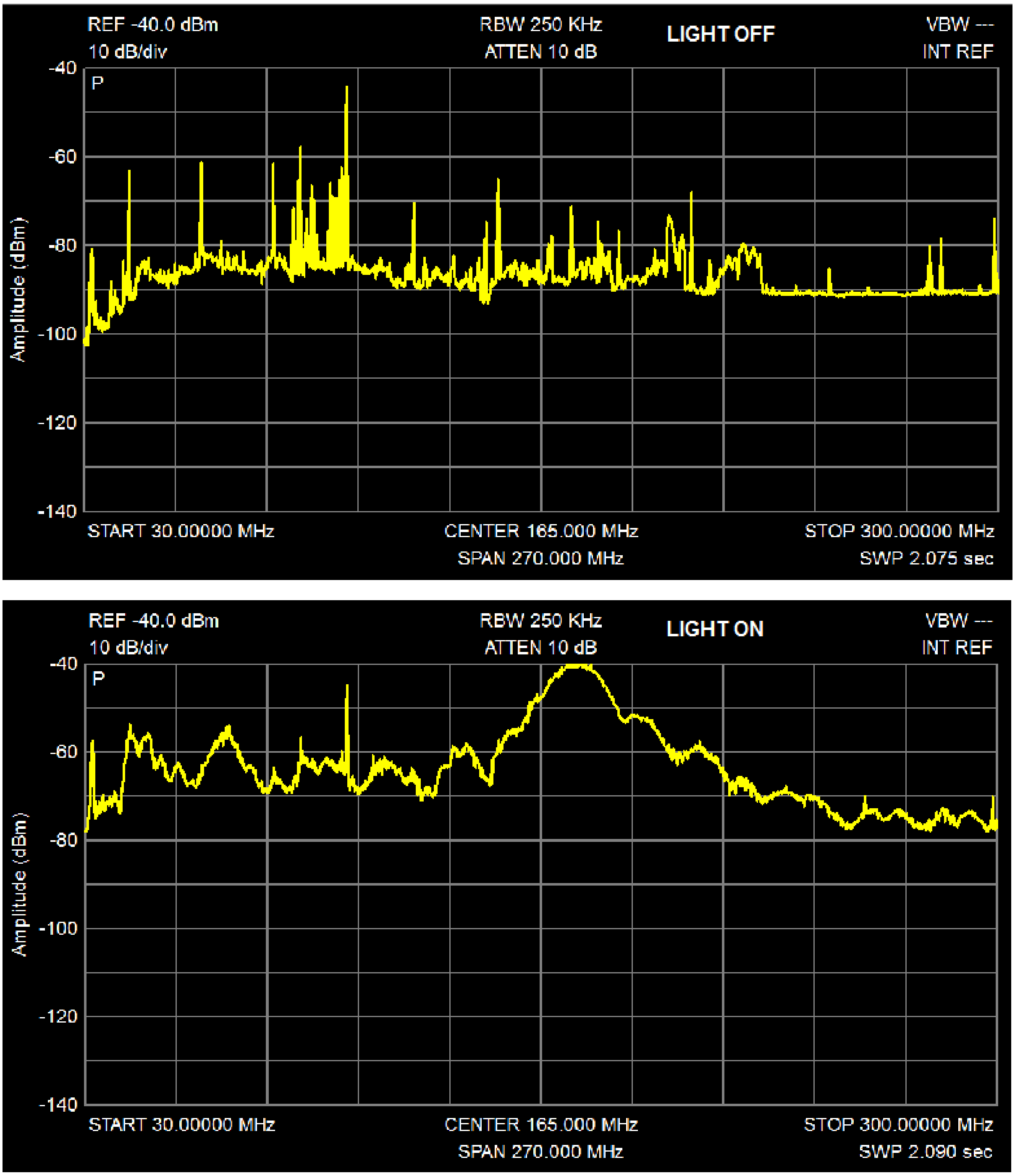


Figure 32: Mirabella 5W MR16 lightbulb (ON/OFF). Source: (ledbenchmark.com, 2021)

In addition, another problem caused by this kind of low-end device is a “buzzing” or “humming” sound, especially in dimmable LEDs.

· **Fluorescent lamps**. There are various technologies but all of them have a tube of glass with substances that emit visible light when irradiated with UV. The older ones need a primer or starter to start up and the newer ones are purely electronic. These kinds of lights are popular as they need really low consumption and are more efficient. In older devices, the moment where most EMI is produced is in the starting, by the inherent function of the starter. In newer devices, EMI can be present in frequencies between 10 kHz to 100 MHz depending on the electronics that regulate it (*Stopping EMI from Fluorescent Lights and Ballasts*, n.d.).

Figure 33: Phillips lamp and starter. Source: (www.Lighting.Philips.Com, n.d.)

One of its main known flaws is the flickering at 50 Hz when using older lamps based on starter drive (Silva & Pallas-Areny, 1996), that flickering is known to cause human migraines, and even in case not being one of its sources is known that blue fluorescent light can worsen its effects (National Headache Foundation, 2017). Even when not causing headaches they are associated with tired sight too, so it’s not really recommended for experimenting with users. That flickering can affect video recording devices, as it can result in photograms with variance in its illumination depending on the recorded framerate. As some software are recording at less than 20 fps, this can lead to a massive failure in the video feed.

· **Old electric installations without shielded cables**. Though not habitual, in some places the electric installations can be old or badly implemented. This is especially an issue for EEG recordings (Light et al., 2010) as reference electrodes used as “ground” can get part of the electrical noise. Although EEG headsets have protection against that (it will be reviewed later in 3.2.4), it is a good practice to increase the distance between the walls and the recording devices as much as possible especially if the gamma band needs to be observed (25-100 Hz).

· **CRT displays**. They have been replaced a long time ago by TFT and LED displays, but some CRT can still be found. As the method to refresh images (at a rate of 50 Hz) is based on scanlines, it shows an inherent flickering that can cause tired sight in users. It is theorized that flickering screens and fluctuant luminance can cause cognitive interference, slowing the knowledge retrieval (Garland & Noyes, 2004) over other presentation formats.

· **Magnets**. One of the things less taken into account, but present in a multitude of devices. Although it is not probable they include a magnet with a field strong enough to affect other devices in the room, the devices used or present during the experiment can contain them and produce interference. One of the common examples are headphones, when close to electrodes can produce both EMI and stimulus artefacts(Campbell et al., 2012). In case headphones are needed during an experiment to add auditory input or to isolate the user from the environment, there are high performance insert earphones for ERP applications (CORTECH Solutions, 2020). Those kind of earphones are calibratable (so sound-pressure at the earphone can be controlled), the transducer is at 6 cm from the electrodes (so there are no stimulus artefacts that EEG can record) and the sound arrives from the transducer to the ear exactly 1 ms after it's produced (so evoked events can be measured with exactitude). In case those kinds of devices are not available, it is recommended to use at least ear-in headphones.

· **Current transformers or inverters**. Most of the devices used in experimentation environments, from lamps to laptops and even the data acquisition systems, need a current input lower (or higher) than the European 220V standard house output. The most usual is converting from 220V connection to 12-21 volts depending on the device. These devices also create magnetic fields so the best advice is to disconnect those that are not necessary during the session and put those that are necessary as far as the cable length allows.

If we can minimize the presence of all the items above we will cover the major part of domestic electromagnetic interference, and we will be provided with a clearer signal. Ambient

3.1.2 Lab Staff

Lab personnel participating in the session are an important part of the interaction with the user and their behaviour cannot be ignored from the session result point of view. There are many roles in a UX team, most of them interacting with the user in a variety of ways that can affect the experiment, especially when the intention is to read biosignals.

The main effect that needs to be avoided is the Pygmalion Effect (Rubovits & Maehr, 1971) also called the Rosenthal effect, which implies that the staff expectations are interfering with the user's performance. It is known that this effect vanishes over time as the researcher knows the user and vice versa, but the average time to accomplish zero "expectancy induction" is around 2 weeks (Raudenbush, 1984) while the user participation will usually last less than an hour. For this reason, it's said that the interaction with the users should be conducted without any kind of preconceived ideas, even when the prior tests have shown possible flaws for them. As zero interaction can lead to user discomfort but too much assertiveness can decrease cooperation rates (Jäckle et al., 2012), the recommendation is to focus on negative traits with "positive feedback" and to not push too much on positive traits to avoid oversizing them (with more positive feedback, upscaling them).

Alternatively, this leads to an unexpected possibility of the Pygmalion effect being useful as external reinforcement in self-regulation topics (as aforementioned in previous sections).

It is important to define roles because many times more than one or even all of them must be performed by the same person, as many UX departments are composed of few members or even a one-person team. Even in large research groups, each project is usually carried out by one researcher or a small group of them. With the roles properly defined, it is easier to control what to care about by each one. In addition, if the workload is too high a given one could be also externalized. Roles fit into two main categories: technicians and researchers.

3.1.2.1 Technicians

This personnel is responsible for the infrastructure and the content that will be presented to the user in a UX evaluation. Having a strong infrastructure allows researchers to focus on their work and lowers the risk of miscarried experiments or losing data. The most common roles are:

· **Hardware and software technicians**. They are important as researchers do not have to be an expert of the technology used during the research. Their duties rely on preparing the computers, the communications infrastructure, and the software that will be used during the experiment. Many times they are responsible too for the data storage, so data researchers could process the results. Managing the machinery, computers and the programs needed usually takes researchers a great amount of time, this is why this labour is usually carried out by interns or lower-rank researchers. In biometry research, they are responsible for calibrating devices and equipping users with them. Because it implies close contact, a set of rules should be applied as human interactions produce involuntary body reflex reactions that can invalidate the experiment if they are not properly addressed. It is important to take into account that these kinds of signals are those trying to be measured and it is supposed that they are produced by the object of study, not by the experiment itself. Every likeness, dislike or any kind of emotional bond between the user and any of the lab members presents a critical situation as the modifications in user reaction could take a really long time to disappear (in some experiments the signal might be affected during all the sessions).

In case personnel is available, it is a good practice to use at least two different technicians from different genders switching roles. They can take turns to calibrate the user-worn devices, so the problem of having the users interaction clustered around one technician can be avoided.

· **Multimedia Designers**. They are responsible for designing the media that will be presented to the user during the sessions. This media will be proposed and supervised by the research team (especially the UX designer) to make sure the requirements are fitted. Usually, they do not interact with the users, but users interact with their creations. For this reason, their work should be clear and reviewed by the researcher.

· **Content Designers** or UX designers. Similar to the previous group, but this role is specialized in designing how the media provided by the multimedia designers and the text provided by the researchers will be presented to the user. They usually have expertise in UX, meaning that they know how users behave in front of a given system. Research designers don't usually make their content look nice, so need to work closely to obtain a polished-user-friendly final version to use during the experiment. The best way to do this is through multiple prototypes validated by the research team. If they perform a good job, users will be able to interact more intuitively during the session without requiring support from the experiment facilitators. For example, in education interventions involving interactive systems based on web pages, this role would be performed by the frontend designer.

· **Recruiter**. It is in charge of searching for users with the characteristics defined by the research designer and recruiting them to take part in the designed experiment. User screening is started by this role (although it is recommended to be repeated in a later phase by researchers before starting the experiment). A good prospect of users should avoid the issue of having to discard users during later phases, thus improving the quality of the research. For example, if 30 users were recruited but 10 had to be discarded, research will have 20 valid datasets (33% discarded%). The quality of the recruitment is basic as much research needs to be validated against a minimum set of users to be considered significant.

3.1.2.2 Researchers

They focus on defining the experiment thesis, the data that needs to be collected, which kind of information should be presented to the user (not how it will be done, this is content designer's work), which kind of users will be collected to probe and how the data will be processed to find out if the thesis is valid or not. They are also responsible for guiding the users through the testing and adding the casuistry seen into the following tests. This personnel keeps the core of knowledge. The main roles are:

· **Research Designer**. Sometimes there can be more than one, but it's not mandatory. It holds the responsibility of defining the research topic and designing the experiments to validate the thesis (along with its requirements). This means that this role defines the user population to be recruited by recruiters, the steps to avoid outliers by defining the screening, when to acquire and which data by the field technicians. Basically, they are the team leaders who assure everyone sticks to the topic when performing their part. At the end of the experiment, they must use their knowledge into the results obtained by the data analysts to build the research conclusions and publish them.

· **Interviewer**. They are a basic part of the research process as they help researchers to understand users' reality through inquiring them. An interviewer effect could be caused by the physical presence of the researcher (Davis et al., 2010). "Interviewer effects" are part of a feature called "interviewer error" that shows a bias between the value obtained in the measurement and the real value. In the case of the interviewer effects, the reason is usually purely referable to a specific characteristic of the interviewer, as for example the gender (Dijkstra, 1983) or race (Schuman & Converse, 1971). This is well documented in research for data retrieving (mostly surveys) where the presence of the interviewer affected the results. As most of the research in that field is related to health topics, a greater bias seems to be caused by the need to obtain a reward, for example gaining access to a given medical service (Williams, Jr., 1968) and how users perceive that the interviewer will be more prone to give them that reward. This has been specified in this thesis in the state-of-art section, as a problem to avoid in rewards systems.

· **Facilitator** or moderator. They are only used in moderated tests. From the user interaction point of view, they are responsible for guiding the users and helping them to achieve the objectives during a task. They can be in the same room as the user or in an observation room (if they are supposed to interact with the user, if not the role is considered as Observer). If they are in the same room as the user, the same risks (and recommendations) from hardware technicians who must interact with the users are applied, even more as technicians are only present during an initial stage. Related to biosignals, (Sonderegger & Sauer, 2009) showed that if facilitators are in the same room, heart rate tends to be higher than when the users were on their own. Generally, when capturing biosignals, unattended or low-moderated tests are recommended.

From the data acquisition point of view, they must register the user's behaviour in real-time to be analyzed after the session. User-facilitator interaction is also recorded to be analyzed afterwards looking for new clues, flaws and ways to improve in other sessions.

· **Observer**. Without any kind of interaction with the user, its tasks are related to registering the user's behaviour in real-time and analysing them after the session. They must provide real-time feedback to the facilitators by a private line of communications, so they hide that data from the user. This feed usually points to things that have been disregarded by the facilitator.

The fact that the users know that they are being monitored usually causes a medium to high difference in the signals as they try to self-regulate their responses. This is not strange as described in the

Hawthorne effect. It occurs when people behave differently because they know they are being watched. The Center for Behavior and Evolution at Newcastle University, headed by Melissa Bateson and Daniel Nettle, conducted an experiment related to the relation between posters with human eyes and the cleaning of an office dining room (Bateson et al., 2013). The presence of posters caused a massive improvement. The presence of moderators and how they are presented to the users are important related to how users will perform during a UX session (Harris et al., 2005) as users that are reminded to be observed perform statistically better than those who don't.

· **Data analyst**. The data obtained by the previous roles must be processed in order to get meaningful results (quantitative data). This task is usually tackled by the research designers themselves but can also be considered as a separate role due to the amount of knowledge this task requires. For instance, how to process each one of the signals acquired during the sessions. They don't interact with users but are fundamental as the final results will be based on their insights.

3.1.3 User

The users will be the central axis of the research as what needs to be measured are the variations over their emotions caused by a given topic: in UX the topic can be interactive software; in education it can be an entire course; in health-care it can be a medical proceeding, etc. Knowing this, it is important to note that the user will not only be affected by the interviewer and the test procedure but also by things that happened in their daily life. There are two important factors related to user traits that could negatively affect the experiment: psychological and physical traits. The first should be detected and addressed during the session, the second must be screened and discarded to favour the signals achieved.

3.1.3.1 Psychological

One of the main problems dealing with users is that they have a previous opinion about how something will affect their experiences. Maybe the users don't know what tasks will have to carry on, but there are some things that they accept as sure about themselves. The self-confirmation bias (Quattrone & Tversky, 1984) theory implies that the answers obtained during the test are not exact because of a self-deception component in user cognition. This means that the user is more likely to process the parts of the experience that are consistent with their existing beliefs. For example, a user who says "it's bad with technology" will reinforce that idea if there appears a mistake in the calibration or if the device, although is not its fault. This can lead to a "spin down" effect if "positive feedback" for those negative traits are not provided by the facilitator.

The emotional user state of mind is very important too, as it will affect its behaviour. For this reason, the most important thing is to try to establish a state of mind as neutral as can be. In addition to their respective mood outside the experiment, it is known that although not invasive, biometric devices could make the user feel uncomfortable, especially as it requires physical contact with an unknown stranger during setup. For this reason, when dealing with users it is recommended:

· Listen. We're facing human beings, most of them only want to be heard or want to understand what we are doing when manipulating the devices. Be present and give the user your full attention, focus on the message they're saying and not the feelings behind their words (if there's any). Answer the questions, and don't interrupt them when they are talking (They usually provide useful information that the facilitator must understand and take note of).

· Emphasize and apologize. Sometimes proper calibration of some devices can take a while and we must understand that patience has its limits for all users. Communicating what is happening is a good way to not generate frustration for the user. Don’t say anything it is the user's fault, neither say jokes about state of mind issues (as effectively you can make them focus on their everyday issues).

· Maintain a calm tone of voice and don’t get frustrated. The previous point can affect the technician too, especially with the first few users of the experiment. Sometimes calibrations show that a device is not working as expected and the user is asking all the time what is happening. The doubts shown by the technical staff are mirrored on the users that should be centred in the experiment so avoid negative language.

Along with Pygmalion and Hawthorne effects (Explained in the Technicians section), there is the fact that monitoring equipment increases stress levels of users (Alharbi et al., 2014) affecting even the metrics measured in the sessions with the most intrusive monitoring equipment. The experiment design must contemplate this fact to choose the less intrusive equipment available. When not possible and as this effect usually tends to diminish over time, the recorded sessions must be long enough for the user to be distracted by other things in the environment and even the focus on the experiment itself.

It is recommended too that the first part of the experiment presents a neutral experience that works as a calibration validator, which could be used to deduct the importance of this effect during that session if the initial calibration differs a lot from the in-experiment calibration. The device's calibrations must be performed as soon as it can, so the user starts to get used to it and stops thinking about it.

3.1.3.2 Physical

The users in the experiment will often be a heterogeneous mix, not only psychologically but physiologically, this means that one of the most important decisions in the experiment design will be defining the user scope to recruit for testing purposes.

Those limitations will be caused not only by the restrictions of the experiment itself but by the devices intended to be used during the experiment (this will be explained in depth later). Biometric data catching could be difficult for people with accessibility issues (Blanco-Gonzalo et al., 2018) and as with any UX research in the design phase, it must be taken into account (those special needs).

Another thing to be taken into account is the lab staff interactions as explained above: most users will react to the different roles present in the session in different ways. But there are many conditions or impairments that need to be taken into account even before designing the experiment.

Some limitations are postural, meaning that some of the data recorded can present wrong values depending on the user not sitting properly. Note that these values won’t be bad ones, as they cannot be associated with any kind of external artefact. This has the most affectation on breathing quality, which has a direct relation with EDA signals (remember how when calibrating the device the user is asked to breathe deeply to see peaks in the signal). The posture plays a heavy role in optimal breathing (Chronic obstructive pulmonary disease net, 2017).

Figure 34: Optimal sitting posture. Source: colourblindawareness.org

This can be easily addressed if users are reminded to rest their feet on the floor, touch the back of the chair with their own back and rest their arms on the table.

One of the most common user limitations to ask for is the need for corrective lenses. There are many types and each one affects eye trackers in different ways, but more important: Some users who need them don't use them (Holmes, 2019). It is important to keep an eye on the user showing certain signs such as squinting or red eyes. It is always handy to keep in your lab some low-correction cheap lecture lenses (in Europe they can be bought in any pharmacy without prescription) for the time the user forgot theirs at home (because this happens).

Another limitation is Color Vision Deficiency or colour blindness, usually due to genetic causes and affecting statistically 8% of the male population and 0,5 % of females (colourblindawareness.org, s. f.). The people who suffer from it are usually unable to fully differentiate (or see) red/green, meaning they cannot see those components in colours. Being a birth condition adds to the fact that some effects can be moderate or mild, which ends up with this problem not being detected in the 40% of high school students suffering from it.

Figure 35: Types of colour blindness. Source: colourblindawareness.org

The people affected by this condition can evaluate a full UX experience if a component of contrast and luminance is added to the classical colours scheme. Accessible UX colour palettes are a known trick that can assist in this task: even if the user cannot say which colour it is, that colour can still be differentiated by the rest.

The hearing ability can be a decisive point in the evaluation process although there are different degrees of severity and different ways of interacting with the sound (deafness, crackling, whistles, etc), so it's important to differentiate what is called the little d to the big D (Herrod, 2008). Little d refers to people with non-birth related hearing impairments, while big D refers to people who have been born without the capacity of hearing. That difference causes the people belonging to collective D to identify themselves as a community or culture different from the rest. This comes by the definition of culture by a group of people that share a language (or sometimes a given set of common experiences that is not usually lived by those not belonging to the group). The fact that their "mother tongue" is their local sign language (sign languages are not international, as they are based on the main spoken language they're coexisting with. For example, the Australian Auslan, the Spanish LSE, etc) establishes a differentiated language from their spoken version, and from the rest of the languages. If multimedia it's needed in the experiment and the participation of these users are not avoidable, the best solution is to provide captioning (subtitles containing transcribed sound effects) and voice subtitles is the best solution. Adding sign language video is not a good idea due to the "locality" of the sign languages explained above and the fact that the user is not going to look at the media while reading them (this issue is shared with subtitles, but it's inherent and definitely text is less emotion inspiring that one person moving).

Actually, around 5% of the world population have auditory disabilities and this will be incremented up to 10% by 2050 (World Health Organization, 2020). If the experiment involves media with sound, captioning and audio description can be provided.

People with neurologic disorders have troubles when they need to process and understand information. Many impairments cause this state, such as ADHD (Attention Deficit Hyperactivity Disorder), autism, memory issues or learning disabilities. But the most important part is that an experiment can cause seizures in some of them, for example in some mental health disabilities like schizophrenia or brain conditions like epilepsy disorders. Interestingly but not completely related to the topic, the symptoms that usually suffer people with those affectations like reduced working memory and light problems in locomotive functions appear transiently in people stressed or even with the flu (Atherton, 2018). It is extremely important to design the experiment aware of this to not cause a disruption in the user's daily life. To do so, a series of rules must be accomplished: a design for people that cannot struggle with a complex interaction; use short sentences in texts when possible; do not overwhelm the user with choices; present a certain degree of consistency in the media presented; and finally implement alternative input support (for example, if a mouse is used, try to give the possibility to use the keyboard too).

If a given session has any user interaction with text, images or sound, it is always highly recommended that complies with the WCAG - Web Content Accessibility Guidelines (Initiative WAI, 2008). Those guidelines are made for web content, but even when the session doesn't need any kind of web interaction most of their rules can be applied to any piece of media to improve the accessibility for all users. WCAG is a technical standard, not a set of guides, for this reason, some governments have set it as a legal requirement for products and services related to them (www.gov.uk, 2020).

When which kind of users will be recruited has been decided, proper screening surveys will be procured to filter those not matching the minimum requirements.

3.2 Technology dependant issues

On the other hand, there are some issues related to devices specifically used during a session. Those issues are present obviously only if devices of that characteristics are used (for example users cannot wear high graduation glasses when using an eye tracker), but can be related to an interaction with various devices too (as a problem with a shared communication channel).

3.2.1 Device communications interacting

In addition to the aforementioned elements, most electronic systems or equipment used in the experiment generate some kind of signal. That could potentially interfere with other equipment signals, so stacking up electronic devices is highly discouraged. All the devices used in a session must be as far as possible between them.

One of the main RFI issues is Bluetooth, wifi '802.11 version' devices, Zigbee and some cordless phones **sharing the same radio frequency spectrum** (2.4GHz) to send information (Sendra et al., 2011). To avoid too many devices using the same frequency, and with the fact that 2.4 GHz operates until 2.5 GHz, the total band is divided into different parts depending on the technology. As wireless "wifi" devices are increasing its numbers in society, the communication (even in a channel only used by one device) can be slow as it can be stacked over many different channels receiving communications from different devices. This is the main cause why in cities the connection over wifi is extremely slow at some key locations such as bus stations.

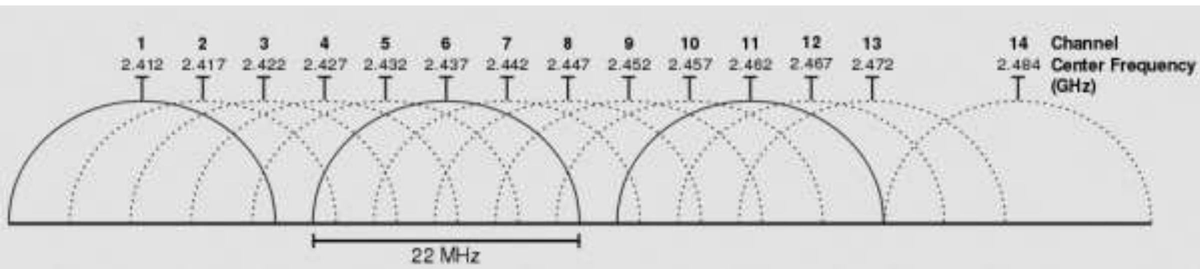


Figure 36: Channel splitting over 2.4Ghz. Source: (Hruska, 2020)

· **802.11 wifi** routers split the 2.4 GHz into 22MHz segments, meaning there are 14 different channels for use. The most used channels are 1, 6 and 11 as they are the most separated ones without overlapping. A good number of devices per channel is around 25, but for high-demand connections, there can be a delay in communications starting from 10 clients (Salem et al., 2018). They are prepared to work in a shared environment with other devices of the same type (routers) using the channel feature: when a device tries to send a packet, it first checks if the channel is occupied by another transmission. If it doesn't detect any transmission, it sends a Clear-To-Send packet that prevents other routers from disturbing the connection.

This slows down the communications but avoids collisions. The process will repeat until the channel is quiet or the router changes channel to improve this decaying process. Some routers allow you to change the channel manually, while others select by the demands of the neighbourhood (a test is performed by the router to decide the channel). A different thing is when many Bluetooth devices share space with many Wifi routers (Mathew et al., 2009), in that scenario, the routers may experience minor problems in latency.

· The same way, **Bluetooth** devices are prepared to deal with this issue, but with a different approach: it splits the 2.4 GHz band into 79 channels with 1MZ amplitude each one, hopping during communication about 1600 times per second using a semi-random pattern. The channel hopping pattern is defined by the master of the piconet (a piconet is a cluster of connected Bluetooth devices).

Interference between Bluetooth doesn't affect the communication due to the hopping feature (it can lose one packet, but can be corrected by the used algorithm). Other 2.4 GHz devices can affect Bluetooth communications by occupying a high amount of frequencies used. Newer versions of Bluetooth define a workaround with an "adaptive frequency hopping" that can avoid certain channels if they give bad performance when used.

· **ZigBee** is a standard solution for sensors (Rajasekar & Vivek, 2012; Jianwei Niu et al., 2013) that massively improves battery life by optimizing communications with minimal energetic needs. It can use multiple bands depending on the country laws, but in all countries, 2.4GHz is used. The 2.4 GHz frequency is split into 16 channels of 3MHz, with the particularity that each channel has 2 MHz of unused frequency to avoid overlapping.

This technology implements a similar collision avoidance as 802.11 routers to avoid issues among them, but as they are focused on low consumption they don't change channels as they don't have any mechanism to detect low-quality communications. If communications are overlapped, most communication attempts will not reach their destination.

· In every home and most offices, a **cordless phone** that uses 2.4 GHz is easy to find. Although they use the 2.4GHz band because it's free to use all over the world, they don't use a standard communication protocol nor a fixed channel split, relying on company ad-hoc communications for each model. They usually have a button to split between the channels defined by the company, each one occupying up to 10 MHz, to avoid interferences with routers and other phones from other brands.

Interferences caused by those devices can be catastrophic due to power in the signal and the wideband they occupy. Depending on the frequency they are using, it can affect any kind of device. For this reason, it is not recommended to have one in a laboratory, especially if they are close to the device (router, Bluetooth device, etc). Having interference in the phone signal is not considered important, as they are not usually needed for the experiments.

Cell phones using 2G, 4G or 5G technologies are not a risk to interfere with sensors except in really close range (Morrissey et al., 2002), but usually, they can use more than one of the technologies explained above. For this reason, all non-essential electronic devices must be left outside the testing area. This includes the user and technician phones, as they are nowadays so integrated into everyone's life it's easy to forget that they are there. They usually become the main source of interference in the EEG headsets and can lead to connection loss.

3.1.2 Sync issues

During the development of the different experiences, various products must be used and it's output analyzed. Most of them required preparation to work in a research environment as they are more focused on the user-side service. Each device has its software to extract data, its refresh rate, and its timestamps are usually from different sources.

This means that they don't usually have any official (and easy) way to synchronize their respective data acquisition systems, so resulting sessions cannot be aligned easily.

As most systems come with a timestamp feature to link a given measurement with a moment in time, it is the most obvious way of synchronizing the different data sources. However this timestamp could be extracted from different sources too: internal device clock, data-storage clock (usually computer) or even came without timing (for example with Arduino-based devices that provide a continuous signal).

If the devices are connected to the same single data acquisition system (like a PC, or a specialized device) the solution is to synchronise all the data between them. One easy solution is mirroring all the real-time data into one system (from complex systems like a recorder to easier ones like a screen), and centralizing the recording there.

If the devices that collect the data must be more than one, the most effective solution is to use external visual and sound signals that can be detected in all of them. This way data from different sources can be aligned properly when it is not possible to sync the clocks of all devices.

Finally, recordings of the user interaction present the same issues, as they need to be synced both between them and with the data acquired. The same solution can be applied as the biosignals recording, trying to record them from the same computer, share the screen into a centralized desktop and store them in real-time or use a signal recorded from all devices.

3.2.3 Eye Tracker Technology

Lack of accuracy in eye tracker technologies is a vital problem to be avoided. Each model has its problems, they can be found by searching user ratings over the internet, but there are some common issues for all devices and some groups of users.

Software eye trackers rely on RGB cameras (webcam) to detect gaze points. For this reason, they are extremely weak to reflections in the glasses, this it's applied to all types of mounted corrective lenses.

As they don’t detect retinae reflections but pupils they work well with contact lenses except for sclerotic-covering ones. This type of eye trackers are less accurate than infrared ones,

In infra-red based trackers the precision is higher, but the physical effects of the glasses and contact lenses present some problems too. There are many types of corrective lenses, each type affecting gaze recorders in different ways (Holmes, 2019).

Desktop infra-red trackers work well with single-prescription glasses if they don’t surpass the +/- 6 diopters range, but not so well for progressive lenses as they distort the image recorded. If the eye is not rounded-shape the tracker cannot find it.

Portable eye trackers shaped like glasses usually come with an adapter for corrective lenses, because this kind of device doesn't have enough space to add the user's own.

Figure 37: Tobii pro glasses. Source: tobii.com

For all infra-red devices, the accuracy deviation is usually set by the manufacturers less than 0.5 degrees in ideal conditions, but often deviations larger than 1 degree are observed in controlled contexts (Feit et al., 2017). This is important to be taken into account when deciding the items that will appear on the text, as if elements are too close there can be a mismatch in detection.

Besides, there are known flaws for data obtained in non-ideal conditions. Eye trackers allow users to use glasses up to certain graduation, but all glasses can cut the direct view of one eye at a given moment (by the point of view of the system’s cameras). The appearing-disappearing eyes in the projected gaze is one of the main issues as many Tobii trackers report data for both eyes even if only one it’s visible (Niehorster et al., 2018). Research-oriented Tobii trackers come with a built-in RGB camera (a normal webcam) to record the face of the user synced with the session, so if the event detected is set during a movement of the head it should be discarded. During the calibration, a proper angle should be found to avoid anything that interferes with the tracker line of sight.

The reliability of the device depends on the distance of the user to the tracker, and even the race of the user (Blignaut & Wium, 2014). Seems that Asian users perform worse than African and Caucasian users, while larger gaze angles worsen tracking in African users. In short distances, these issues are not present, so it is recommended to keep the user at less than 60 cm from the tracker/screen.

The overall approach to mitigating issues with eye-trackers usually relies on screening users properly, not letting users move much during the session (both keeping a given distance to the tracker and discouraging head rotation) and finally discarding those users with low tracking fidelity to keep those deviations as low as possible.

3.2.4 EEG Technology

When dealing with budget EEG headsets, two main kinds of artefacts are critical: environmental (external) and physiological ones.

· Regarding the first kind, external interferences can cause variations in the signal as wireless devices don't have ground attached sensors. This is especially severe in 50-60 Hz bands. Usually, the frequency to be measured by an EEG is from 1 to 35 Hz, this is the reason why most EEGs come with a low pass filter that deletes all signals above 40 Hz. If the headset doesn't come with one in-built (and to be sure, even when they come with one as you cannot know the quality) it is recommended to use a digital filter to process the signal file. Matlab provides various functions to do so.

As many EEG sensors must be hydrated with a saline solution, variations in the saturation of these sensors can affect the contact quality and hence the quality of the data obtained. Saline solution can make a direct connection between electrodes, so applying a high amount can be counterproductive. Dry solid-gel based electrodes provide a constant-state sensor that can help to avoid this problem. Anyways and with any type of sensor, it's a good idea to clean and dry the zone of the user's skin that will be in contact with the sensors.

A mention should be given about external sounds, as environmental sound, music and people speaking can be classified based on the EEG response (Zuk et al., 2020). It is a fact that when the brain is "hearing sounds" EEG output is affected.

Special mention in environmental artefacts at light conditions in the room. As it's known that light conditions modulate brain activity by affecting the amygdala (Park et al., 2013 and Vandewalle et al., 2010) and it is used in therapy to modulate affective disorders (Terman, 2007). The affectation in alpha bands is demonstrated even in completely visually blind users if they keep intact their photosensitive ganglion cells (Vandewalle et al., 2018), this is said to remark the importance of this factor. As there is no conclusive data about which kind of light, by colour and intensity, is better for non-emotive responses the only thing that can be attempted is that all users in the experiment are exposed to the same light sources.

· The other critical artefact is the physiological: movements and facial expressions. By the way, those devices acquire the data, all involuntary movement like eyes blinking, smiles, muscles moving and heartbeat is recorded, as the electric skin response produced by them is way stronger than the brain activation activity. EMG (electromyogram) interferences caused by muscles are one of the main artefacts, especially adobe 20 Hz in central electrodes (Whitham et al., 2007). Usually, all these signals are removed via independent component analysis (ICA) techniques, but each one (artefact feature) can be removed with different functions and approaches: (Fitzgibbon et al., 2015) for EMG; (Subramaniyam, 2018) for blinking and (Tamburro et al., 2019) for heartbeats, for example. If movement is mandatory for the experiment, maximizing the surface of electrode contact has a major improvement in decreasing artefacts recorded (Symeonidou et al., 2018) so it would be interesting to use a customizable headset like OpenBCI and apply some motion artefact removal algorithms like Matlab Detrend (EEGLab). If budget is not a problem, amplifiers with active shielding could be used to reduce or completely remove motion artefacts (Askamp & van Putten, 2014). The main issue in the movement seems to be the swaying cable that connects the EEG with the acquisition system, so it's not present in wireless devices.

Some of these can be physiological effects caused by external factors, such as perspiration produced by the sweating glands causing changes in the sensor measured offset. This adds complexity to skin-related artefacts as appears in the signal low-frequency artefact in the delta-theta bands. It's not difficult to address, but heavy sweating can cause the electrodes to “bridge” and totally disable the results obtained by them.

Anyways to assure a low amount of problems the user should not move or speak to minimize captured noise. Be sure to clean the contact zones of the user skin before connecting the sensors. At the end of the test, the data must be filtered to remove eyes blinking (as a recognizable pattern they are not-so-difficult to remove, not saying it's easy), heart rate, movement, muscular and any possible external artefacts.

3.2.5 EDA (Electrodermal Activity) Technology

EDA wearable monitoring devices have been popular in research topics due to the possibility to collect long-term data in a non-medical environment, but there are some things to be taken into account when recording and processing those types of signals.

As the measures taken are physiology-dependent by monitoring changes in sweat glands, one of the most important things is to assure that the variations came from emotive data and not by other sweat glands purposes, as compensating temperature changes. Ambient temperature too high can cause variations and peaks when the body tries to compensate for the heat, while low temperatures can decrease overall skin response. The ideal to avoid skin responses triggered by the ambient temperature is to keep the lab around 23 degrees Celsius (Braithwaite et al., 2015). Has to be taken into account that during certain seasons users will need some time to adapt to the temperature, so it’s important to let them for some minutes when they arrive before calibrating the devices. This time is ideal to show them the informed consent and previous documentation or surveys.

Figure 38: Phasic signals (Circled) over a tonic baseline (Line). Not all of the peaks are stimulus-driven. Source: (Empatica, 2020)

Moods can influence the skin's responsiveness and it is used effectively in detecting depression and suicidal behaviour (Sarchiapone et al., 2018). This is done via the detection of hyporesponsive electrodermal features as it seems to be a reliable marker in that kind of illness; meaning most patients present this condition, but not everyone who presents this condition suffers from depression. Some users with cardiac issues may present peaks in the EDA signals, or hyporesponsiveness too. Users suffering from depression should be filtered by the recruiter and pre-test surveys.

The skin conductance is not predictable due to a component of habituation, as if exposed repeatedly to certain stimuli the reaction will soften each iteration. The speed of this process varies over the different users, but it is usually a constant in the majority of cases *(Healey & Picard, 2003)*. Independently of that, around 10% of all participants in any test will present hyporesponsive EDA signals (Braithwaite et al., 2015) those users' features simply cannot be monitored properly.

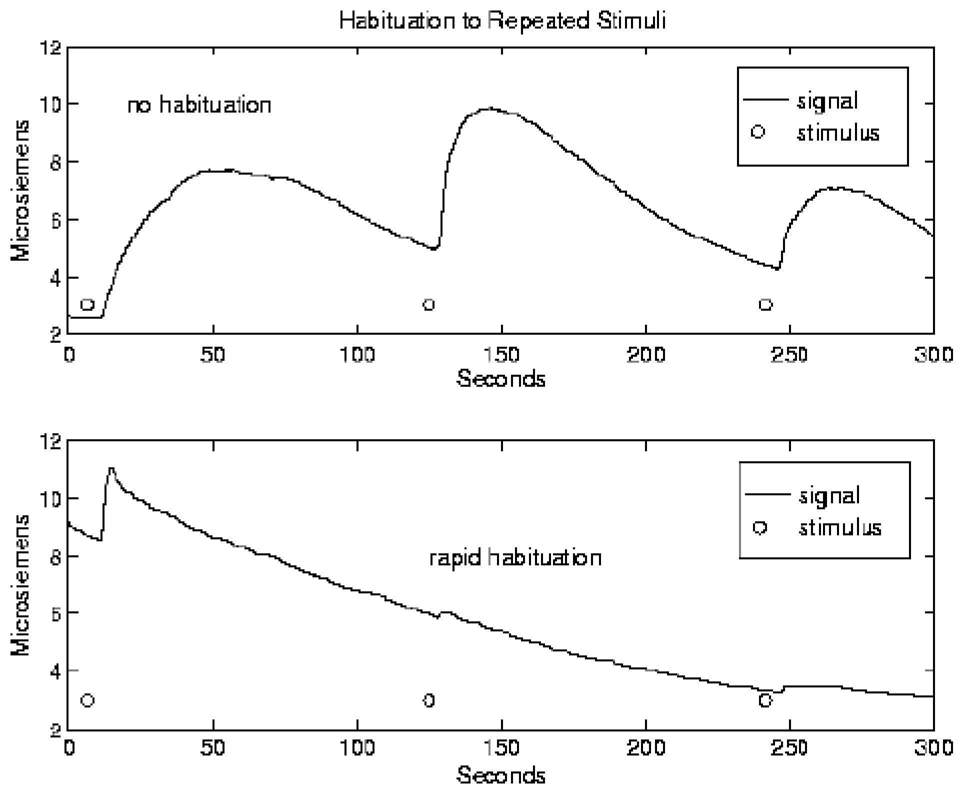


Figure 39: Habituation to repeated stimuli in two different users. Source: (Healey & Picard, 2003)

There are several noise sources caused by the user within EDA signals (Taylor et al., 2015), especially when using the cheapest devices. Long term acquisition means that the user is performing daily tasks over a long period; the movements needed to perform those tasks introduces noise into the recorded signal. This noise can come from user motion, user adjusting the sensor wristband voluntarily or involuntarily or hitting it against something during a task. Those issues are less present in a short UX experience as all movements can effectively be kept to a minimum, but they have to be addressed too to assure good signal quality.

To assure the signal quality is good enough, it is usually recommended a pre-recording during the calibration phase to see if the electrodes are well attached. This usually saves time later. To minimize the issues caused by changes in pressure of contact between the sensor and the skin some EDA devices need their sensors to be soaked in some type of high-conductivity gel, that gel needs to be settled on the skin for some minutes before start recording.

Wet electrodes present a degraded signal over time as sensors are dehydrating, increasing the measured impedance. Also, they tend to decay as a result of their use due to the gel damaging the sensor's external protective layers. For this reason, there are usually used dry electrodes as they don’t decay and are more constant in their measurements. In reusable electrodes, one of the main issues is the polarization-related one. In the active EDA devices, where current flows from one electrode (anode) to another (cathode) the silver layer is increased in the first and decreased in the second producing unreliable data (Fowles et al., 1981).

There are many algorithms to remove artefacts in EDA signals and they can be classified into two different groups: supervised and unsupervised algorithms. Supervised ones require a huge amount of pre-labelled data to train the models and therefore a great amount of researcher time. All automated (unsupervised) algorithms seem to be at least as effective as the supervised ones (Zhang et al., 2017), at over 95% success rate (Xia et al., 2015), for this reason, they are widely applied.

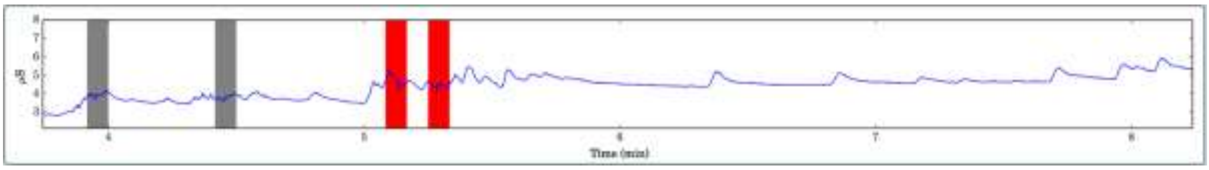


Figure 40: Automated motion artefacts detection (Red: noise, Gray: suspicious). Source: (Taylor & Jaques, 2015)

Some methodologies provide an option to add accelerometer data (most wristbands comes with an integrated one) to improve motion detection (Taylor & Jaques, 2015) but it seems that it is only effective for supervised ones: unsupervised methodologies results are worse when adding this data (Zhang et al., 2017) than without it. Anyways as an initial visual analysis is mandatory to see which kind of artefacts can be found before selecting the proper filters, when performing a short experiment an observer should be used to mark the moments when users are speaking, coughing or sneezing, so it is easier to analyze it later.

To see if everything is well attached to the user and that is not of the hyporesponsive type, you can ask them to take a deep breath, hold it for a moment and exhale. The user should sit in a comfortable position with both feet on the ground (not allow crossing legs). There should be shown a mountain in the tonic skin conductance like the following image:

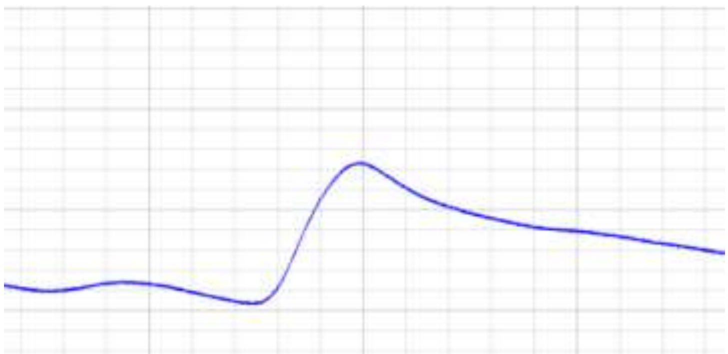


Figure 41: Hold the breath for a second, EDA signal. Source: (Biopac Systems, Inc., 2015)

If the signal appears as a flat line and detaching/reattaching the sensors doesn't solve the problem, the user can be considered non-respondent (Biopac Systems, Inc., 2015).

Last of all, if the sensors used are hand-made Arduino-based, there are a given set of recommendations that needs to be attended: Proper electrical shielding must be applied to them to avoid external artefacts coming for EMI and RMI. In hand-made devices, the electrodes can vary their composition and type, but they must be exactly equal, as a difference in materials can cause a differential in the conductivity measured.

3.3 UX Contexts

The physical location where a session is recorded comes with its own characteristics, both strong points and flaws. UX experiments usually are performed in four different contexts, ordered by the capacity of researchers to modify the environment: A laboratory, an office, a public indoor place and recently at a user's home. Most projected experiment locations can fit into one of those categories.

Outdoor contexts are out of scope in this thesis as too many things like room temperature are out of control, hardening the biometric data acquisition.

Anyways there are common factors to be taken into account in all environments.

Observing and recording the users during testing is not only important but mandatory. Multiple things are happening at the same time and it will need various reviews of the full session to extract all the valuable data. To do so, it is recommended at least 3 different recordings:

- Screen. The interface presented to the user will give us insights into how the user is behaving (if there's interaction) and puts into context the reactions that can be seen in the other cameras. For example, if there's a disgusting picture on the screen, it may be perceived as unpleasant and shown in the user's face and a mild shrink in its body.
- User Face. Facial expressions help to identify emotions through the test. In addition, if properly synced it can help to decide when to filter muscular or speech artefacts in biometric signals. Placing a camera in front of the user is not the best solution as they tend to control their expressions, but if the camera is not so obvious they tend to forget it during the experiment.
- Lateral 3rd person recording. A general plane of the user would be useful to detect incorrect leg positioning and overall posture. Built-in accelerometers can be used similarly, but it is more effective to see them in real-time as users can be corrected.

The key point is synchronization, so all the images must be following the same chain of events, not only between them but with the data recorded (Refer to 3.1.2 sync issues).

3.3.1 UX Laboratory

A proper UX laboratory is the easier context to conduct any experiment. It is a space dedicated to developing and testing the studies, decreasing the researchers' effort to improve the quality and speed of the research. Most research groups have one for their own, but most company departments working in UX don't. To solve this inconvenience most researchers use sort of "portable" usability labs (They will be covered in the following section) or hire university's labs (University of Melbourne, 2020).

Even if there is a dedicated laboratory, it doesn't mean that the usability group is centralized, so, normally, different groups of researchers are using them for different experiments. In fact, multiple activities are usually performed in a laboratory where users are not tested as experts applying heuristic evaluations, the researchers designing the experiment, etc. The importance of this location is that all the elements that will be present in the experiment can be modified for the sake of it.

The most important thighs to be controlled in a lab are two: light conditions and temperature. Especially in those experiences that take place for more than one day, controlling those variables is not only recommended but mandatory, as the conditions must be kept as equal as possible between sessions. Light conditions have effects over EEG (3.2.4) and variations in temperature (as well as a different stable temperature) will affect EDA outputs (3.2.5).

As the place is dedicated to research, elements described in 3.1 causing interferences and artefacts are not present or can be removed if so.

There is no all-purpose solution, so most research groups have different laboratory styles with different elements. The most common static UX laboratory element has a shape and furniture adapted to its needs:

· The lab needs two spaces minimum, each one with the capacity for at least 3 persons in it. Those two spaces are to differentiate the one where users are being tested from the one used by the observers to evaluate the experience. A room for the test subjects is mandatory, while the observers can be in the same room or having a dedicated one. It is recommended that the observers are in a different room so users don't even see them before the session.

· The testing space is the most important place of the laboratory, as it will have repercussions over the obtained results. As a dedicated lab, this space will be prepared with all the requirements for the planned test and will have enough space for the test user and the moderator (in case it's needed). This space must be isolated from the rest of the participants to avoid contact between them and it would be ideal that they have an exit path that doesn't go through the waiting room once the user finishes the session (sometimes users would be friends or relatives, so it's difficult for them not to communicate).

It is difficult to choose the best types of furniture as depending on the experience they may vary, but generally must be comfortable without being extra-comfy (sofas and chairs are not recommended for biometric acquisition, as the optimal posture is to sit properly without crossing the legs not forcing the back as seen in 3.1.3.2). This space must be properly equipped with cameras to record the session.

If there's room enough, additional separated spaces for participants can be provided as some studies can be carried out simultaneously. To avoid those multiple sessions influencing each other, this is only intended for evaluations where moderators are not required.

· The observers need a way of observing the experiment without being noticed. For that reason, it is recommended that those spaces are one next to another. If they are in different rooms a one-way mirror can be installed. In case mirrors cannot be installed, it's usual to put cameras streaming to view the session from different angles, remember that observers need total visibility on the users and the interface they are interacting with. The cameras had the advantage that sessions can be recorded to review them later.

Observers work better on a team, as it is easy to get distracted if they are on their own. With the opportunity to discuss there is an improvement of the understanding of the user behaviour. To help them in this task, a shared screen (or a projector) should be provided to them, alongside appropriate speakers and a table with room for collaborative note-taking and discussion. As they can be there for a long time, refreshment is mandatory to help them keep attention and focus.

· As biosignals will be monitored, it is recommended to have a separate room (waiting room) with the same temperature conditions so the next users in the testing could get used to them, especially during the more hot or cold seasons as they will generally come from the outside. For this exact reason, refreshment and snacks should be provided, as it's intended to have users in optimal conditions, and dehydrated users can experience issues in performance and even signal monitoring. This space can be used to host group discussions or focus groups so usually it's bigger than the test space.

The room must be separated to avoid information leaks (outgoing user speaking, or waiting users hearing a reaction from the current user) and expectation raising that could interfere with the results. In the waiting period, the needed documents and surveys can be filled by the users and the experience can be explained to them, saving time in the experimental phase.

3.3.2 Office

Similar to the previous one, but with restrictions in the quantity and quality of variables under researchers' control. Some of the artefact sources described in 3.1 will be present and the light conditions and temperature are fixed or vary depending on the location.

To address experiments outside the ideal environment the most used thing for researchers is to have a "portable UX lab". There are multiple guides on how to make a budget one like (Margolis, 2019) or (Maddy, 2018) and there are complete pre-build ones that can be directly bought (Noldus.com, 2021). They consist of the same equipment that can be found in a usability lab, but in its portable versions: laptops, smaller cameras, portable trackers, etc.

Figure 42: Noldus Portable Usability Lab. Source: (Noldus.com, 2021)

There are two versions of portable labs: those that try to replicate lab spaces and those that are only the test room (lite).

The ones that try to replicate a usability lab use a lot more space, as they need an experimental room, an observer's room and a waiting room as the lab. There's a variant as the observation room can be present in remote, meaning that the observers will be following the session online through the cameras. It has the advantage that a research group can invest in portable equipment directly, and when they need to get off their lab they are using the same material. The disadvantage is that the devices will be smaller at a cost in price or performance (sometimes both).

The lite version relies on the recorded sessions. The testing room will be the centre of the experience, where the moderator will follow its script with the user. While the data is obtained the session is recorded. This session will be viewed and commented on by the researchers after the session when the recording arrives in the lab. In addition, there is no need for a waiting room.

3.3.3 Public Indoor Place

Try to avoid this scenario when possible. Public places, even indoors, are difficult places to record valid data by the presence of people roaming around. They tend to speak (affecting EEG data when the user hears them as seen in 3.2.4), open doors (affecting EDA by changing temperature as seen in 3.2.5), record the experience (Affecting again EDA by putting test user nervous) being too close with their smartphones (causing device communications issues as seen in 3.2.1) and usually they want to be the next users to be tested, so they are affecting themselves with anticipation expectations.

When unavoidable, the most recommended is to follow a set of rules if it is possible:

· Establish two different groups: test users are not going to be present in the test space looking at the experience of other users.

· The current test user will be put at a distance from the crowd. A good idea is using the public as observers, explaining to them the observer role, that silence is needed to carry out the session and that they should keep the distance from the testing user.

· It is recommended to tell people to activate the “airplane mode”. Not everyone is going to do it, but if a 50% decrease in devices connections can be achieved it can suppose a great difference (remember in 3.2.1 the Bluetooth random packet channel send).

These kinds of sessions are more often seen as divulgation work, so even when following those steps the results cannot be trusted without a more limited control group to compare results with. This will be needed in case results want to be published.

3.3.4 User Home

Experiments involving users at home would provide limited biometric data, as even low-cost devices are not affordable enough (or functional outside research groups) to be owned by general users. Nevertheless, the great scope of potential test users that can take part in the experiment is so huge that it is ideal for education interventions.

The most used biometric user data extraction in remote is the web-based eye tracker, as newer technologies allow the use of a webcam via browser to collect it. These technologies have many flaws as the low resolutions in most laptop webcams and issues relating to eye detection with low light conditions, but laptops now come with better cameras and they are improving the eye detection algorithms with each version.

Education interventions are ideal to be carried out in this context, as users can access the platform when they want to do it, improving the access times for busy users as can be students.

Using remote technologies, an eye-tracking session can be carried out with quality data comparable to a traditional lab setting (Xu et al., 2015), so especially in pandemic times could be interesting to be taken into account when defining the experiment.

3.4 Chapter summary

So we can say that the answer to the question **“How should an experiment be performed?”** is:

- Taking into account all the possible things that can invalidate our experiment to address them during the design stage.
- Choosing the most suitable devices for extracting the desired metrics.
- Choosing the correct set of users to perform tests depending on the test topic.
- Choosing the proper location to carry out the experiment and searching for all the known devices that might cause artefacts in the signals. This would make filtering easier.
- Filtering the resulting signals to obtain significant data.

Chapter 4 - Experiments

Taking into account all the previously specified items, a series of experiments have been conducted with both the objectives of increasing knowledge and applying them to new areas, so not only defining new ways to obtain UX data but to enhance more classical-research results. One of the elements that have been tried to explain in more depth has been the observable differences from a gender perspective. It is a known thing (Abdi Sargezeh et al., 2019) that gender is a determinant factor in the way the user explores a given scene when measured with an eye tracker. This data, although controversial, is used with success to enhance shopping attitudes in many online portals (Hwang & Lee, 2017). The secondary objectives are to know if this gender perspective applies to the other biosignal devices too. If this is so, it means that there are cognitive and automated differences, while if not it means that only cognitive approaches are gender split.

For all the reasons mentioned above, not all the experiences finished with a publication, as some of them are preparations to obtain a trusted methodology, others the results were in part property of a private company and others were simple proof of concepts.

This chapter presents a series of experiments that allows us to answer the research questions. Each item will have those sections: **Objectives**, **Materials used**, **Design**, **Execution** and **Results and Challenges**. They can be used as a guide to follow the steps that allowed us to resolve the need raised.

4.0 Summary table

Ref.	Devices and Soft	Objectives	Achieved
4.1	• Emotiv Epoc • Emotiv SDK • Server with ECS	• Ontology proposed • Description of the user's emotions • Automated emotion system detection	☑ ☑ ✗
4.2	• Muse Neuroheadset • Empatica E4	• Provide clues to patients perception • Automated emotion system detection • Manual emotion system detection	☑ ✗ ☑
4.3	• Emotiv Epoc • Matlab • Empatica E4 • Tobii T60 Eye Tracker	• Establish a protocol for neuromarketing • Manual emotion system detection	☑ ☑
4.4	• Web server • Emotiv Epoc • Matlab • Empatica E4	• Manual emotion system detection • Applications in cross-sectional research • Educational intervention	✗ ☑ ☑
4.5	• Emotiv Epoc • Arduino	• Show how thoughts can affect the real world • Users amusement	☑ ☑
4.6	• Web server	• Improve students motivation using gamification	☑
4.7	• Web server	• Generating specific gaming content	⏩
4.8	• Bitalino • Android Phone	• Build a non-expensive wearable • Make prototype for the treatment of escapists	☑ ☑
4.9	• Emotiv Epoc • Matlab • Empatica E4 • Tobii T60 Eye Tracker • IAPS Imagesets	• Manual emotion system detection • Self-regulation affect the recognized emotions • Provide feedback to the medical students • Machine-learning emotion system detection	☑ ☑ ☑ ✗

Table 5: Experimental Results

Achieved ☑, failed ✗ and waiting for results ⏩

4.1 Emotions ontology for collaborative modelling and learning of emotional responses

Taking into account the possibilities seen in previous experiences (most of them tests about how our devices worked), in the year 2015 and intending to track students' engagement to reduce dropout rates in MOOCs (Massive Online Open Courses), our team addressed this problem from the emotional perspective by defining a framework to collect and represent emotion-related data from different sources.

The main issue was related to not having a formal common representation of emotions to integrate them into applications that had as objective improving the user experience. EmotionsOnto was a generic ontology proposed for describing emotions and their detection, taking into account not only the content but contextual and multimodal information. Although emotion information was provided by users themselves via surveys during the evaluation of the ontology, this was our first project to study the measurement of emotional detection using BCIs (Brain-Computer Interfaces) and the possibility to integrate them with the obtained cognitive data.

4.1.1 Objectives

The main objective of this work was to formalize an ontology flexible enough to fit all existing emotion theories, without the need to be limited to a given one. In the future, this will allow the integration of the emotional knowledge model into a tool integrating Artificial Intelligence to automatize the detection. The secondary objective was to study the viability of providing automatic emotion detection collected via Emotiv EEG Neuroheadset and integrate it onto the ontology.

4.1.2 Materials used

- A server with deployment of the “Emotions Common Sense” project, an enrichment of MIT’s “Open Mind Common Sense” (Speer, 2007) with more structured input based on emotional ontologies.
- Emotiv EPOC NeuroHeadset with 14 saline sensors.
- Emotiv Standard-User SDK. For this experiment, a research SDK was not required.

4.1.3 Design

Before EmotionsOnto, previous attempts of defining emotion-related ontologies were not generic and focused on specific areas: Yvette Yannick Mathieu proposed a lexicon of feeling related to psychological states (Mathieu, 2005) similar to WordNetAffect (Fellbaum, 1998) both to automatically annotate emotions in the written text or (Benţa et al., 2007) centred around speech recognition. The proposed generic approach (EmotionsOnto) allows expressing the multimodal nature of human emotions without being constrained to a particular field, thus providing room for diverse kinds of data sources and ways of modelling emotions.

The first development steps required the user to manually describe the input into the system, but at a second stage, the objective was to evaluate if it was possible to access emotional input in an automated way. To do so, the technology used was a BCI (Brain-Computer Interface) that provides means to access and record brain activity. The most commercially usedBCI by that time was the Emotiv Epoc, actually the most complete portable EEG that fits into any budget. This comes at the cost of being considered as a gaming product and not a medical device (see 2.2.2.3 for more information).

Figure 43: Emotiv Epoc. Source: (Gil et al., 2015)

Emotiv Epoc. Source: (Gil et al., 2015) data from 14 saline sensors, but on this occasion the information will be processed automatically and retrieved by Emotiv User SDK, using their algorithms to analyze the data. "*Affectiv*" Suite from the Emotiv SDK performs automatic EEG data processing and outputs emotional levels corresponding to Engagement/Boredom, Frustration, Meditation, Peak Excitement and Long-Term Excitement. The interaction with the system will be monitored using an eye tracker to see if the data obtained can be related to the features gazed.

As the first attempt with this new feature, the tested users would be the six (two women and four men) personnel from our research group. This means that the facilitator protocol can be more relaxed than with regular users. Moreover, some changes should be applied to not emotionally affect them: as they are researchers, the usual protocol must be somewhat changed due to the demographic sector they represent.

Usually, the protocol defines the way to interact with the user to be clear talk without technicalities. In this case, the protocol can be more relaxed, speaking to them technically to generate more trust is encouraged. As usual, only the facilitator should be present in case the user needs any help or has any question, and the rest of the users should be outside the area of influence of the user. It is important that the user only interacts with the facilitator from the moment the user enters the laboratory until it finishes the experiment.

During the calibration, the facilitator should explain to the user what is being done at each moment and the purpose of each instrument, taking the time needed to answer if the user wants to know anything about the procedure. All that effort was made to try starting the testing phase as emotionally neutral as possible.

4.1.4 Execution

This model was generated by capturing the entities that take part in the emergent emotion process (Gil et al., 2015) as it is seen as a triggered process (Scherer, 2009).

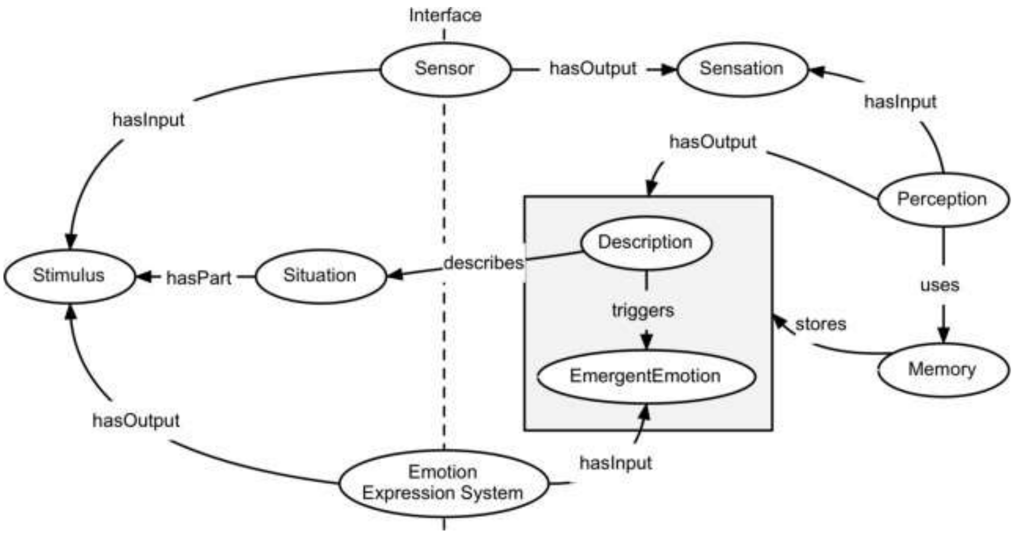


Figure 44: Capturing entities in the Emergent Emotion Process. Source: (Gil et al., 2015)

The model is implemented using the primitives provided by the Web Ontology Language (OWL) (Lacy, 2005), part of the Semantic Web tooling (Lytras & García, 2008). Using this language makes it easy to share publicly the resulting conceptualisation and to integrate it with third-party tools. The main building blocks are the classes, sets of things of relevance for the domain (shown as ovals in the figure), and the lines connecting them, which represent the relations among these classes or concepts. The advantage of using generic ontologies is that upper ontologies could be taken into account to complete the semantics of the classes, like for Sensor or Stimulus.

Upper ontologies are the most generic kind of ontologies, those that define generic concepts like system, object or process and are used as the building blocks to describe things that happen in the real world (Sowa, 1999). Using these generic descriptions is recommended to establish a common language to bind different ontologies together, resulting in a more complete high-level world description instead of different conceptualizations for the same terms. The Upper Ontology chosen for the was DOLCE (Gangemi et al., 2002), standing from Descriptive Ontology for Linguistic and Cognitive Engineering, as its cognitive approach fitted really well with the challenge of modelling emergent emotion processes.

The semantics provided by DOLCE has been reused and extended. The Event concept in DOLCE generalises everything being triggered in the model, particularly Emergent Emotion. Other kinds of specific events in EmotionsOnto are the cognitive processes Perception, Memory and Sensation. Or those kinds of events with at least one agent participating in them, Action in DOLCE, which has been refined into Psychophysiological and Behavioural actions, like Gestural, Speech or Facial actions participating in the Emotion Expression System.

Other key concepts in EmotionsOnto are Sensors, including Senses, and Situations, which represent the social and environmental contexts perceived and which might trigger emotions after going through the cognitive process that results in their internal representations, i.e. DOLCE's Descriptions.

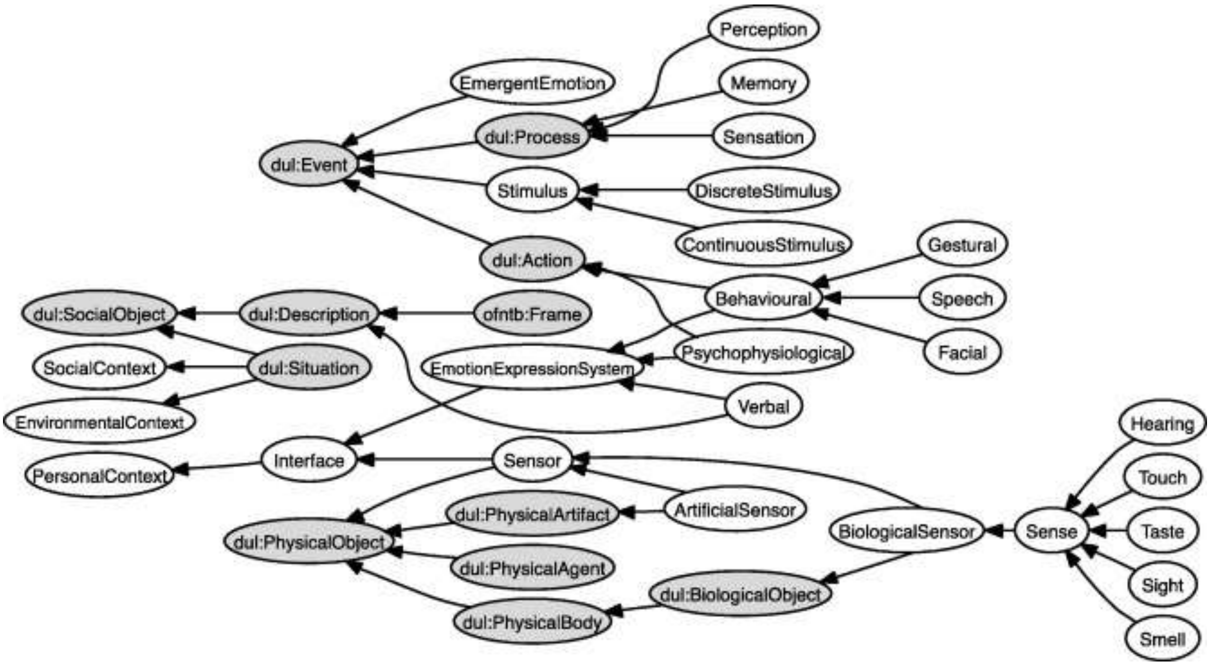


Figure 45: DOLCE attribute and class enrichment (Colored in grey). Source: (Gil et al., 2015)

To represent these Descriptions and add information about how emergent emotions are triggered and by whom, FrameNet (Scheffczyk et al., 2006) is used as the source of concepts and relationships to build these descriptions. The reason is that it is prepared to model schematic representations of a common situation with a set of participants with given roles, so it includes social interaction apart from individual experiences.

EmotionsOnto had been deployed over an Emotions Common Sense project (EmoCS) database inspired by Open Mind Common Sense (OMCS) (Speer, 2007). Both aim to provide a collaborative database of common-sense related topics, but EmoCS adds a layer of Emotions. To do so, an interface to capture a set of pre-defined emotional inputs from users was added. EmoCS differentiates from OMCS by replacing free sentences with representations of situations, i.e. descriptions, that might trigger emotional responses and which are based on FrameNet's concepts and relationships.

As one of the side objectives in this project was to provide the user with an easy way to process inputs, the project included a Web form with a series of autocomplete features against FrameNet concepts, easing that users describe the situations and the emotional responses that they trigger on them.

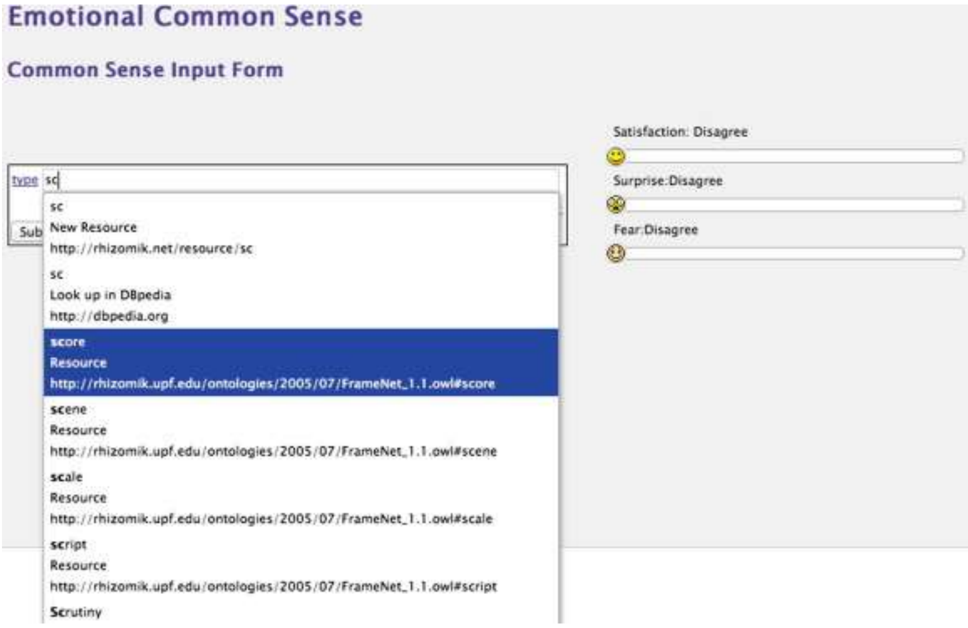


Figure 46: EmoCS user input. Source: (Gil et al., 2015)

Finally, the user must set the valence of the different emotional inputs using the smiley sliders at the side. When submitted, the generated representation is associated with a set of Emergent Emotions. It is important to emphasize that the system was not capable at any moment to recognize emotions, but to model them and get them described properly.

To discover if the task can be automated with Emotiv Epoc headsets, *Affectiv* Suite processed the emotional states of users that previously annotated different situations using EmotionsOnto while viewing pictures and videos illustrating the same situations.

The experimentation with the headset was performed in GRIHOs UsabiliLab, with the last-minute intention to use the Tobii's tracker (although this was not planned beforehand and consent had to be updated with the new info). The users signed a consent form and the calibration began.

The wet pads that need to be filled with the saline solution were moistened before putting the headset on the user. Actually, there is no way to know if they are wet enough, so if an optimal contact level is not achieved the helmet was worn off and the process restarted. The overall process was slow. It was shown that achieving good quality sensor contact was more difficult with long-haired people than with short-haired ones. In addition, the saline sensors dry faster with long hair too. As statistically females present long hair more often than the male population, it was substantially more difficult to obtain a proper contact level on them (but it was only attributable to the length of the hair).

Cosmetic hair enhancements such as lacquer presented by some users needed to be cleaned before attaching sensors to achieve full contact. As that mainly affected when the product was in contact with the skin and not with the hair, this happened more often with men (mostly short-haired).

Users with glasses presented issues with the quality of the sensor contact too, as the reference contacts behind ears are not suitable for users wearing glasses with rods. It was found a way to put the glasses on “after” connecting the headset by putting the glasses in the top of the headset without interfering with the EEG signal (at least with plastic rods, metallic glasses were not tested).

Unfortunately, *Affectiv* numeric output is not available outside Emotiv SDK, so the emotional states detected were annotated manually into the platform after analysing visually the screen output.

Figure 47: Emotiv SDK, Emotion Detection. Source: (Gil et al., 2015)

Emotional Suite from the EPOC SDK performs EEG data processing and shows emotional levels. The success of this suite leaves much to be desired, especially with further testing. In addition to the fact that there are values, such as the level of frustration, which can in no way correspond to the actual stage of the individual. The final impression was that the Emotional Suite was still an immature product or that the final aim was just to have some sort of "playground" for users that a tool with any kind of scientific purpose.

Consequently, the main issue was that the five affective dimensions being evaluated by the SDK were hard to match to any established categorization of emotion, as the company themselves admit that their detected emotional states are not accurately reflecting emotions but more an emotion intensity-based approach. For example, the "Excitement" measure represents an activation state with a difficulty distinguishing its origin, as it increases with both feelings: fear and surprise.

4.1.5 Results and Challenges

The ontology developed has been made independent from existing emotion theories, so developers can use EmotionsOnto in any emotion theoretical frame. It allows integrating not only the media but also the sensors in the experience by the way they behave. For example, the user interfaces as input or the pictures on the screen as output, and to link them with emotion recognition systems. This ontology can be expanded in the future to fit not only almost every emotion theory but to integrate various in the same model, acting as a bridge.

The correct description of the user's emotional state is a good starting point, even when that implies a conscious effort of the users introspecting themselves. This opens the field for emotion-aware applications, where an external agent (like an Artificial Intelligence agent) can react taking into account the user's mood when interacting with the system. In addition, the agent triggering actions in the Emerging Emotion process can lead to an improvement in the mood with its interaction, adding emotional dimensions to the context and multimedia items being used during the interaction. In the same way, a bad interaction with the system can be considered not only unpleasant at a cognitive level, but also stressful at an emotional level, adding importance to realizing proper usability testing.

Unfortunately, no good results were obtained with the objective of achieving an automated emotion detection system using an EEG headset, not for the quality of the extracted data but for the obscure nature of the official SDK that encrypts the data in the headset before sending a Bluetooth packet without providing any output (all the visualizations are performed in the visualizer provided by the headset manufacturer).

After knowing this, a set of Python libraries have been used and adapted to decrypt those messages and override the official SDK constraints, accessing the high-quality raw data provided by the headset. This will allow us to process the data to detect the 6 basic emotions identified by Eckman (1984): anger, disgust, fear, happiness, sadness and surprise.

Anyway, a lot of practice was achieved with the headset setup and how to put it on over users in a fast and reliable way, even with those wearing glasses. Issues with wetting the helmet while the users are still wearing it must be solved to perform longer-term experiments.

For more information related to this research the resultant publication can be consulted (Gil et al., 2015).

4.2 Experience with fibromyalgia patients

The experience was conceived as part of the study "Well-being and health through artistic experience" (Rius, 2014) of the Universitat de Lleida with the collaboration of the Hospital Santa María. The project analyzes the emotional impact that artistic experience has on 18 women between 34 and 67 years old with fibromyalgia and chronic fatigue syndrome (As it is usually diagnosed in women from 30 to 60 years). These diseases affect especially the female group. In addition to addressing different techniques such as collage, watercolour or tapestry, the participants also carried out surveys and interviews to capture the effect on their state of health to measure changes between the sessions. The study was conducted between the end of 2014 and the summer of 2015.

The main issue related to this topic is that the diagnosis is purely clinical (Ministerio de Sanidad, Consumo y Bienestar Social, 2020) and it is not supported by any specific laboratory test or finding. For that, there is no clear unanimity when diagnosing, and in all cases, the patient needs to meet a wide set of restrictive requirements that not everyone matches in. This causes the patient to feel frustrated and alone.

It was qualitative research that starts from the general idea that art improves health, especially in terms of reducing stress and emotional tension. Our research group performed a pilot inside the study to find out if non-invasive emotive data could be extracted during the sessions to provide biofeedback. Photographs, filming and voice recording were also taken.

4.2.1 Objectives

The main objective was to find out if emotive data could be extracted from users who are performing "everyday" tasks, and if that data could be processed to obtain significant information that could be added to the feedback given to the patients. This is important because obtaining information of a user in motion would be a giant step into our research as usually the user needs to follow a series of rules to obtain valid data, such as being quiet and in silence.

The secondary objective was to provide clues about the perceptions of the emotions in patients suffering from this condition, and if those perceptions are similar (or not) to the emotions experienced by people not suffering from the affection. Specifically, if the values detected were in normal ranges or in higher ones. Providing feedback hinting that patients were feeling pain in higher amounts than normal would be useful not only for them but for their surroundings and the society in general, as the main problem for some patients is feeling guilty and unattended by a society that sometimes considers them to be looking for attention. A quantitative measure may help to communicate to others what is happening to them in order to highlight their suffering, improving their social visibility.

4.2.2 Materials used

- Muse NeuroHeadset.
- MuseLab SDK.
- Empatica E4 WristBand.

4.2.3 Design

Two of the seven sessions of the original experiment were carried out in the GRIHO user experience laboratory, specifically in the briefing room dedicated to focus groups. That room was big enough to keep the 6 selected users (the volunteer subgroup that agreed to participate in our sessions) and the moderator (that was in addition their nurse) together during the session. Although only one user was being monitored at a time, keeping the group together was considered important due to the social context of the experiment, as the "group" and the emotional ties were important.

The sessions consisted of users making artistic projects together around a table while speaking among themselves and their feelings, guided by a medical facilitator: In both sessions, they were painting and making a collage with various materials. During these sessions, two users were monitored with a Muse headset and an Empatica E4 wristband.

In this case, the interaction protocol was extremely important as the users were patients with an illness, and the experience was part of a medical intervention. The users were varied on the economic social layer and studies level aspects, but all of them are women with relatively old age and not very versed with technologies. This means they need to be explained carefully each step in plain language and with lots of patience. The facilitator and an observer should be present but in a zone of no influence and going unnoticed. It was important that the user only interacts with the facilitator in case they have any doubt or need help with anything, in this case, the interaction was still monitored by the observer.

The Muse device had been chosen because of its dry sensors, so they can keep the same level of contact during one hour sessions without loosening the connection. In addition, it was the most comfortable neuroheadset available and was the one with less weight, a key point in the experiment. In addition, because only monitoring the frontal activity this headset has a faster calibration time as hair length is not an impediment. The same for Empatica E4, its dry sensors and the huge quantity of data that it provides makes it ideal for combining data.

All the raw and processed data obtained by the Muse headband and the Empatica E4 were stored in a computer to be processed in a later phase to be analyzed during key points of the session. Finally, results will be delivered to the control group to discuss them.

4.2.4 Execution

The First session started on October 1st at 17 hours, an ideal period due to the fine weather that allowed us to keep the room temperature at 24-26 degrees without much effort while using natural illumination. The second session was carried out exactly seven days later (October 8th), with the only change that the monitored user was a different one. All the sessions began with a relaxation and introspection session listening to music (visualizing positive images while their eyes closed), following an artistic session with activities and finishing with another relaxation session.

Figure 48: Focus group preparations. Source: own photo

One user per session carried a Muse neuroheadset and an Empatica E4 wristband. Each user was presented the project and explained what will happen if they accept to participate in the experiment. Then, they were asked to fill a consent and proceeded to prepare the devices in a room apart from the rest of the users. The calibrations were realized as protocolary, with 5 minutes isolated (in the user testing room, that is exactly side by side with the focus group room) pre-session before the first relaxation session: Isolated because silence was required to assure that the resulting biosignals do not include artefacts. It was checked that MuseLab reported good sensor contact quality with the forehead and that the user was not unresponsive to EDA with the deep breath technique (3.2.5). In addition, a short session was recorded to compare previously and during experiment levels.

Both devices were synchronized with the same computer to assure events share the same timestamp. To do so, even with Empatica E4 uploading the data online when connected, a feature of the wristband synchronizing clock with the local computer when there’s no connection with the platform was used. Muse-lab was running on the same computer. To assure the sync was valid, before the session a “smash test” was performed, and the accelerometers from both devices marked the event at the same timestamp.

Figure 49: Focus group artistic outputs. Source: own photo

The wristband showed a great grip during all the sessions, but the same cannot be said about the Muse headset. Due to the nature of the experiment, the EEG presented poor contact quality after sudden move events (such as, making a fuss or tilting the head when laughing). For this reason, we encouraged the carrier user to not move suddenly and we kept an eye on the real-time headset feed to rearrange it if the contact quality descended. With the advice to the user, things went smoothly during the rest of the session, so the same technique was applied during the second experience.

After the sessions, eye inspections were carried out as attempts to automate the process were unsuccessful due to the number of artifacts present in the recorded sessions. It has been decided to look at the calmer moments to evaluate them: the video feed helped in that way, to find moments where no one was talking, as well the Empatica data to find when the user was moving less.

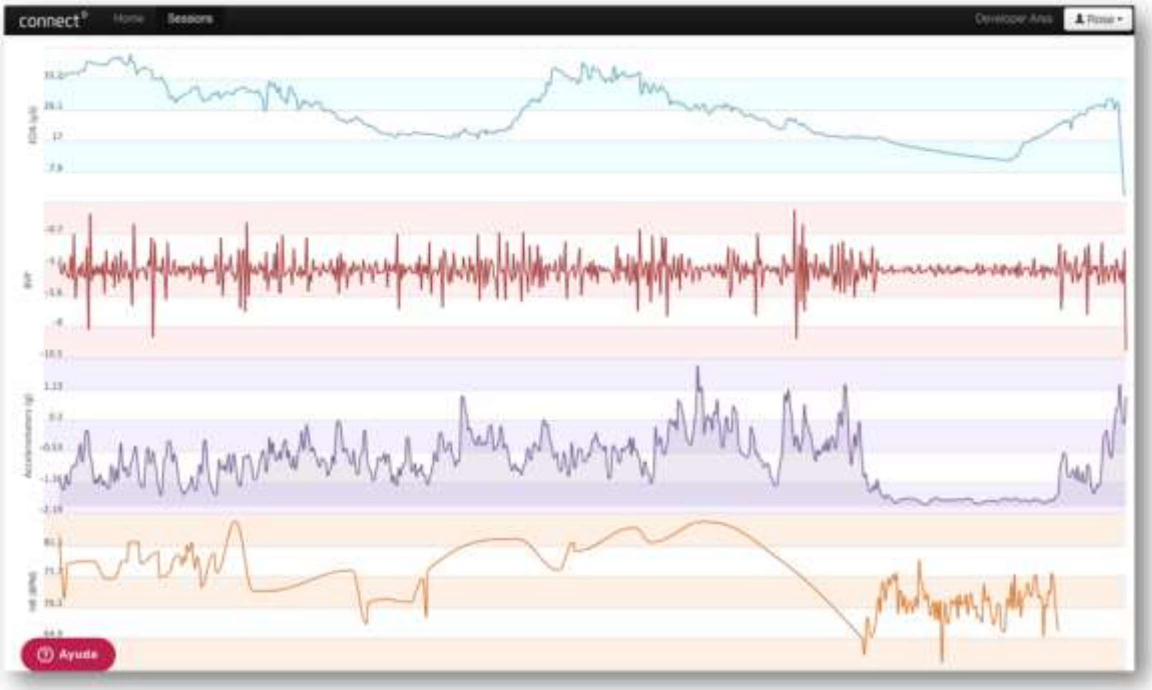


Figure 50: Empatica E4 Results (zoom in). Source: own image from the data extracted

4.2.5 Results and Challenges

The EEG sample of the two users of the experiment agreed on the trends shown, reaching the following hypotheses (to confirm these hypotheses, a more exhaustive study would have to be carried out with more users):

Regarding the extract of the four channels at the point of starting the experiment, before performing the relaxation session: Quite high beta wave values were seen in the frontal area, not in the parietal areas. This may be due to cognitive arousal, for example being nervous under scrutiny. The abundance of beta signals in the frontal zone is associated with states of concentration (therefore the inverse of relaxation) and anxiety. On the other hand, alpha signals are associated with states of relaxation. It may seem a bit contradictory, but they were seen only in the frontal area. So the explanation may be another.

Metric	TP9	AF7	AF8	TP10
/muse/elements/alpha_absolute	0,10495403	1,4587822	0,7852013	0,45389017
/muse/elements/beta_absolute	-0,28992823	1,4456733	1,171252	0,15444803

Figure 51: Muse absolute alpha and beta absolute values in a given point before the experiment. Source: own image from the data extracted

During the relaxation session, it could be seen how the beta band decreased a lot more than expected. As they were "guided" experiences (these were sessions in which patients are asked to visualize relaxing images) it cannot be attributed to a state of semi-consciousness, as users were having active thoughts in the segment analyzed. So it seems that the only reasonable explanation was that the mentor actually reduced the anxiety that they felt only 5 minutes before. On the other hand, the alpha waves have increased, except in one user in the FP1 sensor. There was only one user issue, so it may be due to poor contact in the area or that the patient had one eye semi-opened during the close-eyes session.

Metric	TP9	AF7	AF8	TP10
/muse/elements/alpha_absolute	0,64426565	0,77450705	0,7827972	1,2705215
/muse/elements/beta_absolute	1,282633	0,5644428	0,41849214	1,3982798

Figure 52: Muse absolute alpha and beta absolute values in a given point during the relaxation phase. Source: own image from the data extracted

At a quiet midpoint of the experiment, during the art session: Beta waves remain stable, although they were performing an activity that feels relaxed and can almost be defined as an instinctive task. At this point, we found it interesting to note that the alpha values were high, without being in a relaxed state with the eyes closed. Looking for an explanation for this phenomenon, we found the concept of "Alpha Wave Intrusion". This occurs when alpha waves appear instead of delta for pre-REM phases of sleep. It has been hypothesized to be associated with fibromyalgia (Germanowicz et al., 2006) but our study is inadequate due to the small sample size. Can this phenomenon appear outside the sleep phases? In the future, a session with EPOC headsets should be tested, since with higher quality samples in more different regions we could try to draw more conclusions about it.

Metric	TP9	AF7	AF8	TP10
/muse/elements/alpha_absolute	0,8929922	0,8002109	0,61104226	1,2705215
/muse/elements/beta_absolute	0,9940644	0,61122304	0,2717077	1,3982798

Figure 53: Muse absolute alpha and beta absolute values in a given point during the artistic phase. Source: own image from the data extracted

Alpha waves remain high at the end of the experiment. The same experiment should be tested over a control group with users who do not suffer from this condition (fibromyalgia). Regarding beta waves, the frontal values obtained were lower than the initial ones. This seems to show that patients feel less anxious after performing the activity. The activity could be programmed a little earlier in order to check the duration of this observed effect, as well as the permanence of the effect over time.

Metric	TP9	AF7	AF8	TP10
/muse/elements/alpha_absolute	0,83511424	0,61221488	0,41982645	1,2705215
/muse/elements/beta_absolute	0,94646895	0,4543646	0,49796757	1,3982798

Figure 54: Muse absolute alpha and beta absolute values in a given point after the experiment. Source: own image from the data extracted

Bilateral symmetry was not worth analysing because the sessions have had multiple failures in the quality of contact in the sensors, mainly because they involved a lot of movement. Dry sensors seem to not be intended for this type of activity.

Biosignals wristband did not provide any useful information due to the bad quality of the recording during the activity part of the sessions. The lack of quality in the data was a catastrophic mixture with users asking for a more "loosen" wristband (as they felt discomfort when it was tighter, remember they were patients with an illness) and all tasks performed by the users being manual (and implying a lot of arms movement). Only showing relaxation during the meditation sessions, without having a good signal monitoring the activity phase doesn't have much value. A general decrease in the overall tonic EDA levels was detected, but at that point it can be even due to the wristband touching different parts of the skin.

Due to the experience being more a proof of concept than a formal experiment with a huge control group, no publications were made from them. Anyways we have learned a lot about using various devices at the same time, and how to properly conduct an EEG acquisition session. It was interesting to notice the physiological effects of the moderator over the users, especially when there's a trust relationship between them.

The volunteer users were delighted to collaborate with our experience and for being provided with a new kind of data that helped them to understand, if not their illness, how their body was working and how they processed the experiences lived. Many years later, a study in the Vall d'Hebron Hospital (Serrat et al., 2020) demonstrated the effectiveness of combining medications with neuroscience of pain and cognitive behavioural therapy in the treatment of fibromyalgia. Understanding the neurobiological mechanisms associated with pain effectively reduced their pain perception starting from six weeks.

As future work, more experiences related to patients should be performed, especially those suffering from illnesses with a known affection in daily actions. Ongoing research in this field is being developed as a part of a FIS scholarship ("Fondo de Investigación en Salud") given by the Government of Spain with the title "Effects on treadmill walking in a gamified virtual environment with noninvasive brain stimulation in Parkinson disease" That is scheduled between 01/01/2021 and 29/12/2023. The team is composed of a multidisciplinary team.

4.3 Study of the image of the new Mini five doors

It was the first experiment in this thesis direction that can be classified as a neuromarketing experiment. This type of experiment seeks to find the cognitive and emotional reaction of groups of people to various stimuli, mostly capturing people's neurological and sensory activity.

The experiment on the "perception of the image of the new mini five doors" was part of a larger experiment on the study of the perception of different brands that took place in Universitat de Lleida (UdL) and TecnoCampus Mataró (TCM, part of Universitat Pompeu Fabra) between 2014 and 2015. Initially evaluating phone carriers, drinking, banking brands and national political parties logos, the car brands were added to the study after a marketing company (Bitlonia) contacted us to help them with their campaign "NEUROMARKETING - MINI" for Pruna Motors.

4.3.1 Objectives

The main objective was to establish a methodology and a protocol to define scientific experimentation in the field of neuromarketing and the emotional and affective interaction of people with sensory stimuli, in this case with images that were evoking strong likeness or dislikeness.

This will be achieved by validating or invalidating our initial hypothesis:

· The main hypothesis indicates that a greater activation of the left PFC (Prefrontal Cortex) indicates pleasure or liking, while the activation of the right side indicates rejection or discomfort. The validity of inter-hemispheric discrepant activation needs to be checked.

· Evaluate if left and right-handed users presented differences in the EEG, causing discrepancies in that frontal asymmetry. This can be caused (when they are reading for example) by the fact that the center of language seems to be at the opposite hemisphere that the hand used to write: right-handed people have language processing on the left side and vice versa.

· As there exist gender bias in the navigation and exploration methodology (it is known as explained in the introduction of the chapter), evaluate if these differences can be found across all the other biometric devices, not only in the eye-tracker data.

· Emotions are processed by subcortical activity, but the EEG measures only record cortical signals. Are those cortical signals enough to detect emotions? We believed that complementing EEG info with other biosignals coming from Empatica wristbands could help in that task.

· The raw data extracted from the headset with our custom scripts can be filtered and processed with better results than with the limited data obtained by the official graphical interfaces from headset SDK.

The secondary objective was to study the emotional and sensory reactions of a population with the sight of cars in photos, one of which was the by-then "new" five-door Mini. The company had the theory that this more robust 4-door would be more attractive to the male public (it seems that previously their brand was more liked by female drivers). Besides the obvious enterprise benefits, this allowed us to study the ethical limits and work on an ethical code for this type of tests.

4.3.2 Materials used

- Emotiv EPOC NeuroHeadset with 14 saline sensors.
- Emotiv custom scripts to extract data from the headset (in python2).
- Matlab.
- EEGLab (Matlab plug-in).
- Empatica E4.
- Tobii T60 eye-tracker.

4.3.3 Design

The experiment was intended to be carried out at the GRIHO usability laboratory, both for having the proper space to carry out the experiment and because of the possibility to use a high-end eye tracker (Tobii t-60) for enhanced precision.

The design started with the decision of which kind of images were going to be presented and how. Users were monitored while looking at images featuring (by order) phone carrier logos, banking brands, car models and national political parties. It was decided to add a first image presenting popular refreshing drinks to measure the baseline response with emotionally neutral images. Having a baseline to compare with allowed us to calibrate the activation intensity over the different pictures.

Representative logos were chosen for each brand. To solve the problem about some of them having different sizes, each brand was surrounded by an area of the same size painted with the cooperative colours of the company.

Each set of images show a 3 x 3 grid with nine images of different brand logos. Five image sets were presented to each user, one for each category. To assure that the position in the grid was not affecting the results, the position of each brand in the grid was randomized for each user. Users have been exposed to each grid for 10 seconds.

Figure 55: Brands selected for the test. Source: own images

The system that showed those images needed to be equipped with a Tobii Eye tracker to obtain the gaze information associated with the user fixations. The software that comes with them was specially designed for those tasks (showing media) so time and presentation configuration were not a problem.

Two focus groups were carried out with researchers in our group and students (from other courses, so they won't be on the testing experience) to choose the nine most representative brands for each category:

- The emotional neutral screen was chosen to be refreshing drinks due to the fact that these do not usually have an emotional bond, and if there's one it is generally considered a positive one. Practically no one hates a drink because they like another one. Some brands were discarded for not being recognized by all the members in the focus group (for example 7up and Sprite), as we wanted universally known kinds. Finally, we tried to choose representatives from non-sugar centred refreshments like Nestea or Lipton.
- The carriers were chosen among the ones most used by the members of the focus groups. Casually it all sum 8 elements, so we added Simyo for having a popular advertising on TV by that time to get 9 elements.
- The political groups were those present at the parliament of Catalonia during that year plus two important national parties that don't have a local equivalent (*Podemos* and UPyD).
- Banking brands were exactly the nine elements that cover all the variety used for the members in the focus groups. They agree that there are the most representatives.
- Car brands were provided by the external company and were (believe it or not) cars that competed by that time with the Mini brand cars.

The initial experimental group consisted of 30 young university students from Lleida and Mataró between 18 and 25 years old, and the study segmented them by sex to see if differences can be established. This was due to the intention not being to have a broad demographic sample but to find similar patterns between similar types of users.

Subsequently, the sample was expanded with a group of ten women and men between the ages of 25 and 50 by petition of the neuromarketing company for the Mini to test one of their hypotheses due to the results shown in the first test: the new mini model was more attractive to the feminine mid-age population than the previous model. This new hypothesis appeared as the previous one, that the new Mini 4-door model was more interesting among the male drivers than previous models, was invalidated (see secondary objective and results), as male drivers didn't even notice the difference… but the female drivers did!

Figure 56: Cars selected for the test. Source: images provided by Bitlonia for the test

The interaction protocol defined for this session was a more classical approach than the previous ones. The users are average persons with no special needs. They need to be explained carefully each step in plain language and with the usual patience that characterizes a good facilitator. Only the facilitator should be present but in a zone of no influence and trying to go unnoticed. It was important that the user only interactuates with the facilitator in case they have any doubt or need help with anything, but the user needs to understand that not talking or moving during the 1-minute central part of the experiment is very important (in this case, that segment will be invalidated).

During the calibration, the facilitator should be explaining to the user what was doing at each moment and the purpose of each instrument, taking the time needed to answer if the user wants to know anything about the proceeding. All that effort was made to try starting the testing phase as emotionally neutral as possible.

Due to the high number of users participating in this experiment and anticipating that their schedules were similar (the majority were students), the crystal wall that separates the testing room from the waiting room was covered with curtains. A “stepped path” was defined to be sure the users that finished the experiment were not crossing paths with waiting users, using two different and opposite doors to make new users enter and letting users leave.

The experiment had three phases from the point of view of the user:

- Each user must read and sign an informed consent before filling a pre-test document to define their demographic group and preferences. Before start calibrating the devices, the facilitator should be sure that they have fully understood the agreement in the consent and that they can finish the experiment at any moment, but carefully not explaining anything about the content of the images the user is going to see.
- The facilitator guided the user through the testing process that lasted around one minute (5 images of 10 seconds plus 10 seconds to spare at the beginning). The user had to be sitting on a chair, looking at the screen without speaking while the images were showing up on the screen. The users didn’t need to answer any questions at this phase, because the information about how they were feeling should be recorded passively by the instruments.

- After that the user answered a post-test document about the experience, providing direct input.

Pretest survey was designed to establish a fast custom personality mock-up of the users, with dummy questions intercalated to distract their attention:

- Preferred colour: Important to know, as the brands have inherent colours. It was used to see if the brand with more gaze visits has something to do with that preference instead of the brand.
- Studies: Dummy question, as it was not important to know. We didn't have a great variety of groups, even in the second phase as the demographic objective was well known.
- Healthy food: A Variable that could explain the gaze detection at the initial stage (baseline recording) due to the exploration of the (sugar)/(not (so) sugar) drink.
- Philosophical questions: Aimed to divide left/right-wing attitudes. Related to the political parties question, as a validation.
- The visual attractiveness of a polygon. Dummy question.

The post-test survey was intended as a validation of the experiment, so it didn't have any dummy questions. It was aimed to see if the user was feeling uncomfortable during the experiment and questions related to brand recognition.

The biosignals wristband, the EEG headset and the eye tracker are three different devices with their respective clocks. This presented a problem related to data synchronization. To solve it, the headset and the wristband info were acquired by the same computer (an external laptop) without an internet connection, forcing the wristband to get the timestamp from the system (not their online server). The script to obtain EEG raw data was synced with the laptop too. The session recording was initiated first in the eye-tracker, with a first slide awaiting a key pressed in the keyboard, as this activates their webcam and microphones. When the EEG acquisition started, the recording program (EmotivUdl.py) produced an audible signal, which was recorded by the eye-tracker. This way all the obtained data were synced on the same timeline.

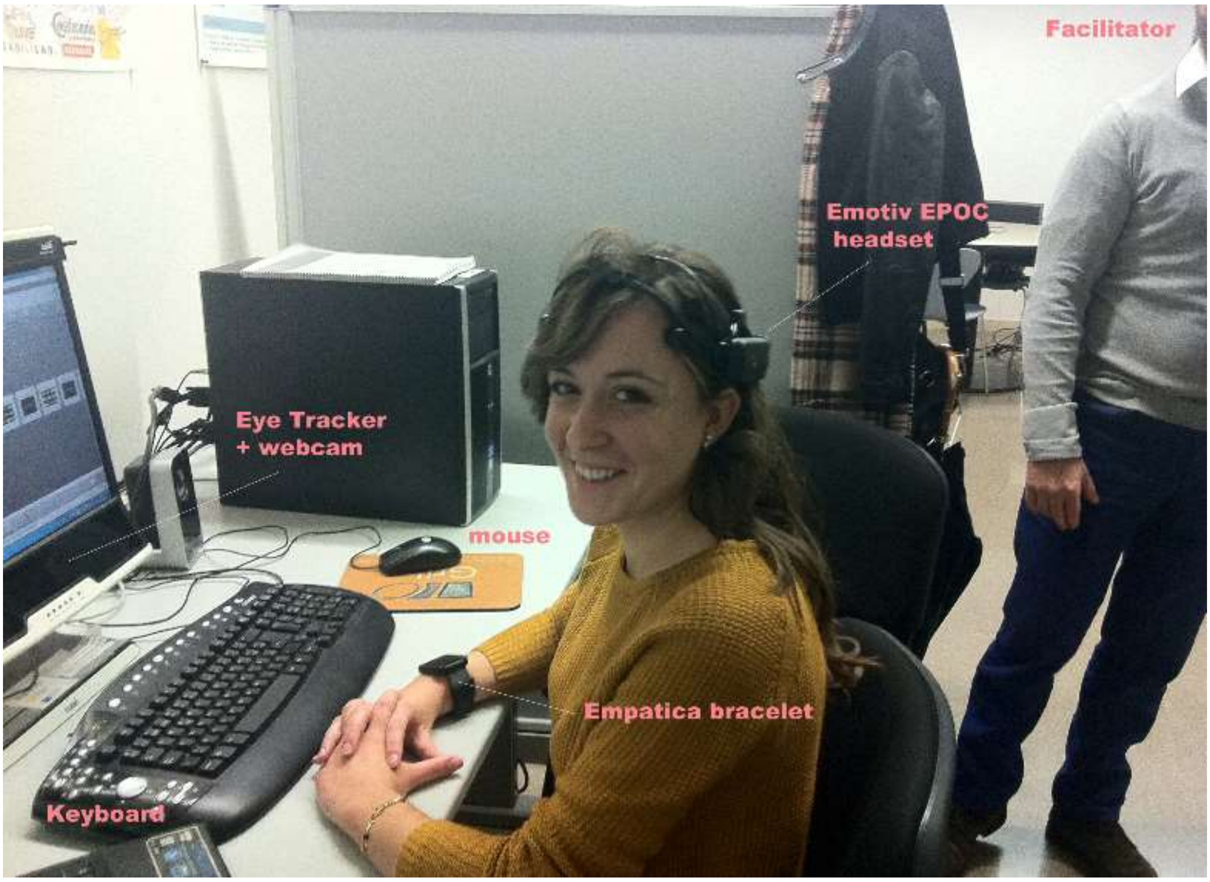


Figure 57: User after the test (equipment marked). Source: own photo

Emokit was a Linux-oriented python library by that time (it used some specific features) but we managed to get it in Windows so the official software could be used at the same time to compare results… The script worked fine if the correct equivalent libraries are installed on the system. Some references should be fixed at that time, although it seems that they've been applied before letting the project die in 2016. Once running, the Render.py script had to be modified so that the gyroscope sensor's data was ignored as it caused various random crashes caused by providing out-of-bounds data.

For Windows, using these scripts required the following dependencies with the exact versions (assuming a 64-bit Windows 7): gevent-1.0.1.win-amd64-py2.7, greenlet-0.4.2.win-amd64- py2.7, pycrypto-2.6.win-amd64-py2.7 and pygame-1.9.2a0.win-amd64-py2.7; obviously Python is also needed (version 2.7). Keep in mind that it uses python 2.7 as python3 isn't going to work. It should be noted that to work properly under Windows OS, python scripts must be modified by adding the includes from the socket or _socket library, even though they are not used (this seems to be a dependency problem). All these dependencies and modifications needed were undocumented at that time.

We created a simplified clone script that only can read and store the headset decrypted data called EmotivUdl.py, being our official standalone Epoc data extractor from then. Although the library seems to need to be installed (again, by that time) our tool was compiled into a single .exe file using PyInstaller (Cortesi, 2005) a tool that bundles a python application with its dependencies into a package. This allowed us to run it without even having Python installed on the machine.

As the experiment was related to user signal processing, Raw EEG data was extracted from the aforementioned EmotivUdl libraries, storing raw data sampled at 128Hz.

EEG RAW file sample (headset quiet over a table, not on a user):

[CODE]

```
2014-12-16 12:52:01.319000
PacketCounter Sync F3 FC6 P7 T8 F7 F8 T7 P8 AF4 F4 AF3 O2 O1 FC5
7 False 8249 8514 7173 8756 8242 8319 6936 8184 7657 8069 7610 7895 6977 8393
8 False 8254 8506 7176 8758 8246 8342 6947 8198 7659 8067 7620 7900 6968 8391
```

[/CODE]

Although it was suspected that the marked values were microVolts (the data extractor only provided raw numeric values) they have no units and it was difficult to find information about it. So reading the device specs, it can be addressed that:

In the official hardware documentation (Always hideous but today almost disappeared) it is said that Emotiv Epoc uses 14 bits to address a floating-point number to represent the differential detected, each bit with a resolution of 0.51 µV. So the range number our headset (extracted through the library) represented measures as an unsigned integer was from 0 to 16383 units (2^14), but in a resting state our signal needs to be aligned through the 0 axis… simple math: if 8192 are subtracted, the resultant number would be zero aligned, and each unit represents 0.51µV. Then the resulting data made more sense as the typical EEG values obtained are in the range from 0 to 200 µV. The majority of researchers of that time seemed to not care about that as they were comparing different zones on the same scale, but our data was changed to the µV format before being processed… using an excel sheet. The reason to not automate is that if the signal needs to be converted (as the next step) it is more useful to have the raw values.

The resultant raw data cannot be loaded directly onto Matlab (or EEGLab) to be processed so it needed to be converted to a more universal format. The chosen format was EDF (European Data Format), commonly used to store EEG signal data. In this sense, the EDFBrowser validator program not only allows to directly view the data (to discard erroneous sessions or sections of it) but also has a tool for parsing raw data and saving it in EDF format. Quite useful considering that the format of these files is very repetitive and it was not automated not so long ago.

Figure 58: EDF Browser: Signal and export page. Source: own capture

The aforementioned "ASCII to EDF converter" enables to convert these data to the new format, assigning each column to a sensor signal. As the order in which the signals were saved is known (in fact the order is written in the header of the raw file) there is no problem with it. Note that this program uses the physical maximum to set the offset, so the resulting files will be aligned at zero, in units U (but we know the equivalence 1U = 0.51 µV). These resulting files can now be opened with any EEG data processing software such as EEGLab.

In EEGLab (an open software plug-in for Matlab) the data can be pre-processed to remove artifacts (as sometimes integrated hardware in the headset doesn't do that) avoiding unwanted signals and decompose them using Independent Component Analysis (ICA). Maps and spectra of the signals were generated by groups of channels then.

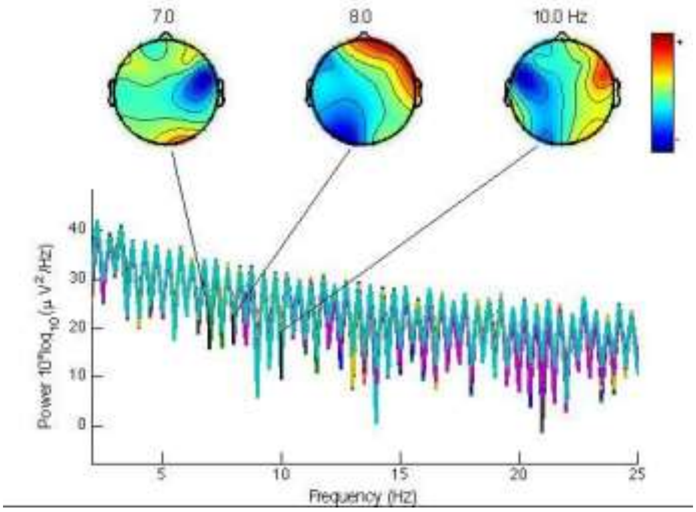


Figure 59: EEGLab Power map. Source: own photo

After that, the surveys are parametrized and the biosignals were studied together to validate (or invalidate) the experiment hypothesis.

4.3.4 Execution

The waiting room was prepared before expecting a high amount of users coming together. This was unavoidable as being students they came when finished classes, although they had an assigned time they came in 2-3 groups. The preparations were acclimatizing the room in a slight cold temperature to compensate from the rest of the classrooms heating the laboratory (it is situated on the 3rd floor, with climatized classrooms beneath). As expecting users with slight physical needs and with the aim to having them in optimal physical conditions, water to drink was put at disposal to everyone before the experiment as well as something to eat, but they are encouraged to only eat if they need it or after the experiment, as sugar levels could affect the results (just in case). The users are encouraged to visit the bathroom too if they feel the need to do so (students tend to not ask for it as they are used to doing so in class).

Each user must read and sign an informed consent before filling the pre-test survey. The facilitator should be sure that they have fully understood the consent, and that the user can stop the experiment anytime. It was important the facilitator does not explain anything about the content of the images the user is going to see to avoid habituation nor expectations. After that, they entered the testing room to start the calibration process.

The calibration of the devices followed the pattern of a mini session where the typical values must be observed: good contact quality in both headset and wristband sensors and peak detected in EDA when holding breath and releasing after a couple of seconds. If the peak was not detected, the user was not discarded, but they were noted as possibly unresponsive. The headset putting-on protocol varied slightly with the learned from other experiences, with the wet pads being only slightly soaked before putting it on the user, producing a bad contact with the skin. Then and only when the sensors are in their correct place over the user's head, each wet pad is soaked individually and locally using a syringe (obviously with the needle removed, only the plastic piston). This improves the time needed as the headset doesn't need to be worn off to soak one point, and improves the quality of the signal by not "closing a circuit" between two sensors by a conductive bridge. Eye trackers calibration process was automatic: it asked the user to look at a moving ball to calibrate the gaze positions for each point.

The users were asked to keep sitting properly, with both feet on the ground and not talk until the experiment finished, and that the experiment will start in 5 seconds if they don't say the opposite. Then the facilitator started the experiment.

The subjects traced an ocular path through the different images that were displayed during the testing phase. When viewing the route that has been made, it can be possible to see, thanks to the synced data, which images they like the most and which images they like the least (eye-tracking using non-invasive sensing) by the activation of the left prefrontal in the instant gaze was centered at that given point.

Figure 60: User during the test. Source: own photo

The most important EEG electrodes are the ones corresponding to the prefrontal cortex (those that include the letter F, mark of Frontal, and a number to show the position). There were being monitored the different brain waves in different frequencies: Delta waves (1-4Hz), Theta (4-7Hz), specifically Alpha (7-13Hz) while omitting the Beta (13-30Hz). In addition, the heat map provided by EEGLab could show, although only visually, this difference in inter-hemispheric intensities (being only visually they would not be empirical data).

The gaze route followed by the user as well as the timings that fixation was held at certain points will provide information about the user too. All this data was complemented by a small interview during the post-survey filling to directly ask for the opinion about the car due to the lack of questions over that topic in the survey. This was due we wanted direct feedback about it, so notes were taken in a notebook with the phrases the users told us.

Figure 61: Heat Maps. Source: own photo

The results (see next section) of the first test group were exactly the opposite as the company hypothesized. This required repeating the experience but changing the objective population, from young students to mid-age women. In this second experiment, political parties' slides were removed due to the interference they caused after its appearance (see results).

4.3.5 Results and Challenges

As a general result a different pattern of visual exploration had been detected for men and women, one systematic and the other focal respectively:

The systematic technique visited all the nodes in a coherent order, without revisiting nodes that previously have been seen if they are further than 1 jump of distance (they sometimes revisit the last node before jumping to the next). They were mostly all men.

The focal technique followed a graph-based exploration, deciding a central point of interest and returning to them each time the node followed was not more interesting (from the user point of view) than the previous. When something more interesting was found, that node became the central point from so on. They were mostly women.

In users with focal exploration, a great part of the brands was unexplored, with not even a gaze on them. When individually asked about that fact, some of them admitted that their center point of attention was their preferred brand and that they were mentally comparing them one by one, especially in the cars slide. Other users said that they did not even notice the other brands and were totally incapable of reminding them, but when informed of them they claimed that they don't have any interest in that brand. This gave us the clue to suspect that if it is not interesting for them, they unconsciously ignore the brand.

Figure 62: Female participant exploration route (Focal). Source: own photo

Figure 63: Male participant exploration route (Systematic). Source: own photo

Notably, this gender-bias exploration technique was found in almost every representative of each gender with only six exceptions in the female population presenting systematic explorations instead of a graph-based one.

There was a third type of exploration: Erratic scanning. It matches with the lack of information, when the model of the car does not give enough information to identify it. This was usually translated in a user looking at different characteristic points over a given car to try to extract more information about the brand. Interestingly some men cannot properly identify the new Mini, noticing something different but failing at pointing the difference (the back doors). From this, it was theorized that there was not enough information in the image provided to see the product effect (Mini 5 doors), only the brand effect (Mini).

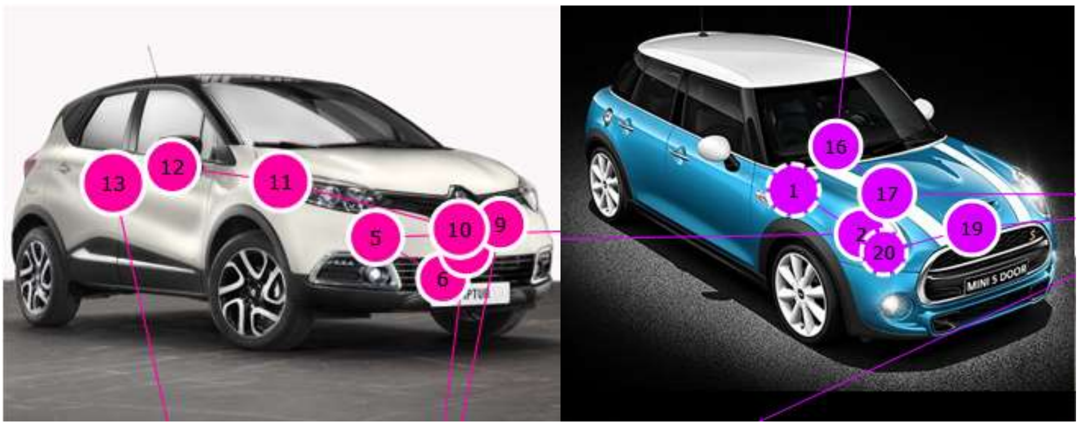


Figure 64: Erratic scanning, trying to obtain more information. Source: own photo

Although many users seemed to be EDA unresponsive at the first image set (refreshing drinks), in the calibration phase the heavy breathing peaks were showing in all of them except one. That point at the images shown was not appealing to the affective side of the users enough. This was repeated for the phone carrier brands, the car brands (with one notable exception with users that really liked cars), and the banking brands, both for EEG and EDA values keeping at normal calm levels The reactions measured seemed to be more related to inner thoughts than a reaction to the brands. When arriving at the political parties' brands, the reactions were varied, but much higher values were obtained both in EEG and EDA phasic and tonic values. The majority of the frontal asymmetry detected were negative, and the EEG signals varied from high activation to mild one. It seems that the effects evoked did not vanish when changing the image, so during the last slides “contamination” coming from this political brands slide were present, by a higher tonic EDA level and a still negative frontal asymmetry that was not reversed until the middle of the following image set. In this case, the convoluted political situation of the country by that year (and it would even worsen) had a direct effect on the results obtained.

Very consistently with the main hypothesis, an increase in the galvanic response of the skin was detected when an inter-hemispheric discrepancy appears with left-side dominance, thus indicating pleasure or tranquillity (most cases during calibration). At the other extreme, we could observe the same increase in the galvanic response, when the most activated hemisphere was the right, thus indicating rejection or discomfort (political parties brand). In this measure, both extremes were similar, since the response of our body when seeing a stimulus, both positive and negative, is activation (the sympathetic nervous system is activated against the parasympathetic). Although the activation produced by a negative stimulus seemed to be greater than that produced by a positive stimulus, consistent with (Cantero, 1996).

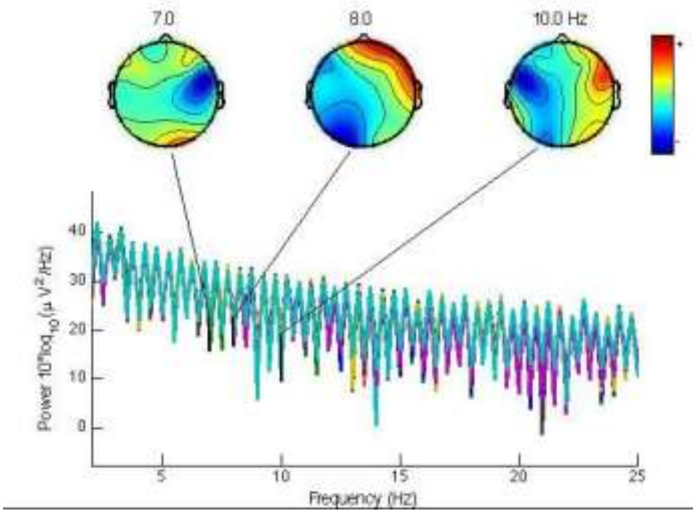


Figure 65: Frontal asymmetry signal processing. Source: own photo

This must be taken into account both when selecting images for future experiments and when repeating experiences. Images selected should have a pre-defined activation value like in the IAPS (International Affective Picture System) standard that provides images along with their average emotional impact rather than custom-selected images. During the second repetition of the experiment with female users, political parties' slides have been removed to not affect the last image show (car models and brands). As expected, tonic levels kept without heavy spikes and no negative stimulus was detected.

Noise or interferences generated by muscular origins were detected as expected. Specifically, noticing when blinking or keeping eyes closed, the Alpha waves presented a general acute activation above the other frequencies (this exercise is usually the calibration method in a clinical EEG study).

If looked at the car slides, Mini was the most recognized brand among the nine options provided, almost always getting the first attention and being the only brand that did not go unnoticed. Regarding brands like Mazda or Renault (there are three models of the nine) where there was a group of participants who neither see them nor notice, Mini was a leading brand in aesthetics as everyone was aware that there was one among the cars, even those who disliked it looked at them. So we suppose that taking into account the fact that some users ignore the brands that feel more irrelevant, Mini has a moderate to high success in that field.

In the visual aspect, it seems that the color was decisive, especially among women. More than the brand itself, the choice by aesthetic or color was more acute among female participants and polarizes their "like / dislike" opinion, being less significant in men. The brand was very important but for different purposes depending on the gender: for fidelity to it among women and for dislikeness over it among men. Surprisingly, what evokes a brand among men is the dislike if they had a bad experience with them.

As a final result in the first test, it seemed that the Mini option was more attractive among women than among men. Men, in general, shown little interest in that model. As this was contrary to the theories of the company, the experiment was repeated with a group made up of only women to see if their expected public needed a total overhaul. This was confirmed by the second group of users with the majority of mid-aged females showing more interest in them among the other options.

More experiments related to neuromarketing were discontinued from this point, as emotions detected were not easily evaluable, as they usually depend on cognitive processes.

4.4 Managing emotions for the treatment of patients with chronic low back pain

At this point, our research group was focused on another aspect of the interaction with the user: The Empowerment of the user. Our target audience were patients with chronic low back pain (CLBP) as a part of a pilot study by Dr Francesc Valenzuela in primary care. His fear-avoidance theory explains how patients with different attitudes over their chronic pain develop different degrees of disability in their daily lives. Thus, if the patients can learn to manage their emotions (through external inputs like biofeedback and neurofeedback) their knowledge about emotions can be changed with the result of avoiding pain, as the pain is to some extent a matter of perception. It is important to remark that only the perception of the pain was changed, not the underlying disease.

This was the case in chronic pain patients caring, where current methods have failed. As pain is a multifactorial experience associated with psychological and emotional factors that play an important role in the transition from acute to chronic disease, influencing these factors should have a positive impact on their evolution. The proposed approach was aimed to provide a new interaction that was not exploited by that time: technological education interventions.

To carry out this process a gamified platform, in addition to the management of bio-signals such as galvanic skin response or using electroencephalograms to know a user's emotional state, had been designed. The main reason to use a gamified platform was to make the learning experience more enjoyable. In addition, using a gamified learning system instead of a traditional one shows a statistically significant difference in the measured knowledge (Gentry et al., 2019), being "at least" as effective as traditional learning methodologies. So in the end, a more enjoyable experience with possible benefits and no counterpart is always more desirable when dealing with people with affections, as their process is usually worrying and feared. Those two technologies were detached so the patients can continue accessing the platform and using it from home without needing any biometric device.

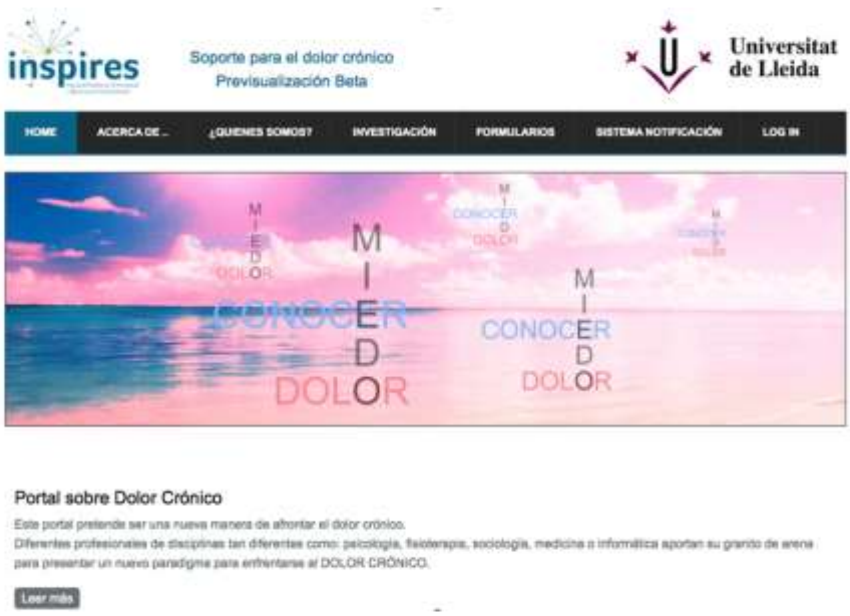


Figure 66: Gamified portal, 1st beta version. Source: own photo

This platform had been the base among the years of multiple educational interventions to the point (see 4.4.4.1) that the last of their variants had been used as a part of the official teaching material for the University of Lleida (UdL) and Catholic University of Valencia (UCV) nursing faculties during the pandemic of 2020 and 2021, due to its value as an online intervention to add knowledge.

4.4.1 Objectives

The key objective was to present a methodology applied in cross-sectional research, so one discipline (in this case nursing) and its users (in this case patients) can benefit from technological advances coming from another area (computer science). The area providing the technology benefits too, as their methodologies are improved and validated through the process. This objective was reflected in:

- The introduction of technological components in a nursery model that was increasingly accepted.
- Adding to the model a layer of interactivity and putting it at wide disposal by allowing its access from remote sources as user homes.
- Adding enjoyable experiences that allow patients to understand their condition and overcome the difficulties related to their illness. The technological components introduced should help the patient to build motivating routines to increase their quality of life. Gamification techniques were applied to enhance motivational support.
- Using the concepts of neurofeedback and biofeedback to highlight the shortcomings of low-back pain current educational methods.
- Investigating how currently selected biosignal analysis technologies can be used to infer emotions, focusing on fear detection (to apply fear-avoidance techniques).

4.4.2 Materials used

- Emotiv EPOC NeuroHeadset with 14 saline sensors.
- Emotiv user SDK.
- Emotiv custom scripts to extract data from the headset (in python2).
- Matlab.
- EEGLab (Matlab plug-in).
- Empatica E4.
- Tobii T60 eye-tracker.
- Computer with an internet connection (preferably a server) running Drupal7.
- An internet domain.

4.4.3 Design

The use of information and communication technologies to transmit information to patients for their health care has become a powerful tool. Thanks to the wide range of possibilities offered by the Internet, it is considered an important platform from which to display information based on evidence, in an interactive and high-quality format (Rini et al., 2012). Numerous studies have shown that websites supervised by medical departments can change and improve the knowledge of patients with chronic pain, showing they have a positive impact on their attitudes and behavior. For this reason, the focus on the design was from the starting point to develop a platform that was available for healthcare specialists and their patients even after finishing our tests.

A deep knowledge of the problem and the model proposed was needed to understand how the technology can help to disseminate the knowledge.

There was evidence that disability in CLBP patients is caused by fear of injury and some attitudes derived from pain avoidance. These chronic patients have higher levels of beliefs and behaviors focused on avoiding such fear. One of these theories is known as Lethem's FAM or Fear-avoidance model (Lethem et al., 1983). The main contribution to this model is based on the fact that patients who develop a fear of pain do so due to their perception of situations or movements that they think may be painful. For the authors there are two types of individuals, those who confront and those who avoid, only the latter developing chronic pain. In an acute situation, this attitude is normal for any individual as a response to avoid painful situations and allow the body to heal itself, but chronic patients need to overcome that limitation up to a certain degree to continue with their lives in the best possible way.

Patient education can be seen as a way to provide information to change the cognition of patients about their chronic state, with the objective to reduce fear about future negative consequences and being able to resume normal activities (Cherkin et al., 1996). The use of pain neurophysiology as an educational intervention has shown its effectiveness in pain-related problems related to other illnesses. In most experiences of patient education, interventions are focused on ergonomics and exercises based on anatomical and biomechanical models; Educational interventions for patients with chronic pain focus on the description of the central and peripheral processing mechanisms (of the nociceptive signal) and how it is modulated and processed by the brain. This way patients learn that their pain is not always only related to tissue damage, having a psychological component. Another treatment that promised to be helpful is neurofeedback (NFB). It is related to the operant conditioning paradigm, where individuals learn how to modify their brain waves (Vernon et al., 2003). This has been used with different health conditions such as fibromyalgia with success being effective in improving fibromyalgia symptoms, such as pain, psychological symptoms and quality of life.

These two types of education interventions could be complementary and assist healthcare professionals in helping patients in reconceptualizing their pain with the result of improved function, reduced disability and lesser catastrophic thoughts.

It was considered to use data from electroencephalograms (EEG) in the first interaction with users, the main reason was that it was possible to detect the user's emotional valence with it. Different theories describe the relation with emotions and asymmetry in the frontal lobes, as the “frontal EEG asymmetry model” (Davidson, 1993) or the “valence-arousal model” (Heller, 1993). This thesis is not going to deepen on the main differences between those theories as they diverge conceptually, but the fact that they ended with similar results seems to validate that asymmetry pattern more than dismissing it (Spielberg et al., 2008). Both theories point that negative emotions are associated with more activity in the right brain region than in the left brain region. To measure this feature, an EEG signal coming from a multi-sensored headset can be used to calculate the spectrum of the left and right sides associated with the sensors on the front. With a common offset for all electrodes (monopolar sensors) the activation of different zones can be compared.

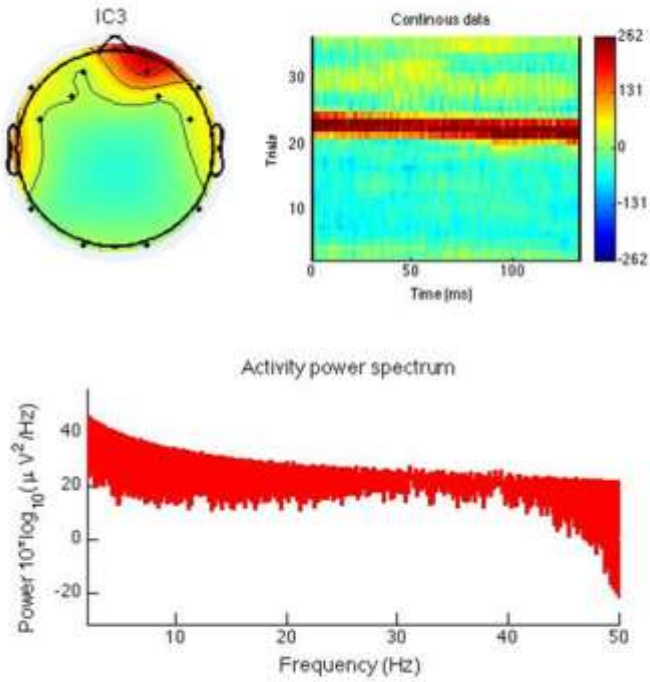


Figure 67: Frontal asymmetry, Negative stimulus. Source: (Iranzo et al., 2016)

For EEG analysis It was needed a device that can be used in a medical consultation and was not too invasive for the patient, so that it does not coerce their emotional response. Emotiv EPOC could be chosen for being a budget EEG headset with monopolar sensors, but at that point the process needed to be manually processed due to the difficulty of automating it, so it was discarded. It was then studied the possibility to use GSR wristbands as there were studies that even try to detect cognitive activations. However, the experimentation was focused not on detecting exact emotions but arousal (Miltenberger, 2015) as a variable that allows relating emotional changes. Those measurements should be taken before and after the educational intervention to measure if effectively something has changed at a physiological level.

In this education intervention, the metrics measured were “pain intensity” and “fear-avoidance beliefs” as the main outcome, being “kinesiophobia” and “disability” the secondary outcomes. The scores in those items were assigned using validated surveys that had been integrated into a telematic survey as part of the educational intervention. To be more specific, each survey was based on:

· Pain intensity: Visual Analogue Scale (Scott & Huskisson, 1976) is a survey that can be used more than once to evaluate the evolution of pain over a given period of time. The main difficulty to develop an online survey is that it “specifically” needs that the line where the user evaluates her/his pain (in the survey) feeling has to be exactly 10 cm long. The conversion from cm to screen pixels is easy with CSS features, but it can be difficult for some devices. Some research points at this survey as the most effective to evaluate this item (Younger et al., 2009).

· Fear-avoidance beliefs (Waddell et al., 1993) is a 16 fixed questions survey with 7-point answers about how the beliefs of users about their activities (especially in their workplace) are affecting their pain perception. The objective of this test is to detect the false beliefs that are increasing their fear to a point that they avoid certain activities.

· Kinesiofobia is the fear of making movements due to painful consequences. It is measured using the Tampa Scale of Kinesiophobia (TSK) survey, performed in 1990 for the first time (Hudes, 2011). The questionnaire has 17 items with 4-point answers.

· Disability scores are measured using Roland-Morris Questionnaire (RMQ) (Roland & Morris, 1983). Its aim is the auto evaluation of mild to moderate physical disability, oriented at low back pain disorders. Different versions are used depending on the focus of the experiment, but all of them have statements that the user must point out if they hold true on the day the survey is performed. Each mark scores 1 point, and following the literature, a variation in 4 points must be considered clinically important (Roland & Fairbank, 2000). This implies that it needs various iterations as what is measured is the variations in the total points more than one instance amount.

4.4.4 Execution

The intention was to make patients feel that health professionals care about their ailment and that they have developed a methodology that aims to help them by providing an enjoyable experience. For this, a gamified web application had been designed. It was built using the Drupal[9] version 7 content manager, a PHP platform a bit outdated by today standards but very stable and easy to modify/create widgets for custom needs, as it is based on module integration. Each module can be defined as a set of functions that completes a workflow and can have its own tables in the database or access other modules tables. The reason why using a CMS (content management system) like this is the impossibility to use any superior framework, as at that moment we didn't dispose of a server with enough capacity, only a shared web hosting, and the ease to use it when adding information. That allowed the engineer researchers to work on the platform while medical researchers were filling the categories with medical-approved quality content. The system is implemented over a MySQL5 database and only needs a total of 64 Mb memory to run efficiently.

The platform presented a heavy degree of customization, modifying the necessary modules and creating others from scratch. Most systems can be used with a bit of re-working, such as the registry modules adding security through Advanced Encryption Standard encodings for the data that must be available, in addition to the automation of mail modules to massively communicate with patients automatically. It cannot be made public for the duration of the experiment, but now is still present at http://inf.virgili.org, being restricted to patients, students and medical administrators. At all times, patient data is protected through encryption and scheduled information erase each time a patient finishes a utilization cycle (explained later). There are also statistics on the content each patient visits and when they did it in the web application database.

As all user data in the platform needs to be anonymized, a custom set of modules were designed that assigns each new user an id to represent it all across the platform integration: it automatically sets a group (control or experimental) for that user and stores their data (surveys, interaction, etc) anonymized. There's no way to know who the user 'X' was at any point.

As previously explained in the design section, the first task before users can use the web, was always to respond to a series of surveys in order to know a variety of things about the user itself. Users in the control group only have access to the surveys, but after filling them they are informed that as a

[9] https://www.drupal.org/drupal-7.0/

member of that group they cannot see the contents, directing them to the usual channel they had with the primary care center.

The surveys used to describe the metric measured for this experience (see 4.4.3) had been modelled into a Drupal Module named ‘Quest Survey’ that keeps the anonymization policy and stores the metrics obtained for that user at a given moment. This module allows retrieving the results of a given user over time, keeping the anonymity and the data tracking.

At all times the patient can choose different sources of information such as videos about the origin of chronic pain, 3D representation of the processes that occur, frequently asked questions or even continuous contact with a specialist in the neurophysiology of pain. Personalized tasks were modelled in the platform with the aim that the users feel that they are the ones who choose their own paths. These tasks had different themes:

· Educative: Documents divided by sections can be found following exploratory patterns, as they are ordered by topics that patients find interesting. Those elements have been chosen due to their appearance in previous focus groups (Valenzuela-Pascual et al., 2015).

Apart from the documents, a gamified version of the theory had been developed using custom made videos. Those videos are set to explain to patients visually about their common misconceptions about their suffering. They were made with the theoretical supervision of medical specialists and with our technical supervision to fit the requirements by ILERNA multimedia advanced vocational students. Then those videos were integrated into a choose-your-own-path navigation frame. In this frame, a set of questions about what they understood are present, and depending on their answer, they see a supplementary video or goes to the following topic, which will vary depending on the element selected. The different possibilities were chosen in a pattern that covers the most usual, and unusual paths, meaning that all users can see the videos more related to their interests first.

Figure 68: Custom videos follow-your-own path. Source: Own photo

· Recreation: Games have been made as part of different final degree projects and added as external links into the platform. Those games focus on the knowledge that the user must obtain when seeing the videos and reading the documents at their disposal across the different sections of the web platform.

· Social: An anonymous chat was set for patients to share experiences, supervised by medical personnel that can answer the patient's concerns. Anonymity was declared an interesting point as the user can speak totally freely as it should be in the primary care center (but was not always lie it due to their various fears).

· Contact: In the same manner as social, the anonymized modules prepared for the platform allows a totally private and totally anonymous communication between the medical professionals and the patients by mail, using them as a central node to resend the messages keeping the identities protected.

With these items in the first version of the platform, the web-based intervention named in (Valenzuela-Pascual et al., 2015) was carried on.

The technician didn't have any contact with the patients, singing the consents and being informed about the experience in the primary care centers. The experiment was considered finished 15 days after the user entered into the platform, then they were asked to fill again the initial surveys and their access disabled up to the end of the experiment, when they could enter again if they wanted to.

The effectiveness of the method was calculated over the comparison of two differentiated groups: the patients into a control group, one which followed the treatment prescribed by the primary care physician, and an experimental group that followed the treatment described on the website with the theory presented. Said separation was carried out randomly by genre, to assure that 50% of total males and 50% of total females are split between groups. 48 patients were participating in this experiment from their homes.

4.4.5 Results and Challenges

Biofeedback was used only as validation of the model with some users, as it was really difficult to obtain reliable data from patients with special needs and the best result seemed to be obtained when they have space and can follow their own rhythm. This means that the best results are obtained from web interventions when the users are interacting freely from their homes. To add biofeedback information, cheaper devices should be created to allow users to wear them in their daily life, so they can be integrated with our platforms. The pandemic didn't help with that either, as sharing devices between different sensitive users was heavily discouraged. The main issue is related to obtaining disposable and cheap devices that can be given to the user without the need to be returned. That inspired the experience related on 4.8 and my final MSc thesis.

The results were carried out using a two-way mixed variance factorial analysis. There was a statistically significant variance for fear-avoidance beliefs, kinesiophobia and disability for both groups, but the experimental group presented more favourable results, proving that a web-based pain education intervention was more beneficial in some sub-scores than the conventional care provided in primary care. If analyzed in-deep the pain intensity and fear-avoidance level were improved in a similar way, but the disability in the short term were higher in primary care. It may be something related to the user doing the same task from home or in its primary care center, where mental pressure is always higher.

The designed models in (Valenzuela-Pascual et al., 2015) have been tested in (Valenzuela-Pascual et al., 2020).

The future work of this experience was carried out in an “iterative way” from its validation in 2015, being the base of 4.6 and 4.7 educational interventions. In each iteration new content was added both to expand the content for patients and adding content for new roles, such as students and professionals. Those experiences altogether will conform to a macro-platform for pain-related education interventions not only focused on the UdL subjects, but for patients and professionals.

4.5 Side tests (Scalextric experiments)

During the first stages with the patients (in the experience 4.4), a small test was proposed to offer patients a verification that their thoughts can generate actions in the physical world and reinforce their self-confidence. The experiment proposed a "game" with a Scalextric, an Arduino device and an Emotiv EPOC headset to generate actions by mapping the thoughts of users using the EPOC API, in which two people had to drive their slot car by concentrating on an idea or experience that they could freely choose.

4.5.1 Objectives

The main objective was to show the users that their thoughts can directly affect the tangible world. The subsequent tests made with users of all ages presented a lot of situations that formed a good idea of the best methods to set up the involved devices, especially EEG headsets.

The secondary objective this experience pursued was to both have fun (for the users) and self-knowledge, in a divulgative way for patients, their families and in certain occasions for society in general.

4.5.2 Materials used

- Scalextric or Carrera device.
- Computer.
- Arduino UNO.
- Protoboard.
- EMOTIV EPOC.

4.5.3 Design

The idea was to have a device capable of affecting something in the real world by reading user EEG's signals, to show them that their way of thinking has its influence in their environment, and for so in their bodies That device did not exist so it should be designed and manufactured. The signals detected from the official Emotiv SDK didn't have any research value (for that reason our own data extraction libraries were used for that kind of EEG device as seen in 4.3.3) but strangely the Cognitiv suite presented a coherent interaction. This suite (2.2.2.3) allowed users to map a few seconds of neural activity and compare them with the actual activity in real-time. When the signal is similar enough, the program shows the mapped action on the screen. This was a good starting point, as the system we searched for was almost there.

The hardware should be controlled by an Arduino, as the prototyping using these boards was very easy and we didn't want to spend much time developing this experience. The middleware used to communicate those devices were provided by the official Emotiv platform, but as a long-term project have been changed two times (see 4.5.4) as it was banned from the official store for unknown reasons.

The first idea was to use it in part as a gratification for the users participating in the experience, as the calibration process is done during the experiment and the use of it is almost immediate.

4.5.4 Execution

If analyzed the electrical input and output given by the Scalextric, it can be noticed that the controller pad is usually only a resistor that provides more or less signal to the main circuit. With that in mind, the solution given was to join the input of the track with the rails, in a way that the given power will go directly into the car, and use an Arduino to control the current, modulating the slot car speed. Arduino boards don't come with a real analog output, it gives a pulse train with high-low states.

Then an integrated peripheral with an electrical circuit that emulates the resistor controlled by a "pulse train" was made. This way, when the more high state is applied, more power is given to the track.

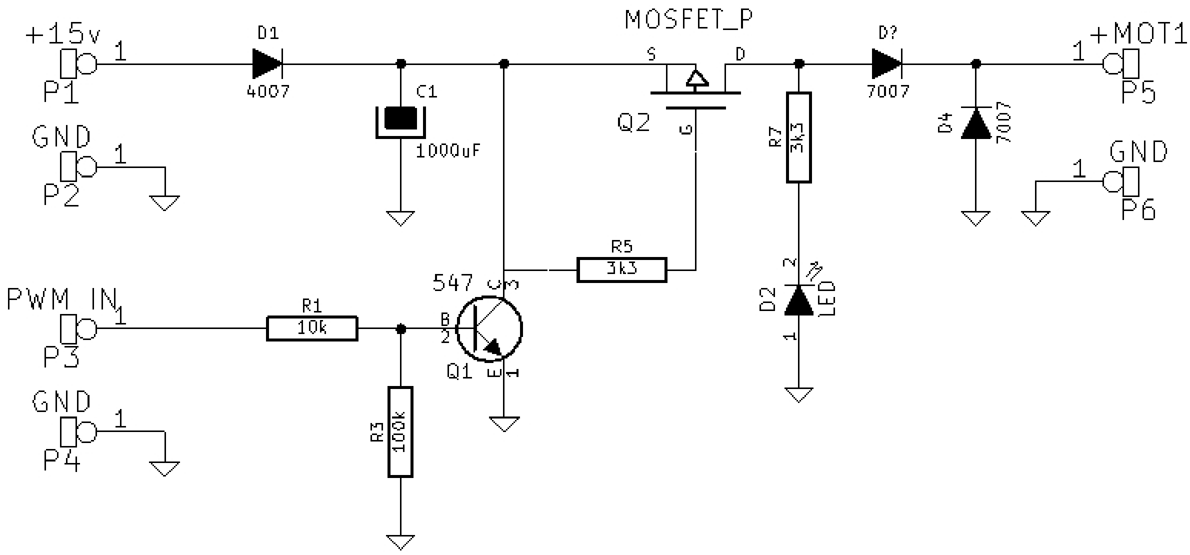


Figure 69: Train pulse to resistor board. Source: www.virgili.org

Using Processing and Arduino programming environments, a simple program was made to capture signals in OSC (Open Sound Control) format from localhost IP. Depending on the value detected, from 0 to 1 (with decimals) the current that the circuit receives varies, being 0 zero volts and 1 the maximum provided (in this case, 15v). Once there's at disposal a device that can activate the real world hardware depending on the inputs received by software, the remaining process is easy.

Finally, the EEG actions must be trained with the 'EmotivControlPannel API', an application provided by the official SDK that allows users to associate thoughts with EEG signals obtained. To move the car a PUSH action (one of the types of actions that the software allows to train) had to be used. Then to communicate the PC with Processing code via OSC, the application "Mind Your OSCs" (by that time, a free application sponsored by Emotiv) was used. If the program uploaded in the Arduino chipset is a 'Standard Firmata' (can be found in the Arduino IDE example projects, no coding abilities needed) the board enters in a "slave mode" for the Processing code, making all the process easier.

Figure 70: Project finished and working. Source: www.virgili.org

With this integration, the action detected by Emotiv EPOC can be transmitted to the slot car. Note that this integration is for each track, meaning that with two headsets the experience can be competitive. The values for the maximum and minimum voltage in the Processing code must be calibrated each time to time depending on the state of the car engines (as they decay with the usage).

This device has been used with people of all genders and almost every age through the years. Being used as amusement and to carry on divulgative actions mostly, we didn't ask to the users to permit us to record the data, for that formal statistics cannot be provided, but a lot of useful information has been extracted from those sessions, especially all those related with headset positioning in non-adult users, those related with non-laboratory contexts and those related with how to deal with the myriad of electronic interferences caused by people (or their devices).

4.5.5 Results and Challenges

Users were really impressed by the fact that they were controlling the cars with their minds, and some of them started to believe more in the feedback theory when explained It after playing with the toy. At first, this was conceived as part of the feedback model but soon was considered to have the potential to be used as the gratification for participating in the following experiments (for example, playing for a while), for this reason, the device stayed in our laboratory for a long period of time.

The experiences with the slot car machine were very successful among the youngest relatives of the patients. Fruit of the experiences with the patients' relatives we remembered that an important part of the research that is not usually taken into account is the synergy with the society. In our case, a great number of workshops and courses were developed and shown to students, teachers and occasionally street performances to promote the university's (and our research group) task in our city. This side project aimed to divulge the message that knowing how your mind works to improve the quality of life in everyone, not only the patients of primary care. All those divulgation events were extremely successful, with hundreds of participants institutions offering space for us in other events.

As the experience was developed in many different contexts, the basis of our protocols when using EEG headsets were refined, especially those that needed to deal with electronic communication interferences. The best context to obtain a clean signal was outdoors, as all electronic devices were far and the phones were set by the public into "Plane Mode", but the amount of acoustic interference made it difficult to calibrate the headset (it is supposed that the noises were distracting the users). The most difficult context was the schoolroom, as many wireless devices were interfering without us knowing it as the classroom Wi-Fi projector, situated just above the helmet. When noticed, moving to the farthest corner in the room solved the issues.

The results were similar among men independently from their age, obtaining the best performance (around 90% success rate at first attempt without having to re-train the SDK) with thoughts evoking motor actions, like kicking a football ball or using a bicycle pedal.

Shockingly different was the case of female users, where it was shown heavy differences depending on their age. In the case of female users, thoughts about colour worked more efficiently in youth (80%) than in adulthood (60%). Regarding sensory experiences such as taste, the effectiveness among grown women exceeded 90%, while in men it did not exceed 40% at any age.

As an aclaration, in 2018 the application "Mind Your OSCs" was being discontinued, so it was used another project based on node-red[10] called node-red-contrib-emotiv-bci[11]. This system followed a different communication schema, and all the communications were moved to a TCP socket. In late 2020, the windows service communicating with the EEG validator via node-red was discontinued again, leaving only the option to buy the official programming SDK to access the Emotiv data.

No further research was foreseen following that topic due to having poor research-related results and the extreme difficulty of obtaining clean signals.

[10] https://nodered.org/

[11] https://flows.nodered.org/node/node-red-contrib-emotiv-bci

4.6 Second educational intervention

The second education intervention was an official ‘Teaching innovation project’ of the University of Lleida (Code PID 015161). That project was focused this time on medical professionals in training, as there were evidences that there were difficulties when professionals were interacting with patients suffering from chronic pain. This study was carried on UdL’s double degree programs in sports sciences-physiotherapy and physiotherapy-nursing.

4.6.1 Objectives

The previous educational intervention (see 4.4) was aimed at patients, but their only problem was not only their illness. Various studies pointed at difficulties among health professionals when dealing with patients suffering from chronic pain (Ruiz Moral et al., 2006; Acuña Ortiz et al., 2017), even with some of them pointing at up to 32% of the professionals having a lack of knowledge about that topic (Perrot et al., 2012). This has a direct influence over the patients as some of them are not properly diagnosed or they taking a long time to be, lowering their quality of life.

The Universitat de Lleida (UdL) provides curricular activities to train their health professionals on pain issues, some of them focused on eLearning as this methodology has many success stories (Watt-Watson et al., 2019) when looking at the student ratings. But not many of those studies take into account the student motivation and willingness to consume the knowledge present in the platform.

The main objective was to see if a gamified online educational intervention can improve not only the student’s qualifications but their overall motivation. This objective was even more important as during this intervention the global pandemic closed all the universities, so the online content generated for this activity should be applied to all the students of the subject to keep the classes as part of the official curriculum.

4.6.2 Materials used

- Computer with an internet connection (preferably a server) running Drupal7.
- An internet domain.

4.6.3 Design

In this case, the contents of the platform used for patients with chronic low-back pain (4.4) were adapted for the new type of users (nursery and physiotherapy students) with the intended result of increasing knowledge from a more professional-oriented point of view while increasing the students' motivation and concern about chronic pain.

Initial surveys have been adapted, removing the pain perception ones and adding an adaptation from (Escobar Pérez & Lobo Gallardo, 2002) to measure students' knowledge, motivation and satisfaction.

Figure 71: Side projects based upon the platform. Source: Own image

Menus and items suffered a complete overhaul, passing from a standard web content template into a highly customized one based on pictograms that act as big buttons, with minimalistic text. The reason was to achieve a platform easy to navigate from all kinds of devices more intuitively, appealing at visual attractiveness.

Sections related to patients have been substituted by theoretical contents, with those new sections:

· Notes. The section containing the documents related to the classroom subjects were divided into eight blocks: basic neurophysiology, advanced neurophysiology, chronic pain in clinical practice, fibromyalgia, arthropathies, scientific articles (English), and assessment systems for serious pathologies related to low back pain and psychosocial aspects (flag system).

· Videos. The media section was heavily increased with new videos and splitted into categories related to the classroom subject.

· Quiz. This section contains links to Quizziz[12], an online platform that allows conducting formative assessments for students using online custom quiz games. That platform allows content creators to easily implement most of the common gamification items as badges and leaderboards.

The intervention was focused to be carried on a mixed approach, online complementing presential classes, so the students have direct access to their teachers in case they need to answer any issue.

4.6.4 Execution

This second intervention was prepared to start in February 2020, being prepared during fall 2019. The platform uses the same user anonymizers as the 1st educational intervention (4.4), with all the students following the common subject via classroom and the students from the experimental group

[12] quizizz.com

(50% of the total) having access to the gamified platform, with none of the medical teachers knowing until the final results which students have access to it.

Although the plan was to have a control group and an experimental one, the beginning of covid-19 lockdown forced the researchers to change some objectives of the intervention. All the users from the control group were granted access due to the faculty needing quality online contents to continue the subjects. The final sample from the UdL were 60 users, 50% men and 50% women, and another group with 60 users from the 'Universidad Católica de Valencia' (UCV) were added due to a joint effort over that topic (online materials). Most of the users were in the range of 20 to 25 years. They had access to the platform all semester.

4.6.5 Results and Challenges

The designed models in (Valenzuela-Pascual et al., 2015) have been tested in (Valenzuela-Pascual et al., 2020).

Not having a control group limited the amount and quality of the obtained results so, in the future, similar studies should be carried out with a more evolved version. At least results seemed positive, which makes us optimistic about future experiences that will prove the theories formulated here.

The final results suggested that using a gamified platform effectively increases the motivation and satisfaction of the students, having 58.4% of students thinking that the classes were more interesting using the platform and that they effectively learned more from it. Taking into account more than four months of heavy lockdown, this was a success. 66% of them said that the provided tools motivated them in reviewing content and more than 60% felt more prone to interact with the media provided compared with the typical notes from the virtual campus.

Knowledge scores result overall high, but without a group to compare them the data has little sense.

By lacking a control group, the publication (Valenzuela-Pascual et al., 2020) had been converted into a CIDUI 2020 ('Congrés Internacional de Docència Universitària i Innovació 2020') congress communication. But it was well-received, and various institutions were interested in repeating the experience outside the UdL with our collaboration (see 4.7).

Our challenge defined in 4.4.5 to develop a platform to unify pain-related web educational interventions not only continued with this experiment, but added more institutions to it. This was seen as a success and encourages us to keep pursuing the goal. As a future implementation (when control groups can be established as the situation normalizes itself, in a way or another) UX remote evaluation methods will be applied, starting with online webcam-based eye-tracking metrics and custom devices as can be seen in 4.8.

4.7 Third educational intervention

Due to the success with the previous educational interventions and the usefulness shown in online courses of the second intervention during the covid-19 lockdowns, another ‘Teaching innovation project’ was granted, this time from the ‘Universidad Católica de Valencia’ for their physiotherapy degree (Code PID 19302), to continue improving the experience they joined the previous year (4.5.4). This time, the improvements were centered around adding serious games.

4.7.1 Objectives

The main objective was to keep improving the platform, adding content to expand the knowledge while keeping and improving the interest shown by the students over the topic. Two games were added (a platformer, and a tabletop game) to evaluate the differences for the students between the types of serious games, if any.

4.7.2 Materials used

- Computer with an internet connection (preferably a server) running Drupal7.
- An internet domain.
- Phaser3 Framework.

4.7.3 Design

The headers, menus and some items have been modified to establish a common format for the joint effort of the two universities, using both logos.

Figure 72: Side projects based upon the platform. Source: Own image

The didactic content was the same as in the second intervention, but more gamified items were added, specifically two custom-made games.

The first game added was a platform-based one (a game of skill involving platforms to jump) made by Ilerna students with our direction. In that game, a worker must find his path to the work dealing with real and imaginary pain (actually in beta). During the game, the worker must find items that help him to lessen the pain by providing positive feedback. The game was made using Phaser3 Game Framework[13] (a project called Lazer many years ago), a cross-platform WebGL-oriented game designer that provides html5 enabled projects. Those projects can be easily integrated into any web platform as each project produced is a standalone version of it.

[13] https://phaser.io/phaser3

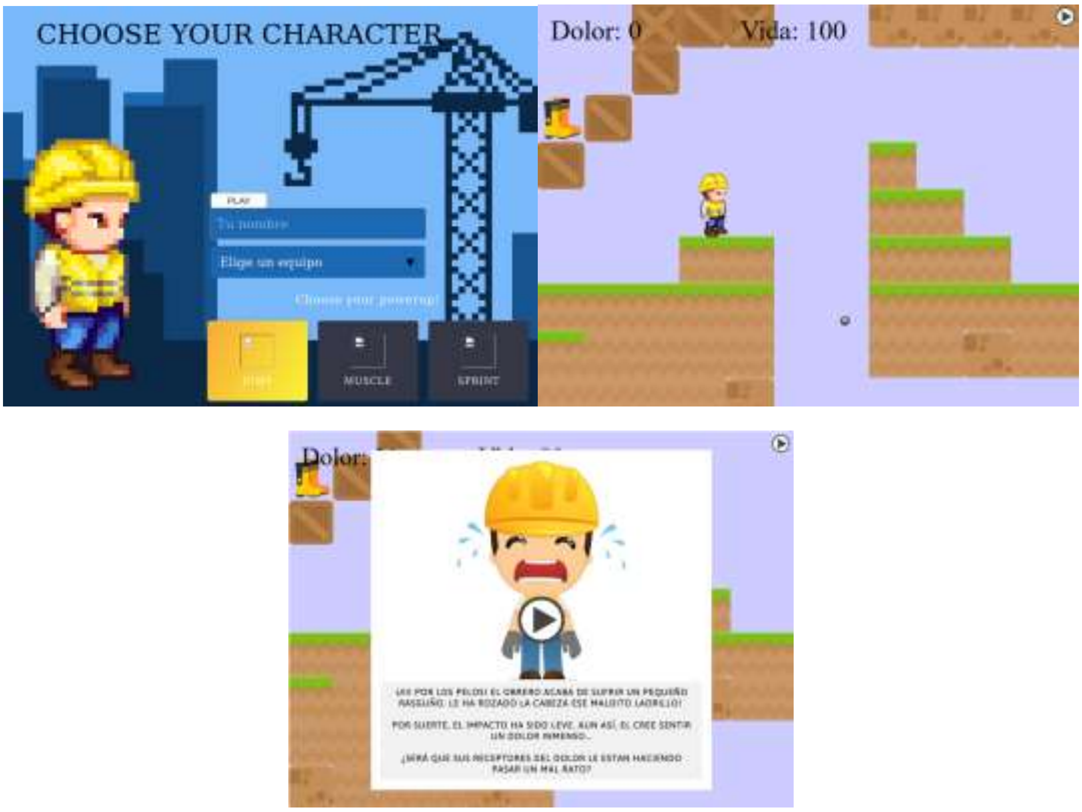


Figure 73: 'Path of pain' game. Source: http://inf.virgili.org/0/franjoc/

The second game was made by the researcher of this thesis based on the board game DolorÔmeter[14] by (do-Nascimento et al., 2020). The game was a ported version of the aforementioned board game using WebGL to obtain maximum compatibility with all kinds of devices, from desktop computers to smartphones. The user must answer a set of questions using the same cards as in the board game. Each card contains the representation of a thought that can be a correct fact or a misconception, the correct value of that thought several points (they can be seen in the top-left corner of the card). The objective of the user is to answer if that statement was true or false, and depending on their success the user's health bar will increase (if right) or decrease (if wrong) an equal amount of the score in the card. The final score never reaches a loose state, simply notifies the health level of the user when all questions have been reached, allowing as many replays as the user wants to improve their scores. The objective of the game is to address the misconceptions about chronic pain that the users actually have applying gamification techniques.

[14] http://www.paininmotion.be/storage/app/media//DolorOmeter-Game/RULES.pdf

Figure 74: 'DolorÔmeter' game. Source: http://inf.virgili.org/0/joc/

4.7.4 Execution and Results

This intervention is currently under development and results will be published by the end of 2021. This platform evolved from a small component of a PhD thesis into a platform with three different institutions generating content. The objective of promoting a centralized web-based platform for pain education is increasing its acceptance each year, being used by the beginning of 2021 by more than 300 professional health users.

As the platform basis is robust enough by the time that this thesis is being written, and the content is added by those institutions, the next steps would be centred on researching implementations and effectiveness of acquiring remote UX biometrics (webcam eye tracker and proof-of-concept experiences with custom devices).

4.8 Multipurpose biosignals wearable

When the first educative intervention experiment finished (4.4 1st intervention) there was a need for disposing of cheap, disposable and quick-to-build devices that allowed researchers to deploy UX experiences related to obtaining biosignals in a budget way.

The currently available wearables are aimed at a specific audience, mostly people between 20-35 years of age and relatively healthy to monitor some specific context, mostly for monitoring during sports activities (90%) or sleeping (the remaining 10%). While the wearables for monitoring health are more important, they are up to date highly experimental and for so excessively expensive. They lack validations against medical-degree devices, with the notable exceptions of Empatica (see 2.2.3.2).

This work has partially been presented as an MSc final project in Computer Engineering from the University of Lleida, and as a short paper in IEEE 11CCC 2016 congress (Virgili, 2016).

4.8.1 Objectives

The main goal was to design and build a non-expensive wearable device that was helpful in different scenarios in a quick and economical way. The prototype had to be easily modifiable and autonomous to carry out different types of tasks and monitor a multitude of parameters depending on the context of the experiment.

Having a close experience involving long-term hospitalized elder patients, specifically the moment when they have to return home, The proposed device formed part of an integrated solution for elder patients, specifically those who have fewer possibilities of keeping active watch of them, an increasing problem nowadays. This situation presented two problems that families struggle with: “escapists” and falling people. “Escapists” is a term to describe people who get disoriented (mostly affected by a mental illness) and decide to flee; those individuals usually get totally lost. Falling is a common problem among the elder, as they usually need assistance to get up and the family must know when it happens. The secondary objective was evaluating the utility of a device focused on home assistance in case of the user is incapacitated.

4.8.2 Materials used

- Bitalino wired kit
- 3.7V Li-Po Battery
- Android phone
- Google account

4.8.3 Design

As the experiment was related to making a new device from scratch, we began with a study of the different possibilities available in the market in terms of monitoring of individual beings, trying to find those more orientated to obtaining health information rather than biosignals from sports (this represented the majority of devices by that time), to see if any meets the objectives of the current proposal (See 2.2 and 2.2.3). This included physical devices and software solutions.

Most of the activity tracker devices seen during this phase have an integrated pedometer as they were oriented to sports tracking, although some of them added a heart rate monitor for the same reason. Often the limited data provided to the user is correlated with geolocation, a quality that was proposed to be added into the prototype. Without the notable exception of Empatica bands, all devices lack any kind of medical validations, as their state to be only valid for recreation purposes. Only devices oriented to sport can be found (with again the notable exception of Empatica), without devices oriented to medical purposes or even to obtain biosignals in a reliable way, at least in the budget price range.

Arduino-based shields were discarded because even their same manufacturers reported that they are only intended 'to play' as their measurements were unreliable and without any kind of accuracy.

By that moment the best two possible proposals for a new and cheaper EEG sensor were to re-craft a device that used a Neurosky TGAM chipset, which already comes with interference filtering, or using OpenBCI diagrams to make specific hardware for a given task. This way the cost could be reduced to approximately half. The first option was not currently retailed in any store, but many toys like the MindFlex Duel (€ 80) or Neurosky's low-end headsets (79 €) carry one or two that could be easily disassembled and repurposed keeping part of their original software. The second option was only recommended for complex tasks that require more than two simultaneous sensors and was not by any means so cheap (as explained in 2.2.2.4).

A third option was to craft them manually using the sensors for Arduino BITalino (see 2.2.3.1). Bioplux is the parent company of Plux Biosignals and Bitalino. The first brand provides sensors with certified medical validation. Bitalino is its low-cost brand, despite not being a medical certified device various studies pointed at their reliability compared with medium-tier medical devices (see 2.2.3.1). They were ideal for this task for their inexpensive and highly valued hardware but they could be more difficult to use as in-depth programming know-how was required. That device was chosen due to its qualities.

Using this third option implies engineering an application capable of controlling it, but it was not considered as a problem as everyone had a smartphone with Bluetooth capabilities, and they were really cheap too. As the application needs to be simple, the only thing that needs to be assured is retro-compatibility with older android versions. Apple and Windows phones were not considered for this experiment as their expensiveness was too high.

In the reviewed applications we found that an "active" attitude of the user is required so the application could perform its tasks. This is useful especially for security reasons, but as an autonomous system, our application needs to carry tasks by itself, being capable of storing and sending data without the user expressing permission every time that needs to, as a help application must send messages when the user cannot do it. The current proposal presented a theoretical solution to this problem.

The different modules can be purchased separately, so each sensor can be bought on-demand before integrating it onto the device for a determined experiment at a time. The EDA sensor can be purchased separately and costs only 22 €. The modular configuration described also helps in the placement and design of the device so a 3-axis accelerometer can be added to detect movement (both its existence and its intensity), an electrocardiogram ECG sensor that can be worn on the wrist to measure heart rhythm and another EMG could be integrated for electromyography. For less than 100 € altogether, adding for 15 € the central control unit (that performs better for the task) and a Bluetooth 2.0 module for 22€ that communicates with a mobile phone to process the received data and add geolocation information to the data set. Non-essential sensors (such as EMGs, which should monitor the affected body area) can be disconnected from the system while not in use, so that unnecessary equipment is not carried around. That helps the battery as it won't waste resources.

The total design and construction, although more cumbersome (not uncomfortable) than the Empatica bracelet, can cost up to less than 10% of an Empatica E4 price and it will be able to act in more different scenarios by adding or removing sensors depending on the context and the user.

The device had two main tasks, one related to their desirability in research environments and the second related to the viability of usage in that patient-care context:

- Fall detection and geo-beacon in case of an accident.

  Spatial 3D user position is represented with the data of a three-axis accelerometer built in the prototyped device. To identify falling events, sudden changes in acceleration are monitored. This provides information about the position of the user (if they are sitting or lying down), altogether with a brief "status" post-incident report (if he/she is moving or not after the incident, if it is shaking or serene, etc). In case of detecting a fall event, the system sends an alert to a member of the family with the status report and geolocation data provided by the Smartphone google API so they can provide direct help or call the emergency services.

- Long term GSR monitoring.

  It was proposed to obtain continuous data of stress levels during long periods of time for research purposes. A report with measured EDA levels (with peaks and variations over a period of time) needed to be sent to the researcher to be analyzed. The researcher could mix the given dataset with other information to know if marked events also correspond with peaks of arousal.

For that purpose, the application needed to be very simple. The main screen only showed a log of events visible to the user and the information of the last known location. It also included a "panic button" to force an emergency notification to the recipient of the app's messaging service. The workflow of this first application was:

1. The user correctly places the Bitalino device and runs it.
2. The user opens the app, with a Bitalino device previously synchronized on the device, internet access and with permissions to Google location services to start it.
3. Once in the main activity, open the options menu and the email address to which you want to send notifications and emergencies is changed (in case there needs to be changed). The MAC of the Bitalino device must be specified too (in case it is not the last known MAC was used).
4. Return to the main activity, and from the drop-down menu select the start option.
5. From this moment the App is autonomous, initializes the modules, connects to the biosensor device and starts collecting data, analysing them and trying to update the GPS position every 10 seconds. EDA data is stored in memory and sent to the receiving email address at fixed times, while accelerometer data will only be used to try to detect drops.

6. In the event of a fall being detected and subsequent immobility of the user, an alert will be sent to the contact email informing of the fact and giving the most accurate coordinates as possible of the scene.

4.8.4 Execution

The chosen device was a wired version of the Bitalino board with all sensors and the central processing unit holding a mini Molex port to connect them. This was chosen due to the really small size of the sensors and the fear of getting artifacts into the signals caused by poorly soldered cables. As a Bitalino device official APIs were at free disposal to work in BONSAI, c++, Java, Matlab, Python, Unity and Visual C# in a simple way (at some point it was not so simple and easy, as many of the libraries were made by users more or less "collaborative" and associated problems have been found).

As the device needed to be used during long periods, a heavy battery was expected to be needed, but for the modularity of these kinds of projects nowhere can be found information about how much each official battery could last. As Bitalino is compatible with any battery using JST PHR-2 connectors, the smallest and cheapest battery (700 mAh) was bought to test it on the field and decide. Surprisingly it lasted for more than 20 hours, and as it was a new battery it was expected to improve during various charge-discharge cycles. Anyways a 20h max period was established for this kind of battery as it was the lowest discharge time in our tests.

The smartphone chosen to control the process via the custom app was a Leotec Itrium Y150, a low-cost Chinese-imitation device that could be bought new for under 70€ and secondhand for under 40€.

Figure 75: PluxDroid and BitaDroid apps, respectively. Source: Own capture

PluxDroid was the unofficial application to extract data from the sensors via Bluetooth and it was useful to have a first approach about how to interact with the device (because they open source their code) but was only useful to view the data. The official app BitaDroid added a config layer over the sensor reading that allows it to convert raw data into real-world values and incorporates the mechanism to export the data into a file.

A point to mention was that the basic programming APIs officially provided (only the Android one has been tested) come with very basic examples. Some of the most complete user-made APIs (and recommended in official forums by product designers) installed ADWare on the tablet if not remove parts of the code. Unable to restore, requires root privileges and a lot of time to trace all the changes made within the system. It must be said that it does not affect the functionality of the program, so the code needs to be examined before compiling it.

It was decided to mount a new base project, mixing the code corresponding to the API for Android, using the auxiliary scale functions coming from the Bitadroid project. Finally, this was used only as a guide, since the results pointed at the conversion operations being wrong and having all to be redone, but at least it gave clues on how to convert the data from the sensors to physical units. To incorporate external functions to interact with Google's geolocation services the official google maps API was used, as well as JavaMail API custom functions to send emails with their SMTP servers.

The falling detection was performed with a simple algorithm that detected a heavy acceleration with a sudden stop, following a non-moving time lapse of 10 seconds. If that was the case, it sends a mail to the emergency systems and to the person in contact set in the settings.

In terms of hardware, the acquired prototyping pack, despite carrying all the sensors offered by the brand for Bitalino (EDA, EMG, ECG, Accelerometer and Light) only carries one cable. When trying to mount a custom mini-Molex cable, the surprise comes when standard Molex connectors do not fit the sensor. The brand designed a special mini-Molex that only sells them. However, it was not very expensive and can be re-soldered.

To measure the continuous signal It was proposed that the self-adhesive sensors for EDA be placed in the palm of the hand while the accelerometer was placed on the shoulder, in this way the verticality can be better measured (if put on the limbs, could detect occasional accelerations when gesturing, generating a large number of false positives). The central processing unit as well as the battery and the Bluetooth module were placed halfway on the forearm held by a cotton net so the longitude of the cables could be kept at a minimum. This problem with the position of the multiple components should be addressed if the experience was positive.

For energy saving reasons, a low sample rate (1hz) was chosen, to use sensors that measure faster changes (such as an electrocardiogram or electromyogram) it would be necessary to increase this frequency. With this configuration, the system can operate for more than 20 hours with a battery of 800mAh without stopping.

Incremental tests were conducted in the GRIHO laboratory, carrying the system during increasing periods up to 8 hours, with a user performing common activities, and a full-day continuous final test.

4.8.5 Results and Challenges

This was our first attempt to build a low-cost integrated solution that fits exactly for the research group needs instead of buying a finished and tested solution.

A cheap prototype had been produced and tested. The total amount invested for this project had been 169 €, considering that the increased price was due during the initial testing phase all available sensors were bought as a pack: although tested, many of them have not been used. A more realistic cost for this project could have been 95€, acquiring only the core and the used sensors: 55 € for the central unit with the batteries suitable to work for a day period, and 40 € for good-quality non-reusable sensors (the bag of 20 items, as buying individual sensors don't have much sense if not reusable). There was no need to invest in a new smartphone as it was feasible to reuse a normal one as long as the OS was Android, as the final app did not consume many resources. The total cost was lower than it was initially projected and resulted cheaper than any official device in the market, meaning the first objective was accomplished.

In the various real-life situations where the prototype was tested, It was able to detect falling events in real-time and automatically assess the approximate intensity of the event, the approximate resultant state of the patient and its location. This information was attached to an email and notified to the specified contact as expected. The battery selected for the field tests (700 mAh) has shown a better-than-expected autonomy, lasting longer during cold weather, probably because of being more efficient at lower temperatures. The continuous data acquisition was a success, providing uninterrupted energy during a 20 hours session to obtain a daily dataset, only with minor discomfort for the carrying user. This means that the second objective was accomplished too.

To be viable, work on the sensor positioning must be performed as it actually occupies half arm. This is caused due to the positioning of the accelerometer as being on the wrist would be more difficult to detect subtle falling events, but it could be done with more motion analysis. The size of the central unit with the battery and the power supply needs to decrease significantly too, as it's the main source of discomfort between the users. Only then more functionalities could be added. Uploading the research-oriented data in real-time should be a priority, as it was sent after the session finishes as a final report.

Another issue was the battery efficiency. It was theorized that the most energy consumption was caused by the continuous connection to the smartphone via Bluetooth. If a small intermediate memory could be used to store the data and send them in packets each period of time, deactivating the BT module between that timespan, we believe that the battery life will be improved exponentially.

As the elder population is increasing rapidly in northern countries, this kind of technology will be available soon for the general public through companies providing not only personal security, but integrated family localization care. Actually Neki[15], a Spanish company that in 2015 was aimed to provide SOS buttons for the elder (a kind of a phone with only one button that calls an emergency number when pressed), is integrating GPS technology into adult gadgets for Alzheimer or dementia patients and their families, with more than 3000 families subscribed to their service only in Spain.

[15] neki.es

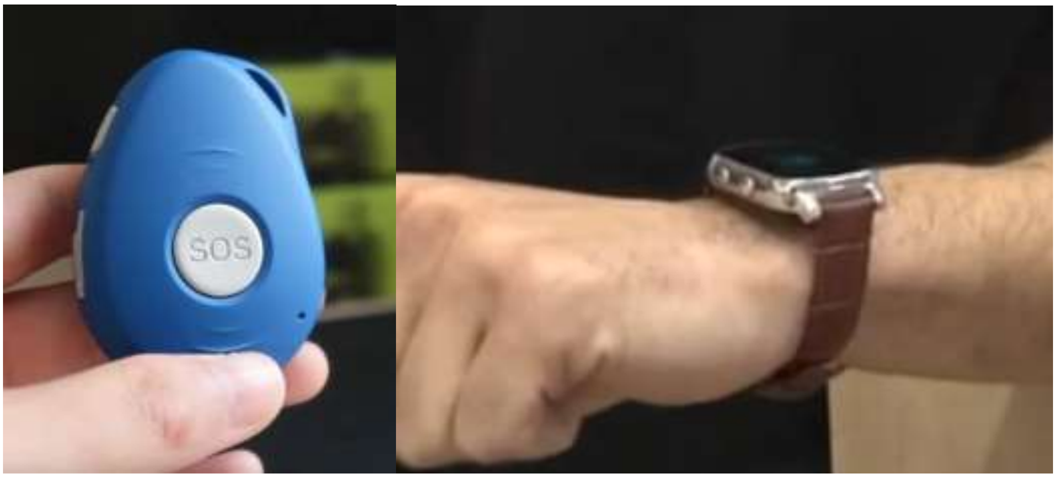


Figure 76: Nock Senior and Nock Senior watch 3, respectively. Source: Neki Youtube channel [16]

One of their products, the "Nock Senior[17] by Neki" has almost the exact functions and interaction related to falling detection (with a warning at family contact included) as our proposed device but with the phone integrated onto it, for 99€/year.

This work was a clear example of what can be done in a budget to add biometry in remote contexts, such as the user's home. As future work, a proof of concept using custom-made devices is projected to be carried on in 2022 to use in the 4th iteration of the educational intervention (next to 4.7, being developed in 2021).

This research was used to defend an MSc final project in Computer Engineering from the University of Lleida and a summary was presented as a short paper in IEEE 11CCC 2016 congress (Virgili, 2016).

[16] https://www.youtube.com/channel/UC6gbtseGA6nFa59-57Z0Uog
[17] https://neki.es/colgante-llavero-localizador-gps-ancianos.html

4.9 Method for improving EEG based emotion recognition by combining it with synchronized biometric and eye-tracking technologies in a non-invasive and low-cost way

As seen in the previous experiences, inferring basic emotions and disruptions in the user's mood (as brief startles caused by external stimulus) was possible by using low-intrusive wearable devices. More complex emotions could be obtained by jointly analysing the stored data from various devices to extract a two-dimensioned metric: valence and arousal of emotional activations. This experience was intended to determine the basic emotions the users were feeling when confronted with a given set of visual stimuli.

The test users were all 6º grade medical students from Universitat de Lleida that were getting close to their specialization selection. Although this decision is not made until after the MIR exam, this is an important step in their career and is not something to be taken lightly: The students must participate in a clinical rotation as interns in various departments as a part of their training. This helps them to elucidate if their expectations are met or not before choosing a path. Those students not only helped us with the research topic but received feedback about their performance that we hoped could assist them in the aforementioned selection.

The media shown to the users in the experiment consisted of a series of images taken from the IAPS (International Affective Picture System) set plus a series of videos of actors simulating facial expressions from the Cambridge Mind Reading set (As seen in 4.6.3).

This experience represented a more mature method to design a low-cost integration of devices to measure emotions and how human beings could cheat them by controlling their emotions.

It was the first attempt to apply machine learning techniques for predicting emotion recognition from the obtained EEG signals.

4.9.1 Objectives

The main objective was to know if user self-regulation could affect in a significant manner the recognized emotions when processing the biosignals. It was hypothesized by then that people with more stable EDA levels (differentiating the unresponsive users from the ones with lower peaks and fewer variations in tonic levels) would show different results when analysing their EEG data over the users with more unstable EDA levels (with higher peaks).

The secondary objective was to provide feedback to the students and obtain a qualitative opinion based on their expectations and their self-knowledge. Was the opinion we formed about them for the metrics obtained right? And how they were affected by this kind of knowledge? And how do those results differ from more classical approaches that are applied up to date, like the 2D:4D finger relation (George, 1930 & Lladós, 2017)?

Carrying out a battery of tests using machine learning classificators was established as a third objective to check if the gathered data could be analyzed in an automated way.

4.9.2 Materials used

- Emotiv EPOC NeuroHeadset with 14 saline sensors.
- Emotiv custom scripts to extract data from the headset.
- Matlab.

- EEGLab (Matlab plug-in).
- Empatica E4.
- Tobii T60 eye-tracker.
- IAPS Image set (with permissions to use them)
- "Mind Reading: The Interactive Guide to Emotions 1.3" official DVD-ROM

4.9.3 Design

The experimental design was similar to the design in 4.3.3, but with some updates in each methodology step. The tests were conducted in the GRIHO laboratory: By using a non-medical environment the users (students) should feel in a more anonymous location. This was expected to cause less divergence in the results, with fewer users trying to impress their teachers (medical researchers) trying to fake their physical responses by means of a sort of auto-feedback.

The same modifications were made to the laboratory, using black curtains to isolate the testing room and using different doors to enter and leaving the laboratory. In addition, tests were scheduled adding extra time between sessions, so users are not present together in the waiting room.

The metrics to be evaluated were:

- User exploration methodology (systemic or focal) of the picture.
- Fixation in different areas of the face when viewing images.
- Emotional activation by images and category (using EDA and BPM sensors).
- The comparative hemispheric activity during the image viewing process, so that not only could be observed if there is frontal asymmetry or not, but its degree and band in which it occurs.

To solve the previous issues about choosing arbitrary images for an experiment without a known impact of each one over the users, this time normalized images and videos with a known effect were chosen. The images belong to the International Affective Picture System or IAPS (Lang et al., 2008), a private research set with more than 1000 images representing all kinds of events, from people doing activities to all kinds of traumatic injuries, with neutral images depicting nothing in particular. The objective of this project was to provide a set of pictures with standardized emotional impact-rated by a wide set of users. These images are free for academic research with some limitations[18], as the researchers compromise to not distribute the images neither show them in the publications of their experiments. The images and the permission to use them in an experiment is given with the acceptance of their conditions and only after sending a signed contract of use. The reason is that those images only have the correct emotional activation for "the first time" the image is seen, as all body-related activations have a habituation component (as explained in 3.2.5 in this thesis). Sadly, many researchers didn't follow this advice one they performed their tests, as sample images can be found easily in search engines as Google[19]. The values used for arousal and valence were specified in the Spanish IAPS validated variant (Moltó et al., 2013). Our medical researchers have obtained the images and the permission to use them.

A total of 31 images were chosen for the medical consultants from the IAPS to be used during the experiment: 13 unpleasant, 11 pleasant and 7 neutral. The neutral images were set as control beacons

[18] https://csea.phhp.ufl.edu/Media.html
[19] https://www.google.com/search?q=iaps+images

to see both if the activations detected in the biosignals were caused by the category of the images, and if there appear anticipation-related issues. Each image was on the screen for exactly 5 seconds.

Nº	NºIAPS	Image	Valence	Arousal	Category
1	1440	Baby seal	8,02	4,07	Positive
2	5500	Mushrooms	5,63	3,65	Neutral
3	3000	Mutilated Face	1,38	7,72	Negative
4	4490	Naked Man	5,59	5,01	Positive
5	1920	Dolphin	7,86	4,43	Positive
6	4690	Naked couple	6,85	6,51	Positive
7	3053	Scorch	1,42	7,00	Negative
8	9070	Kid	4,07	4,69	Neutral
9	5530	Mushrooms	5,57	3,17	Neutral
10	2710	Drug addict	1,92	6,52	Negative
11	3030	Mutilated Face	1,73	6,91	Negative
12	3120	Mutilated body	1,56	7,50	Negative
13	3140	Mutilated body	1,59	7,60	Negative
14	3170	Baby with tumor	1,54	7,61	Negative
15	3190	Cesarean scar	3,71	5,29	Negative
16	3400	Amputee hand	2,42	7,28	Negative
17	4220	Windsurfist	6,49	4,72	Positive

18	4290	Woman mastubating	5,86	5,60	Positive
19	4658	Couple sex	7,11	7,44	Positive
20	5531	Mushrooms	5,77	2,83	Neutral
21	4680	Naked	7,31	6,69	Positive
22	5532	Mushrooms	5,52	3,08	Neutral
23	4687	Couple sex	7,50	6,69	Positive
24	2070	Baby	8,22	4,38	Positive
25	4800	Sex	6,99	7,01	Positive
26	5534	Mushrooms	5,46	3,11	Neutra
27	6370	Balaclava	3,61	6,67	Negative
28	9040	Malnourished child	1,37	7,27	Negative
29	9140	Dead cow	2,54	6,23	Negative
30	8465	Runner	6,82	4,66	Neutral
31	9405	Mutilated hand	1,71	6,91	Negative

Table 6: IAPS images chosen. Source: Own selection

To measure various requirements related to empathy, short videos with actors performing facial expressions were added to the final part of the experience, to measure exactly the same metrics. The set of videos were extracted from “Mind Reading: The Interactive Guide to Emotions 1.3” official DVD-ROM (Baron-Cohen, 2004). It claims to contain a series of media depicting “the entire spectrum of human emotions”, it also included games and documentation, as its purpose is to help children with difficulties reading emotions (Junek, 2007). Only a small subset of the media was used. Each video had a duration of 15 seconds, and it was played entirely to the user.

A total of 20 videos were chosen by the medical consultants from Mind Reading (CAM): 12 negatives, 5 positives and 3 neutral. Note that male was represented in only 6 out of the 20 selected videos, and only 5 of the videos are evaluated as positive ones.

Nº	EMOTION GROUP	CONCEPT	Gender	VALENCE
1	Surprised	Appalled	Female	Negative
2	Wanting	Appealing	Female	Neutral
3	Hurt	Confronted	Female	Negative
4	Disgusted	Distaste	Female	Negative
5	Kind	Empathic	Male	Positive
6	Happy	Exonerated	Female	Positive
7	Sad	Grave	Male	Negative
8	Disbelieving	Guarded	Male	Negative
9	Sneaky	Insincere	Female	Negative
10	Romantic	Intimate	Male	Positive
11	Interested	Lured	Male	Neutral
12	Sorry	Mortified	Female	Negative
13	Touched	Nostalgic	Female	Neutral
14	Liked	Reassured	Female	Positive
15	Unfriendly	Resentful	Female	Negative
16	Unfriendly	Stern	Female	Negative
17	Sad	Subdued	Male	Negative
18	Unsure	Subservient	Female	Negative
19	Afraid	Uneasy	Female	Negative
20	Excited	Vibrant	Female	Positive

Table 7: CAM videos chosen. Source: Own selection

The images were presented to the users via Tobii Studio and recorded by Tobii T60 Eye tracker, adding attention zones to the multimedia items. This is a Tobii feature that allows to define a polygon over an image or a video: in the case the user puts an eye fixation inside that polygon, the program notes it. It can be done visually during the data processing stage, but having a tool capable of that makes it easier and with fewer error possibilities. In each image, some details were assigned attention areas, such as the syringe in the drug addict, this was proposed to see if users see that item as a marker of the different exploration types (being centered in the details or pivoting over a central point without scanning the image). In the expression videos, two zones were defined, mouth and eyes, to evaluate how users behave in social interaction and compensate for the lack of numeric valence in the CAM videoset.

Figure 77: attention zone for the eyes. Source: (López-Gil et al., 2016)

In addition to that information, an RGB webcam was used to monitor the user's facial expressions to evaluate if there is any correlation between mimicking and obtained signals. Tobii Studio allows adding a common webcam to record the face of the user during a session at 24000/1001 fps (23.976 fps as higher values cause the versions of Tobii studio to fail) so it was used for that task.

The hardware used to obtain the biosignals were an Emotiv EPOC headset and an Empatica E4 wristband. The protocol to obtain the biometrical data was the same as the proposed in 4.3.3 (see that experiment for a more in-depth explanation over this topic), using our custom EmotivUdl.py to record the EEG data and synchronizing with the eye-tracker clapper boarding, and with the Empatica wristband using the same timer as the EEG connected computer. Resultant EEG raw signals were processed with EDF Browser to obtain an EDF file that can be opened in Matlab's EEGLab.

A written test and a post-interview were prepared for the users:

- Consent survey and demographic test: It was used to see if there was any issue with their participation in the experiment as well as to contextualize the data obtained by the sensors.
- A short verbal post-test was asked by the facilitator to take notes of the experiences of the users during the test and their concerns.

Learning from the previous experiences, the interaction protocol defined for this session was more restrictive, especially for the first 10 users (that were used to validate the methodology). Only the facilitator was present during the entire session (from the moment the user entered the laboratory, from the moment the user exited from it) so users were not distracted by other researchers. The facilitator should present the informed consent and answer all the questions not related to the content of the experiment (this is a very important point). In case a question about the content of the experiment appears, the facilitator said that they cannot answer questions about the content until the experiment finishes, but noted the question to do so later. Calibration goes as usual, with the facilitator answering all the questions about the devices (this was important as users can, if they want, try to cheat the system). Information about EDA sensors and their functionality were not hidden. After the test, the questions that cannot be answered during the pre-test are answered, as well as any other question the user has. The facilitator finished asking the user if they wanted to receive the results once processed, if affirmative the facilitator noted the user's code, so the main medical researcher can retrieve its results.

Finally, a battery of Machine Learning classificators was used against the datasets to see if the human processed (and costly) results obtained could be inferred only by analysing the EEG signals.

The protocol specified above was sent and approved by the Ethics Committee of Clinical Investigation of the Hospital Arnau de Vilanova (CEIC, as can be seen in the annex). The confidentiality of the data was kept in virtue of the law 15/1999 of data protection, all the data will be stored with an identifier instead of an identifiable entity (name, id number, etc.). Only the main researcher keeps track of the relation between the identifier and the real person for informing each user of their results and performance, in the case they wanted to know it.

4.9.4 Execution

The initial experiment was conducted among 10 volunteer students, all female. With the protocol defined and tested, the sample was expanded with 44 additional students (with mixed genres) and validated.

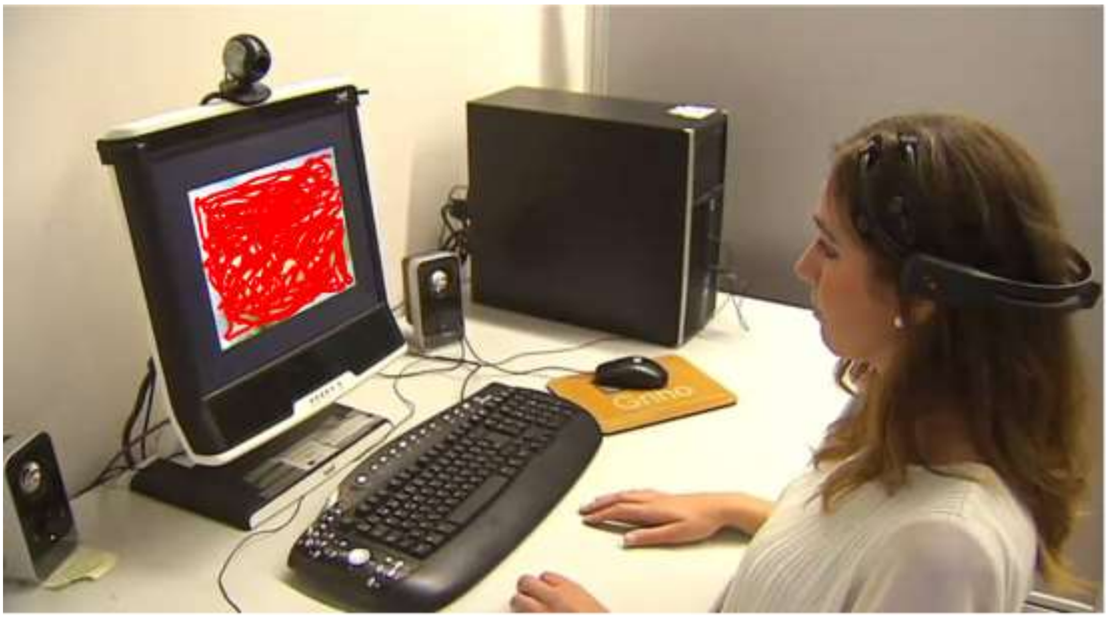


Figure 78: Dramatization of the experiment (Otherwise user results would be invalid). Source: (Lladós, 2017)

The waiting room was prepared as usual with this kind of experiment, with fresh water and some food in the waiting room, but they were encouraged only to eat before the session if they really needed to, as sugar levels could interfere with the experiment in an unknown way. Proper acclimatization was especially important as the sessions were carried out during summer. The user tests were scheduled in a way that two users were never waiting at the same time in the room. This provided some time for the users to drink and use the bathroom if they need to, as well as acclimatize to room temperature, as some of them were sweating (if the user is sweating, do not start an experiment using an EDA sensor, as results will be affected).

Each user was introduced into the experiment (without entering in details) and provided with a copy of the informed consent. The facilitator answers the user's questions as designed in the experiment (4.6.3) and makes sure the users understand that they can leave the experiment whenever they want to, even in the middle of the session. If the user signed the consent and finished with the demographic questions, the calibration phase could start in the testing room.

Before beginning to equip the headset, glasses must be removed and hair bows untied to attach the sensors easily. The calibration session was structured as a short control session: EEG headset sensors are placed, wetting the 14 sensors individually with a syringe until all of them are shown in green (using the official software), the glasses can be added again if needed; EDA wristband was placed and the user was asked to hold a breath and release it after a couple of seconds (to see if appears a peak or not, being a signal that the user may be EDA unresponsive); RGB camera was centred, so the image recorded shows all the face of the user; and finally Tobii studio calibrates the user gaze with a user-guided test.

The facilitator explained to the users that they must not move or talk during the experiment unless they wanted to stop it, and to sit properly with both feet on the ground until it finishes to not affect the data obtained. When they agreed, the experiment started and the session was recorded. After the session ended, the facilitator removed the devices and proceeded to answer the user questions if there were any. When finished, the user left the testing room directly to the corridor.

For each session, EEG raw data, EDA raw data and Tobii recording were processed to be evaluated. This time and to present the final report to the users, all the raw data was sync and simplified, so visual statistics can be made.

Tobii Studio provided heat maps, gaze plots and statistics about saccadic routes and effective seconds of gaze inside each attention point. The percentage of the gaze inside an attention point should be calculated by extrapolating it from the total duration of the image or video.

EDA signal was combined with its accelerometer data to discard signals recorded if there was hand movement at the same time. If not, those activations are used as arousal markers.

EEG data were converted to EDF format and processed using EEGLab as continuous data. As EDF format adds metadata about the sensor position in the scalp, channel location becomes easier. This Matlab plugin was used to remove artefacts by keeping only the signals between 0.1 and 50 Hz (passband filter) and a notch filter (at 50 Hz) to remove field effects. Both software signal filters were considered as an assistance for the built-in hardware filter in the EEG. As the following steps were effectuated manually, the images where there was present more user activation (in EDA sensor) were used to know the periods of time to be evaluated in the EEG signals. ICA (Independent Component Analysis) algorithms were applied to each signal over the selected period to visually remove muscular artefacts as eyes blinking. Using this methodology has the risk of deleting significant activations, as the decision of if it's an artefact or a legitimate signal depends on the researcher. To address the problem webcam data was used to visually match those events with eye blinking and delete them if they appear on both sides (ICA and frame in the video) or keep them if not. The same visual technique was used with the wristband accelerometer to discard events related to muscular motion. Once the signal was clean, frontal asymmetry was used to compute the valence for a stimulus. Using an EEG signal it seems feasible to identify the valence of an emotion, or at least differentiate the positives processed by the left hemisphere, from the negatives processed from the right (this produces alpha frontal asymmetry).

Having arousal and valence obtained from our biosensors, IAPS arousal and valence values could be compared to see if they matched.

Machine learning techniques were applied following a comparative analysis over two differentiated groups over their EEG signal. The first group was composed of members that we think autoregulated their biosignals as an answer to what they were seeing during the experiment, while the second group were not capable of it. This regulation was inferred from the EDA data, if the user managed to maintain a baseline without sudden peaks it was considered to self-regulate signals.

This machine learning test tried to use 10 different supervised classifications to see if any can obtain a good accuracy ratio of recognized emotions from the IAPS image seen with their respective EEG signals.

4.9.5 Results and Challenges

Those results are a mixed summary of the results in the methodology setting-up, the ones for validation experiments and the ones delivered to the users after they finished the experiments.

Looking at the EDA signals comparatively, It can be observed clearly that there are some users not affected in a special manner by the harshness of the images, while some were greatly affected. Those results were theorized that users showing smoother baselines have more control over their body automatic reaction through a self-reinforcement process. It must be noted that the users self-regulating must present a peak on the deep breath calibration, otherwise, they should be considered only EDA unresponsive.

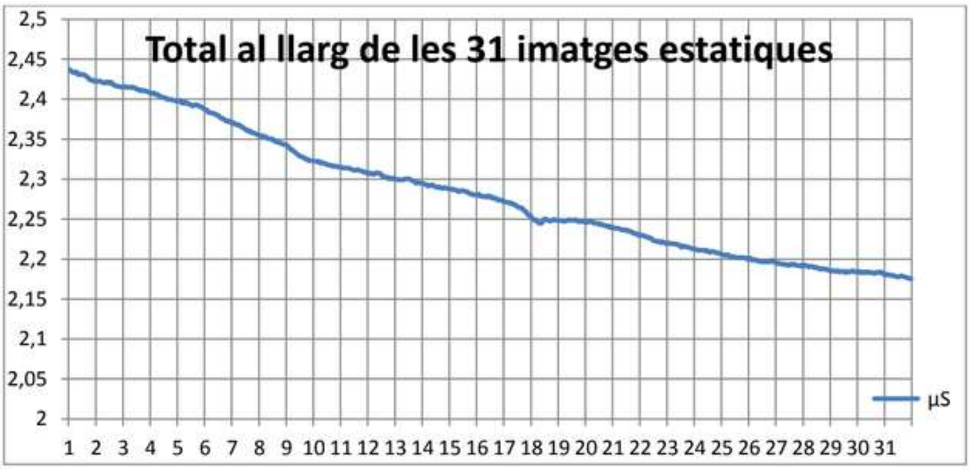


Figure 79: Self-regulated EDA signal. Source: Own graphic

Only half of the total users presented an important emotional activation in EDA signals during the experience, 4 users being EDA unresponsive and the rest self-regulating (at least up to some point.). When asked, users theorized to be self-regulating were coherent with the results, showing themselves proud to be medical professionals and that "those kinds of images shouldn't affect them the same way as the rest of the people". The majority of these users were prone to choose a surgical specialization. Conversely, users with higher peaks pointed out that they empathize a lot with the patients to the point to "feel their pain" sometimes; most of them being prone to choose a diagnosis-related specialization. Strangely the picture with the most EDA activation and higher peaks, even in some self-regulated users, was the image number 28, the dead cow. Naked people and heavy injuries caused heavy peaks, but for some reason, self-regulation works better with human-related suffering. It was theorized that as future medical professionals and as some did rotation services in the hospital, the EDA habituation process has been running on during the lasts years while they get real-life experience, making them more “sensible” to animal suffering than to human one (as they were not so used to see it). More strangely, after the calibration process (the deep breath task) and before the experiment starts, the device was recording without the user specifically knowing it. This was not due to a hidden test but for practical purposes, as the cable was short and the wristband needed to be removed between tests. During that period, the EDA values of the 21 self-controlled users were shown normal, presenting peaks on various stimuli. Only when they thought the experiment began their EDA responses became flat.

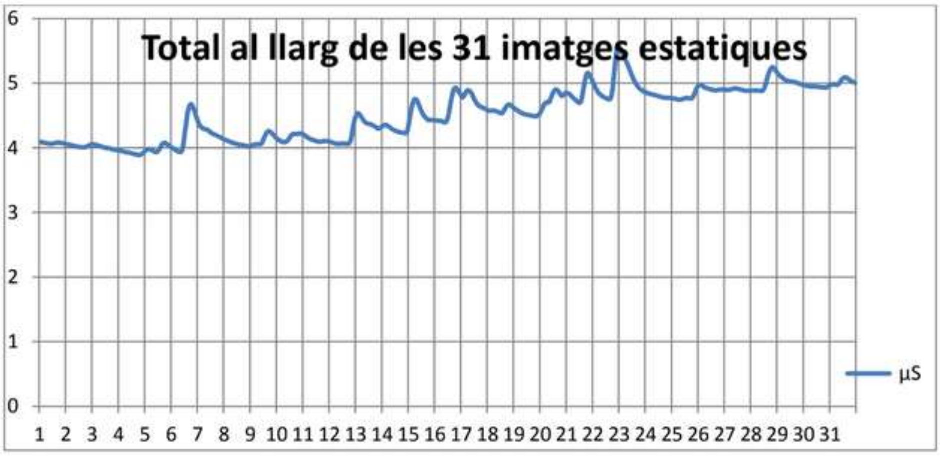


Figure 80: Not regulated EDA signal. Source: Own graphic

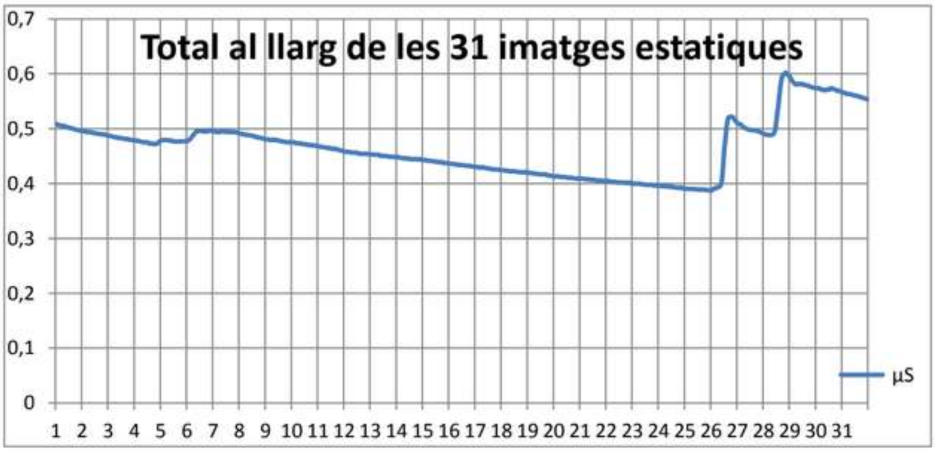


Figure 81: Self-regulated EDA signal, minimal cow activation. Source: Own graphic

When added Beats Per Minute (BPM) info, it seems that even the minimal peaks were related to a variation in the earth rate. This was applied too to the self-regulated users, where peaks caused a slight rise in heart rate frequency. This was shown as a session tendency, but anyway, the exposition time was too short to take this sensor into account for specific images.

Once analysed the EEG data, the image that caused the most activation was the IAPS number 13 “Mutilated body”. This was theorized to be increased by the fact that the image number 12 was another unpleasant one with high arousal values. When the frontal EEG signal was evaluated during the time codes for that image, practically all users presented a frontal asymmetry in the lower (7-8 Hz) and upper (9-10Hz) alpha bands, even those who didn't have any peak present in their EDA signals. Therefore, it can be said that although physically at the level of EDA or heart rate they were not affected, they felt what they were seeing as a strong dislike. The users with EDA peak in unpleasant events presented frontal asymmetry during the same image visualization.

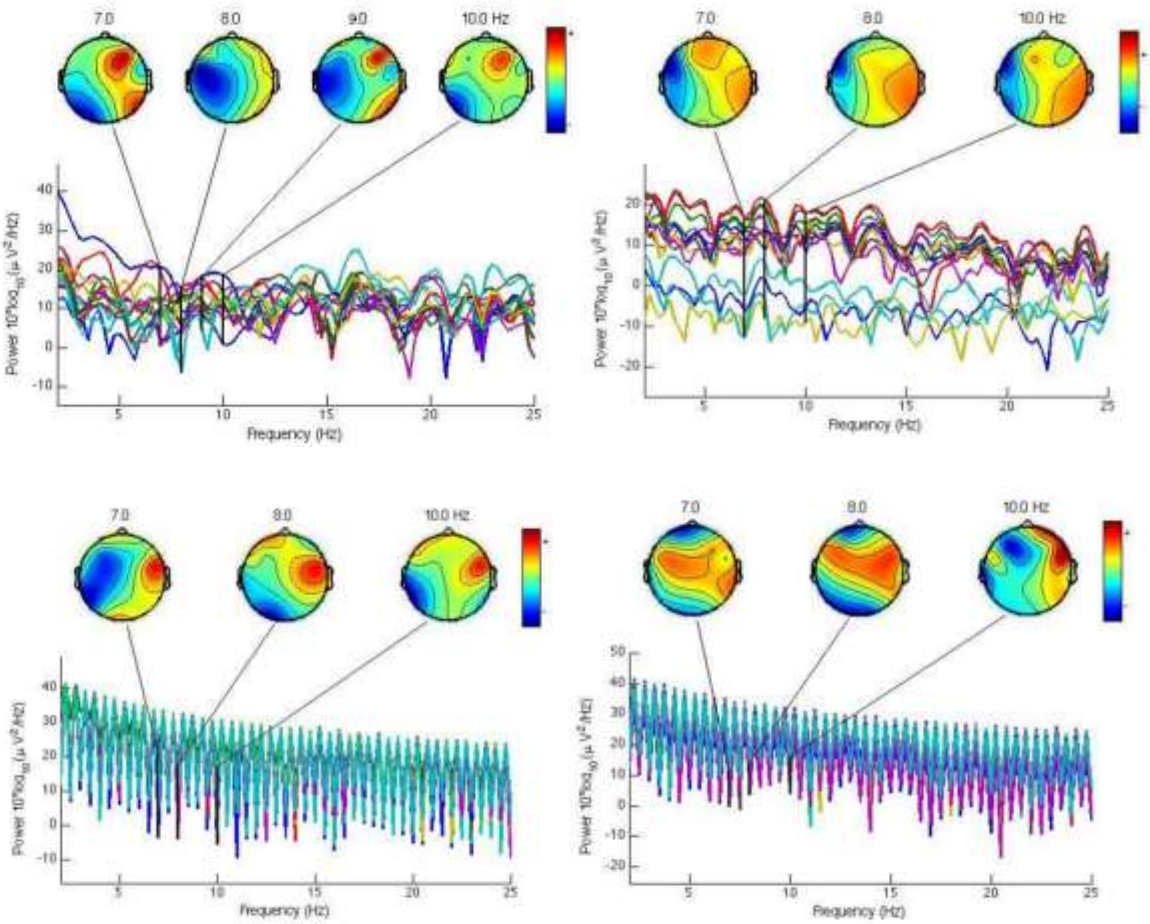


Figure 82: Frontal asymmetry (Dislike). Source: Student reports, own images

In fact, one of the users who didn't present any kind of frontal asymmetry answered on the demographic survey that was under the influence of an anxiolytic. The user was not discarded to know if there could be obtained any differentiated response from the biosignal devices. Only that difference could be found, as EDA responsiveness was limited (but presented peaks) and the interaction was normal.

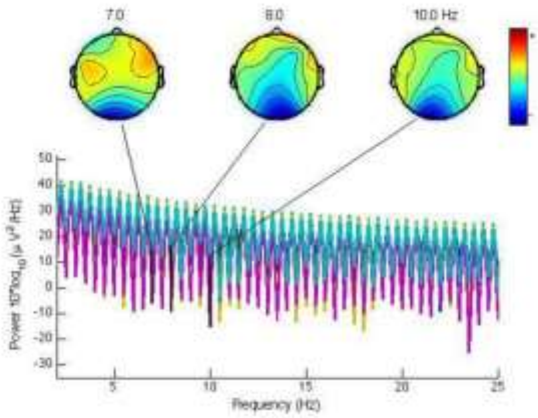


Figure 83: Frontal symmetry (Not affected). Source: Student reports, own image

The exploration and mimic data were extracted and analyzed as usual with Tobii Studio. There could be clearly differentiated two types of exploration depending on the user: some followed an exploration pattern to analyze the context of the image while others were centered in the focal point of the image. The first ones explored the scenario in search for clues that expanded the information of the central history: in the drug addict those users searched the ground for clues of the method used to consume; in the mutilated hand they looked at the table searching for cutting tools. The second ones didn't stay in the center of the image attention: In the drug addict searched the patient's body; in the mutilated hand they looked at the integrity of the different zones of the hand. The users with an exploratory pattern tended more to present a smoother EDA baseline, but not enough to be significant.

Some of the users reproduced the feeling shown in the video or the image and some not, but the users who presented a self-control component only mimicked in the 10% of the cases, an extremely low ratio. Curiously, some users only mimic the positive emotions, but not the negative ones, while the contrary did not happen. This info was added to the personalized resume delivered to each participant.

As a complement to the empathy study that the medical researchers were performing on their own, emotional empathy (a differentiated trait from cognitive empathy) was measured by controlling the amount of time that the user was looking in the zone defined for the eyes as validated in (Wang et al., 2006). This analysis was only performed in the final videos as they were longer and the face dimensions were bigger. The percentage of fixation in videos for each user were analyzed as part of the student report. Although manual selection and interpretation work must be done, results for eye fixations were coherent with the medical surveys passed by the students: the more scored in the written empathy tests the more eye fixation shown. There seemed to be a match between users more empathic and those who followed a more centered exploration. Interestingly, the users with self-regulation capabilities scored all above 50% of the total time gazing at the eyes zones, with the exception of people using antidepressants (3 of the total 54 users).

Global Eye Fixation	Positive feeling Eye Fixation	Negative feeling Eye Fixation	Male Eye Fixations	Female Eye Fixations	Global Mouth Fixation	Positive feeling Mouth Fixation	Negative feeling Mouth Fixation	Male Mouth Fixations	Female Mouth Fixations
68,49	66,23	70,74	89,50	59,48	8,51	9,23	7,78	2,45	11,10

Figure 84: Percentage's fixations in videos for a given user. Source: Student reports, own image

The differences between male and female users were difficult to establish as the percentage of men in the study was unbalanced as most medical students are effectively female. With those results, gaze fixations among men seemed slightly higher than among women. Curiously, mouth fixation in men images was less important for men than for women, while mouth fixation in women was identical (and higher) among both groups.

	Count	Mean	Var.	*St. Dev.*	Min	Max
OVERALL						
Global eye fixation	44	50,468	372,720	19,306	1,542	86,204
Positive feeling eye fixation	44	50,632	388,632	19,714	2,261	91,106
Negative feeling eye fixation	44	50,305	380,752	19,513	0,823	83,256
Male eye fixations	44	62,416	385,179	19,626	1,110	92,186
Female eye fixations	44	45,348	407,737	20,193	1,727	86,102
Global mouth fixation	44	17,159	175,209	13,237	0,000	52,453
Positive feeling mouth fixation	44	17,770	175,027	13,230	0,000	53,060
Negative feeling mouth fixation	44	16,547	189,950	13,782	0,000	57,969
Male mouth fixations	44	11,105	117,774	10,852	0,000	53,560
Female mouth fixations	44	19,753	219,041	14,800	0,000	59,645
BPM min	41	73,829	186,695	13,664	47,000	102,000
BPM max	41	91,098	315,040	17,749	55,000	137,000
WOMEN						
Global eye fixation	38	49,249	381,522	19,533	1,542	86,204
Positive feeling eye fixation	38	49,660	392,246	19,805	2,261	91,106
Negative feeling eye fixation	38	48,838	393,598	19,839	0,823	83,256
Male eye fixations	38	61,685	411,062	20,275	1,110	92,186
Female eye fixations	38	43,919	412,282	20,305	1,727	86,102
Global mouth fixation	38	17,225	167,431	12,940	2,394	52,453
Positive feeling mouth fixation	38	17,980	161,275	12,699	2,379	53,060
Negative feeling mouth fixation	38	16,469	187,681	13,700	1,669	57,969
Male mouth fixations	38	11,338	124,748	11,169	0,000	53,560
Female mouth fixations	38	19,748	203,489	14,265	1,812	59,645
BPM min	35	72,914	174,081	13,194	47,000	99,000
BPM max	35	88,886	283,163	16,827	55,000	120,000
MEN						
Global eye fixation	6	58,192	299,246	17,299	32,170	83,150
Positive feeling eye fixation	6	56,789	386,943	19,671	26,207	84,453
Negative feeling eye fixation	6	59,595	241,927	15,554	38,133	81,847
Male eye fixations	6	67,050	240,846	15,519	49,405	89,716
Female eye fixations	6	54,396	341,909	18,491	24,783	80,336
Global mouth fixation	6	16,739	267,564	16,357	0,000	45,809
Positive feeling mouth fixation	6	16,442	309,349	17,588	0,000	49,908
Negative feeling mouth fixation	6	17,037	244,400	15,633	0,000	41,710
Male mouth fixations	6	9,631	86,700	9,311	0,000	24,840
Female mouth fixations	6	19,786	377,933	19,440	0,000	54,796
BPM min	6	79,167	269,767	16,425	64,000	102,000
BPM Max	6	104,000	360,800	18,995	84,000	137,000

Figure 85: Statistics for numerical measures collected and used. Source: (López-Gil et al., 2016)

The diverse automatic classificators tested were insufficient for detecting the emotion by relying only on the raw EEG signal, performing all of them poorly. This encourages the usage of mixed data acquisition systems to be tried as future work, adding information from more sensors to the classificators.

As a final summary, inexpensive biometric devices performed well in the task of elucidating simple emotions (by using EEG frontal asymmetry joint with EDA sensors) and complex emotions as empathy (using EDA sensors or even the same Eye Tracker fixation zones). The fact that the eye tracker by itself provided this kind of data opens the future work of using webcam-based eye-tracking tests, so the sessions can be conducted at more places. Then the relation with different context and the responses obtained could be investigated, accessing a huge number of possible test users, and applying those techniques virtually everywhere. In addition, the different devices used in this experiment provided the data that, when cross-analysed, allowed the detection of users that were applying a self-control layer over their experience.

These cheap biometric devices seemed to not be too invasive for the users, but this can be caused by their novelty, as the calibration process can be quite long and awkward. Those tests were performed before 2020, this means that the people's willingness to have physical contact or to be in closed spaces with unknown people (even if only the moderator) cannot be dismissed without further tests.

As future work, this validated methodology should be refined and used in other studies as self-knowing has been seen as an important factor among the students when the results of the study were provided. This has the actual flaw (It will be commented on and expanded in Chapter 5) of the testing being realized in a laboratory context, and with the actual situation, lab experiments will be a difficult subject, especially those related to UX. For this reason, more disposable devices should be used so the user could carry the experiments in their own contexts.

The new methodology described in the paper (López-Gil et al., 2016) was validated as part of the study “Empathy in medical students psychometric, biometric, evolutionary study and psychoeducational intervention proposals” (Lladós, 2017), where the same technique (among others) was applied to provide feedback for 44 students with great success.

Chapter 5 - Discussion and future work

The experiments presented in Chapter 4 covered mainly three different topics: new UX approaches to analyse emotional data; cross-sectional research collaborating with experts from different areas of knowledge; and the benefit for users by applying these techniques. The four thesis statements defined in 1.1 are present in most experiments, with a minimum of two appearing in every instance.

5.1 Thesis statements summary

The four thesis statements (1.1) have been answered at some point, yet not necessarily in the order specified in the thesis overview. This was accomplished this way because of the many tools and methodologies that needed to be developed to achieve each point. Recapitulating:

1. ***If users know how an emotion is affecting their behaviour, they can affect the subjective appreciation of that feeling, and by that change the way they feel to improve their overall experience.***

This was intuited in the experiment with fibromyalgia patients (4.2) and chronic low back pain (4.4), detected in the neuromarketing studies (4.3) and it was possible to measure it with the complete methodology (4.9). This evidence validates the statement, as made evident in the case of the many medical students who were able to modify their biosignal responses. Different values were obtained depending on their focus: when centred into the experiment their EDA response was somewhat different from the signals obtained during the calibration phase. We assume that as it was not specifically said that the calibration session was being monitored, their self-feedback was not yet active during it.

This is especially useful for UX evaluation, as adding the user mental state component to the UX evaluation is something relatively new and not much research has been done about it. Classical UX theories point at the elements of the interaction causing satisfaction or discomfort, but in all cases, the responsible are the elements of the interaction, not the emotional starting point of the user. A recent goal of UX evaluation is applying layers of “affective design” upon the classical UX layers, so the interaction could be even more focused on the user and experience customization. In (Reynolds & Picard, 2001) it is said that affective computing applications need to “receive emotional information provided by the user in a natural and comfortable way”, and there is no more natural and comfortable way than disregarding the user from that responsibility by obtaining the data from real-time biometric devices. This automated information will not have the contamination caused by the cognitive processes of the users self-justifying themselves (as seen in 4.9.5) and as said in Chapter 1 (section 1.0) that the metric will be numerically empirical.

The most difficult thing right now is the arduous task of defining the numerical limits and the methodologies to obtain (and process) them.

2. ***We propose a hybrid method, measuring and analysing biosignals and using existing questionnaires as validation of the results, with the objective of achieving a biosignal model at least as reliable as the questionnaires used until now.***

Different contributions have been presented during the development of this thesis to validate the previous statement. First, a new ontology was proposed with the main objective to fit multiple emotion theories (4.1). This way, it is possible to detach the descriptive language from the theory described, thus making it not necessary to use specific representations for each theory, even if the conceptual differences among them are big. This might lead to the creation of affective computing systems capable of evolving by integrating more emotion theories or completely changing the ones used if the context requires it.

The methodology to analyse and interpret the biosignals has been developed and refined through 4.1, 4.2, 4.3, 4.4, 4.5, 4.8 and finally integrating all the accumulated experience in 4.9 and validating it. The results were cross-validated with classical methodologies (those used by each area of knowledge) in 4.2, 4.4, 4.6 and 4.9. Those validations showed coherence in our new approach, but more importantly, they showed that our methodology can serve to complement the cognitive information to know even better the user behaviour. This was due to the fact that our methodologies extract information from a totally different source: the emotional dimension. This way, the validation of our novel methodologies, although successful, was not as relevant in the end as evidencing the complementarity of the two approaches (cognitive and emotive) to obtain a more complete representation of the user experience.

3. ***Various studies have suggested that web-based educational interventions can have a positive impact on user attitudes and conduct, we believe that our methodologies can contribute to that field.***

The web-based methodologies applied and validated in the educational intervention 4.4 and expanded through 4.6 and 4.7 achieved a high level of interest from the users; This is especially relevant due to the different contexts where those experiences were applied.

UX tests dealing with patients are difficult because you are interacting with people that are suffering and, as researchers, we must not increase their discomfort even during testing. In the same way, the results of the experience could be biased in the sense that the users' points of view could be biased by their own inner experience rather than the interaction experience.

For this reason, their good reports were considered a success by themselves. In addition, this group represented the best answer to this thesis statement, as the experience *effectively* had a positive impact not only on their interaction with the platform but a positive impact on their daily lives, especially compared with those following a classical primary care intervention that lasts over time.

The students that used the platform to expand their knowledge provided good feedback too. It can be said that by the time they had to use it (Covid-19 lockdowns) they would prefer face-to-face classes, but it is certain that the platform was not devised as a standalone teaching system, but an assistant designed to reinforce content seen in face-to-face classes. Despite not having data to compare with, different institutions trusted in the methodology to be applied during their lockdown teaching periods up to date to reinforce remote learning. This is seen as a successful case, as experienced teaching institutions valued the contribution of our platform in this topic.

4. ***All the above can be achieved by using low-cost devices, services and methodologies, so it can be affordable for everyone.***

All the experiences were intended to use low-cost devices, and for those using high-tier hardware (basically the T60 eye tracker), it was used to validate the proposed methodology and due to availability purposes. In any case, these high-cost devices are easily substituted with similar low-cost technologies available nowadays without great differences in the results.

The use of low-cost devices does not only imply buying cheaper devices but also studying the proper way of making new ones ourselves. This was achieved in 4.8, where a budget prototype was built to fulfil a purpose, designing the experiment before the hardware to find and solve the issues of that method. The result was a cheap experience-designed wristband that allowed us to obtain the biosignals in an inexpensive way.

5.2 Discussion

As seen in the thesis statements summary (5.1) the four main objectives have been accomplished. The different fields and directions covered by this thesis are a reflection of my own way to see the world in general and the future of UX in particular: they are explained in-depth in subsection 5.4 (Reflections).

In general lines, this thesis had advanced towards an automated system for emotion detection. If it's true that we didn't achieve a fully automated emotion detection methodology, we've set the rules for a basic manual detection that worked as well as other classical approaches (The model used in 4.9 was validated as it is said in 4.9.5). One of the characteristics of the logic behind the proposed methodology is that it is totally independent of the existing theories, as it starts from an innovative and adaptable ontology that depicts emotions, and it is shaped in a way that fits almost any model. This allowed us to test our methodology in multiple fields such as health assistance (4.2 and 4.4), education (4.6, 4.7 and 4.9), marketing campaigns (4.3) and even entertainment purposes (4.5). Another advantage of using a malleable ontology is that we could add specific metrics measured by our own created devices (4.8), so the metrics used by commercial devices are no longer a limitation.

The main issue with the possibility to establish an automated model was signal filtering. As the human component was not properly known, each signal should be filtered differently. This leads to a variable degree of loss of information, but unavoidable if the user has the freedom of movement needed to be comfortable with. In medical degree EEG experiments the restrictions of the patient are so high that a user experience evaluation cannot be done. The automated machine-learning attempt (in 4.9) didn't shed light on the matter, as all the methodologies tested were totally incapable of establishing a relationship. Anyway, after filtering the signal manually, the interpretation was coherent with the known theories and the written user behaviour queries along with multiple validations. This is something that makes us confident to say that we've established a manual model at least interesting to be studied in more depth. The multiple experiences with users from different demographic sectors showed us how to properly behave in a lab environment (speaking about the topic of obtaining valid biosignals) and how an EEG-data-acquisition session should be performed to avoid common issues.

In the health assistance field, we have participated in the research of the feedback effects, and how they can have a positive impact on the user's life. The experiences suggested that using those techniques and knowledge can lead if not to an overall improvement of the patients, to a state of less decay as users not applying it (4.4). Far from being bad, this is seen as hopeful data as every patient seen in those experiments were suffering from a degenerative illness (they were not in any advanced state, but they were not expecting to improve either). Here it was theorised that something related to the context where the patients were being monitored (in their homes participating when they want to in contraposition with primary care centres when they have a meeting scheduled) was affecting these results.

The device created as support for explaining the self-feedback theory (4.5) had an unpredictable success related to the synergy in our university. That quick way of showing how our thinking can impose changes in the real world using only willpower and technology ended up being the flagship of our research in society during a quite heavy amount of time. The interest aroused in patients, and people in general, was an example of how technology must be affordable if we want to cause a change in people's mentality. In this case, we've learned a lot about the different ways of thinking and the gender/age bias existing when speaking about this topic, as four different patterns could be clearly differentiated: young males (used motor actions, as kicking a ball), young females (only group that can evoke colours), adult males (the most unsuccessful group, sometimes can evoke a motor action but not as easy as children) and adult females (can evoke flavours better); each one incapable of performing using the same evoked actions as other groups.

In the educational field, we've suggested that our methodology is at least as good at obtaining profiles as the ones used in Medical Specialization (MIR in Spain) recommendation systems, where the student is oriented into a field following various well known classical methodology. The acceptance of our methodology, although innovative, was very good both among professionals and students. The collaborations in the educational field continued both with patients (4.4) and future health students (4.6 and 4.7) with hybrid educative interventions, comparing the results in a classroom (or medical centre) with a mixed home-classroom approach. In the case of healthcare students, the results could not be measured properly because of the Covid-19, which forced us to dispense with the control groups to prepare an emergency full-online course. The results were a success in the opinion of the medical scholars.

Precisely for this, and in the context of the Covid-19 (I think it is not possible to understand this thesis without it) it was decided to start applying all this self-feedback theory fully in another context as the user's homes. Of course, it presents some problems, such as the lack of specialized hardware among the houses to obtain and interact with biosignals. For this reason, the main goal was to obtain a trusted platform to deploy the new experiments with different stages, without losing the focus on the first of the thesis statements, that is affecting the user's self-regulation to obtain an improvement in their experience. Each iteration of the educative interventions (4.4, 4.6 and 4.7) added new interactions and materials to improve the users' experience when using the platform. It's true that actually, it is not obtaining biosignal measurements, but the idea behind is to create a platform that allows us to add it in a later stage. This way we could research if the context has something to do with the results or not. As an online resource, the pandemic assisted us in obtaining partners, who added our platform into their teaching guides and increased our users' pool.

To do so (adding biosignal acquisition devices) we will need cheaper devices, and the only way to do it is to make our own ones. The experiences in this thesis taught us a lot of things, from integrating commercial systems (in 4.5) to create new ones from scratch that fit our specific needs (in 4.8). Integrating commercial devices won't be an option if the future work is to perform those tests online (the base hardware is cheap at a laboratory level, but not in a homemade context).

5.3 Future work

The future work will spin around the following axes:

- Expanding the ontologies to connect them with empathy, non-verbal expressions, and a wider variety of systems. Empathic systems could be described using those ontologies, adding a quality component over the described data.
- Achieving a real automated emotional detection system.
- Use this knowledge to avoid biases when choosing users for experiments, detecting the different groups (even when they are part of the same demographic section) in a more complete way.
- Continue to develop the platforms needed to perform the research independently of the context (and to see if the context has something to do with the results).
- Creating custom-made hardware to make biometric testing affordable at home contexts.

The ontologies can be expanded to integrate other emotion expression systems such as non-verbal language (that keeps fitting in some kind of biometrical field) or even verbal communications. Actually, this is performed successfully by Woebot (Holt-Quick et al., 2020), where they integrate into the design a purely empathic module to interact with the users. Expanding our ontologies could provide cross-validation between different systems, as when one is validated all the related ones will have the same validation. This integration will help us with the objective of achieving a real automatic emotion system detection by adding different points of view, technologies and knowledge.

While this is not achieved, manual detection could be used to improve demographic user control in the phase of choosing experimental users. This could be used both to improve the grouping of individual users and to avoid outliers, so the provided results will be more exact and easily reproducible.

There’s an important point over automated emotion detection and automatic (or in this case, semi-automated) demographic detection using biometric data: As the technology advances, the laws protecting the people from misuses of the technology advances as well. Our work in the future will have to comply with the new set of regulations of the European Artificial Intelligence Act (European Commission, 2021). This regulation bans all the systems that manipulate the people's will, especially those from vulnerable groups (Title II of the aforementioned document), and establishes a legal framework for those applications that detect emotions or determine categories (Title III, and there’s a special mention for those splitting demographic groups in subgroups) based on biometric data. A set of transparency obligations are now mandatory for that algorithm (Title IV), as the person interacting with them must be informed of everything about that process as well as various authorities. Luckily a legal framework for research is also established (Title V), where the Union encourages the Member States to define their own regulatory sandboxes to be innovative-friendly. As researchers, we can develop our experiments within that context, but the requirements in permissions and needed documentation will increase both the costs and the time needed to prepare them. An important doubt is if the user is informed about the experiment can change the measured results (as in our experiment 4.9), so we will have to see if the ethics committee approves to inform the user after the experiment instead of doing it before (as the European act points to, with well-argued petitions for research and supervised by third-party groups). We hope that will be allowed for research purposes.

The platforms must be adapted to the new framework after consulting with the ethics committee, but actually, the users are heavily informed about the research subject and how it will be performed as future medical professionals (remember that it’s an educational platform), so it is not really an issue.

As we said in the previous chapter, integrating commercial devices for professional use won't be an option in home contexts due to their high costs and their specialized care (their maintenance, complicated for some devices). For this reason, future work needs to use integrated peripherals in the user's computer, starting from the webcam. As the technology gets cheaper, new devices should be created to fit specific needs for each project. The budget could be derived from the user's gratification: if the device is well-designed, it can be the prize for participating in the experiment. This not only satisfies the user but increases the allowed user pool, while doesn't increase the amount spent for a given experiment.

This will be done to contribute to creating standards for UX remote biometry analysis.

5.4 Reflections

It is inevitable to address the fact that the thesis shows two different lines of research, scaled over time: Obtaining and processing UX biometry and online experiences. This is a complex topic that I will develop here. But before explaining how those topics are related, I will explain why they are important individually.

Obtaining and processing UX biometry is, for me, the next step into interactive computing. Some people call it affective, I don't know if in the future devices will adapt to our feeling, but today I can assure that the interaction with our devices has an emotional (affective, if you prefer) component. When I was a student I wondered why the UX measured reactions never come with at least an opinion of the user about the outside of the system: were they negative? Were they sad that day? Were they having such a so-magnificent day, that even a bad menu seems good to them? Then I realized that I know, as a human being, that one of the problems we face is that identifying those emotions can be really difficult even for ourselves, and sometimes we need help to do so (from a friend, family, a professional or a health professional). Speaking in early 2017 with a psychology student, she told me that for some people, being helped by a professional is totally impossible, as they don't have the confidence to freely express themselves. Although this being an extreme case, it also applies to simpler situations, as the stress caused by bad interactions. Emotive computing helps us to face more difficult problems in an easier way while having more pleasant interactions with our devices and systems. We hope our developments now and in the future can contribute to that topic.

On the other hand, online experiences are more important today than ever. Not only do they empower the user and add a layer of *direct contact* between the professional and the user that consumes the data, but they give another component to the user: the capacity of using their willingness. If the user wants, they can stop, or deepen the topic. Without schedule or availability boundaries, without the user fearing to stop the speaker to make them repeat the last phrase. Complete control over their own learning.

But why are they more important now than ever? And how is it related to biosignals and emotive computing? For me, it was a natural evolution, speaking from my personal experience:

I always enjoyed lab work, from when I started as an intern until now that I'm working at another institution (Institute of Agrofood Research and Technology), where different research groups are participating in each one experiment outside our working hours for basically fun (and increasing the amount of data obtained by our fellow researchers). For this, I tried to participate in all the tests I could as a user. All this has changed during 2020, when experiences like the one carried in 4.9 with sixty health professionals became unthinkable. For me, it has changed permanently, and even though

I know it's more an issue related to my personal experience, an undetermined amount of people will hold an opinion like mine. Even when the pandemic finishes (and it seems it will take a long time to do so) the lab work won't be the same: fewer users will volunteer, companies are going to show more difficulties when required to evaluate in person, the measurements would have an unknown component of fear even for being there, or with more people, etc. This is when the online UX evaluation comes into play, as they were not only unaffected by the restrictions but enhanced (as seen in 4.7). In addition, all the present and future issues present in laboratory work do not affect them at all.

During the development of this thesis, my perception of the future of UX has changed, and for so the main future work will be to develop all the methodologies seen in this thesis to be used in a remote context.

The model described in this thesis had been evolved in each experiment (4.1, 4.2, 4.3, 4.4, 4.5, and 4.9) during various years. It implied the comprehension and refinement of the context, the interaction protocol, the devices and the data obtained. Moving that knowledge to be applied remotely faces different problems.

The first issue is the lack of a platform with enough users to use and test the newly proposed formula. This platform was started in 4.4 and improved in 4.6 and 4.7, now counting 300 users and the support of two educational institutions. Those institutions provide funds (important for the research of health) via R+D educational projects.

Once the platform is available, there are users to validate the data and the support to make the research, the next issue is that those cheap devices were cheap at a laboratory level, not at a user disposable level. For this reason, the first thing to add will be an online webcam eye tracker as Gaze recorder (2.2.1.1) to start with user gaze analysis. This data will be followed by specific devices, created from scratch for their particular task. If biometric data needs to be added in massive online UX experiments, those devices should be even more inexpensive or find a way to amortize them. One possibility is to substitute the gratification for participating in the experiment, which is usually monetary in enterprise contexts, with the ownership of the device. If the device is cheap enough, this value depends entirely on your budget, the user should keep it to use them if they want. This has the strong point that your testable "user network" increases over each experiment, so you'll have more testing users over time.

This leads inevitably to the production of even cheaper devices like the one shown in 4.8. Theoretically, even when prototyping (buying on a massive scale would be undoubtedly cheaper, but we are not even close to that point) they can be done by cutting 50% of the price if batteries are removed, using AAA batteries or relying on the USB port charge. This would allow us to have an EDA sensor for 55€/student using adequate-tier devices (Bitalino, as seen in 2.2.3.1). This amount is in the budget for university testing with small groups. For fun purposes, a not very reliable EDA device (a basic *lie detector*) could be made for under 5€ using Chinese Arduino-like boards (those using the chipset CH340), two push pins and a resistor (Monk, 2010). So a middle point can be found for sure.

I believe that using these technologies in a more private context could lead to higher improvements in the results shown if compared with the laboratory ones. This is justified by pondering about the results shown in 4.4, where the patients "good" results were not a direct improvement in their evaluations, but that they didn't suffer the decay shown by the members of the control group. What did happen to them? The intervention was similar, and by no means the medical researchers expected this result. Was it possible that the context (the primary care building) affected them negatively?

Making them feel sicker as they have to "go to the doctor each day"? And the users participating from their homes, without visiting the center so often, they could feel they were better because they were not visiting the doctor? Because they can choose when to do something and when to stop? More research will be developed over that topic in the future, with control groups planned to be added as soon as the entire group could be expected to be face-to-face.

The future for me is remote, total or partial, but remote.

5.5 Achievements

During the development of this thesis the following key points have been achieved:

- The following publications have been produced:

Authors: Gil, R.; Virgili-Gomá, J.; García, R.; Mason, C.
Title: Emotions Ontology for Collaborative Modelling and Learning of Emotional Responses
Journal: Computers in Human Behavior
Volume: 51 **Pages, Initial:** 610 **final:** 617 **Year:** 2015 **Place of publication:** USA **ISSN:** 0747-5632
JCR SSCI 2015: 2.880 (Citations WoS 2020: 17)
PSYCHOLOGY, MULTIDISCIPLINARY – 21/129 (Q1)
PSYCHOLOGY, EXPERIMENTAL – 20/85 (Q1)

Authors: Pascual, F. V., Virgili, J., & Gil, R
Title: Managing emotions for the treatment of patients with chronic low back pain
Journal: Proceedings of the XVII International Congress on Human-Computer Interaction
Pages, Initial: 107 **final:** 110 **Year:** 2016 **ISBN:** 978-84-9012-629-5

Authors: López-Gil, J.M.; Virgili-Gomá, J.; Gil, R.; García, R.
Title: Method for Improving EEG Based Emotion Recognition by Combining It with Synchronized Biometric and Eye Tracking Technologies in a Non-invasive and Low-Cost Way
Journal: Frontiers in Computational Neuroscience
Volume: 10 **Number:** 85 **Pages, Initial:** - **final:** - **Year:** 2016 **Place of publication:** SWITZERLAND **ISSN:** 1662-5188
JCR SCI 2016: 1.821 (Citations WoS 2020: 10)
MATHEMATICAL & COMPUTATIONAL BIOLOGY – 20/57 (Q2)
NEUROSCIENCES – 200/259 (Q4)

- The following research have been presented in conferences:

Authors: Pascual, F. V., Virgili, J., & Gil, R.
Title: Gestión de las emociones para el tratamiento de pacientes con dolor lumbar crónico
Conference: XVII Congreso Internacional de Interacción Persona-Ordenador
Year: 2016

Authors: Virgili, J.
Title: Multipurpose biosignals wearable (Short Paper)
Conference: IEEE 11CCC (Congreso Colombiano de Computación)
Year: 2016

Authors: Valenzuela-Pascual, F., Pàmies-Fabra, J., García-Martínez, E., Martínez-Navarro, O., Climent-Sanz, C., Virgili-Gomà, J., & Blanco-Blanco, J.
Title: Use of a gamified website to increase pain neurophysiology knowledge and improve satisfaction and motivation among students studying for a degree in physiotherapy: A quasi-experimental study.
Conference: CIDUI 2020 (Congrés Internacional de Docència Universitària i Innovació 2020)
Year: 2020

- The following Teaching innovation projects have been carried out:

Title: “Use of ICTs to increase motivation and the acquisition of knowledge about the neurophysiology of pain in students”
Code: PID 015161
Funding: Universitat de Lleida

Title: “Use of ICTs to increase motivation and the acquisition of knowledge about the neurophysiology of pain in students of the Degree in Physiotherapy at UCV”
Code: PID 19302
Funding: ‘Universidad Católica de Valencia

- The following projects are ongoing:

Title: “Effects on treadmill walking in a gamified virtual environment with non-invasive brain stimulation in Parkinson disease”
Code: PI20/00403
Initial date: 2021 **Ending date:** 2023 **donated:** 62.920,00 €
Funding: (health research fund [FIS]) - Carlos III Health Institute

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ANNEX I -Surveys

Informed consent

Consentimiento informado para participar en la investigación de recogida de datos biométricos:

En cumplimiento de la Ley Orgánica 15/1999 de Protección de Datos de Carácter Personal (LOPD), mediante el presente documento acepto que:

Gracias por su interés en participar en este experimento de percepción, donde se recoge actividad cerebral mediante una electroencefalografía (EEG) y un eye-tracker que permite detectar el movimiento ocular.

Si tiene alguna duda sobre este experimento consulte al asistente antes de continuar.

Antes de continuar con el experimento, debe rellenar el cuestionario que encontrará más abajo y firmar su autorización para que podamos usar en usted las herramientas que hemos comentado antes: EEG y eye-tracker.

Al firmar este formulario da su consentimiento a participar en el experimento y a que sea analizada su actividad cerebral mediante una EEG y se registre su actividad ocular.

El investigador asistente que le acompaña le debe explicar todos los detalles que necesite del experimento. Su firma también confirma que ha recibido esta información.

Si usted se siente incómodo o no se encuentra bien, se puede interrumpir el experimento en cualquier momento.

Con su firma, reconoce saber que el uso de los electrodos puede provocar algunas marcas en la cara que se desvanecen de manera natural en algunos minutos; su pelo puede quedar húmedo después del procedimiento a causa del uso de la solución salina de la EEG.

El experimento solo dura unos minutos, en cualquier caso menos de media hora.

<u>Lea detenidamente las siguientes preguntas médicas.</u>

Si la respuesta a cualquier pregunta es "sí", debe indicarlo al investigador asistente para evaluar si puede participar en este estudio.

- *¿Está tomando o ha tomado recientemente, cualquier medicamentos de venta libre?*
- *¿Existe algún motivo que impida su visión normal, con o sin corrección?*
- *¿Alguna vez ha sufrido de epilepsia?*
- *¿Ha tenido alguna cirugía en la que se haya colocado elementos metálicos en su cabeza?*
- *¿Tiene usted un marcapasos instalado?*
- *¿Utiliza algún otro dispositivo médico?*
- *¿Se ha sentido mal durante los últimos días?*
- *¿Sufre de cualquier enfermedad crónica de la piel (por ejemplo, eczema, psoriasis) ?*
- *¿Ha consumido alcohol o drogas en las últimas 24 horas?*
- *¿Actualmente tiene algún corte o abrasiones en la cabeza?*

<u>Declaración del Participante</u>

Doy mi consentimiento informado para participar en este experimento de investigación que supone una sesión de grabación de la actividad cerebral con un Electroencefalograma, la captación de mi actividad ocular y la grabación del experimento en vídeo y fotografía.

Soy consciente de que mi participación es voluntaria y que me puedo retirar en cualquier momento sin dar ninguna razón. Soy consciente de que toda la información dada por mí o los datos grabados de mí será manejada de manera confidencial.

Firma del participante ____

Fecha ____

<u>*Declaración del investigador*</u>

Creo que el participante ha sido plenamente informado sobre el experimento, sobre el procedimiento de registro de EEG al nivel necesario para que dé su consentimiento informado. He analizado todos los aspectos relevantes del procedimiento con el participante, y respondió a todas las preguntas de forma satisfactoria. He observado que el participante ha rellenado todas las secciones correspondientes de este consentimiento para participar en la grabación de EEG.

Firma Investigador ____

Fecha ____

Nombre de la institución ____

Informed consent

Consentimiento informado para participar en la investigación de recogida de datos biométricos:

En cumplimiento de la Ley Orgánica 15/1999 de Protección de Datos de Carácter Personal (LOPD), mediante el presente documento acepto que:

Gracias por su interés en participar en este experimento de percepción, donde se recoge actividad cerebral mediante una electroencefalografía (EEG) y un dispositivo de lectura de constantes vitales.

Si tiene alguna duda sobre este experimento consulte al asistente antes de continuar.

Antes de continuar con el experimento, debe rellenar el cuestionario que encontrará más abajo y firmar su autorización para que podamos usar en usted las herramientas que hemos comentado antes: EEG y pulsera de medición de constantes vitales.

Al firmar este formulario da su consentimiento a participar en el experimento y a que sea analizada su actividad cerebral mediante una EEG, se recojan sus constantes vitales y la respuesta galvánica de su piel.

El investigador asistente que le acompaña le debe explicar todos los detalles que necesite del experimento. Su firma también confirma que ha recibido esta información.

Si usted se siente incómodo o no se encuentra bien, se puede interrumpir el experimento en cualquier momento. El experimento durará lo previsto por la intervención médica de no producirse esta situación.

Con su firma, reconoce saber que el uso de los electrodos puede provocar algunas marcas en la cara que se desvanecen de manera natural en algunos minutos.

Lea detenidamente las siguientes preguntas médicas.

Si la respuesta a cualquier pregunta es "sí", debe indicarlo al investigador asistente para evaluar si puede participar en este estudio.

- *¿Está tomando o ha tomado recientemente, cualquier medicamentos de venta libre?*
- *¿Existe algún motivo que impida su visión normal, con o sin corrección?*
- *¿Alguna vez ha sufrido de epilepsia?*
- *¿Ha tenido alguna cirugía en la que se haya colocado elementos metálicos en su cabeza?*
- *¿Tiene usted un marcapasos instalado?*
- *¿Utiliza algún otro dispositivo médico?*
- *¿Se ha sentido mal durante los últimos días?*
- *¿Sufre de cualquier enfermedad crónica de la piel (por ejemplo, eczema, psoriasis) ?*
- *¿Ha consumido alcohol o drogas en las últimas 24 horas?*
- *¿Actualmente tiene algún corte o abrasiones en la cabeza?*

Declaración del Participante

Doy mi consentimiento informado para participar en este experimento de investigación que supone una sesión de grabación de la actividad cerebral con un Electroencefalograma, el registro de mis constantes vitales y la respuesta galvánica de la piel así como la grabación del experimento en vídeo y fotografía.

Soy consciente de que mi participación es voluntaria y que me puedo retirar en cualquier momento sin dar ninguna razón. Soy consciente de que toda la información dada por mí o los datos grabados de mí será manejada de manera confidencial.

Firma del participante _______________________________________

Fecha _______________________________________

<u>Declaración del investigador</u>

Creo que el participante ha sido plenamente informado sobre el experimento, sobre el procedimiento de registro de EEG al nivel necesario para que dé su consentimiento informado. He analizado todos los aspectos relevantes del procedimiento con el participante, y respondió a todas las preguntas de forma satisfactoria. He observado que el participante ha rellenado todas las secciones correspondientes de este consentimiento para participar en la grabación de EEG.

Firma Investigador _______________________________________

Fecha _______________________________________

Nombre de la institución _______________________________________

Informed consent

Consentimiento informado para participar en la investigación de recogida de datos biométricos:

En cumplimiento de la Ley Orgánica 15/1999 de Protección de Datos de Carácter Personal (LOPD), mediante el presente documento acepto que:

Gracias por su interés en participar en este experimento de percepción, donde se recoge actividad cerebral mediante una electroencefalografía (EEG),un dispositivo de lectura de constantes vitales y un eye-tracker que permite detectar el movimiento ocular.

Si tiene alguna duda sobre este experimento consulte al asistente antes de continuar.

Antes de continuar con el experimento, debe rellenar el cuestionario que encontrará más abajo y firmar su autorización para que podamos usar en usted las herramientas que hemos comentado antes: EEG, pulsera de medición de constantes vitales y eye-tracker.

Al firmar este formulario da su consentimiento a participar en el experimento y a que sea analizada su actividad cerebral mediante una EEG, se recojan sus constantes vitales y la respuesta galvánica de su piel y se registre su actividad ocular.

El investigador asistente que le acompaña le debe explicar todos los detalles que necesite del experimento. Su firma también confirma que ha recibido esta información.

Si usted se siente incómodo o no se encuentra bien, se puede interrumpir el experimento en cualquier momento.

Con su firma, reconoce saber que el uso de los electrodos puede provocar algunas marcas en la cara que se desvanecen de manera natural en algunos minutos; su pelo puede quedar húmedo después del procedimiento a causa del uso de la solución salina de la EEG.

El experimento solo dura unos minutos, en cualquier caso menos de media hora.

Lea detenidamente las siguientes preguntas médicas.

Si la respuesta a cualquier pregunta es "sí", debe indicarlo al investigador asistente para evaluar si puede participar en este estudio.

- *¿Está tomando o ha tomado recientemente, cualquier medicamentos de venta libre?*
- *¿Existe algún motivo que impida su visión normal, con o sin corrección?*
- *¿Alguna vez ha sufrido de epilepsia?*
- *¿Ha tenido alguna cirugía en la que se haya colocado elementos metálicos en su cabeza?*
- *¿Tiene usted un marcapasos instalado?*
- *¿Utiliza algún otro dispositivo médico?*
- *¿Se ha sentido mal durante los últimos días?*
- *¿Sufre de cualquier enfermedad crónica de la piel (por ejemplo, eczema, psoriasis) ?*
- *¿Ha consumido alcohol o drogas en las últimas 24 horas?*
- *¿Actualmente tiene algún corte o abrasiones en la cabeza?*

Declaración del Participante

Doy mi consentimiento informado para participar en este experimento de investigación que supone una sesión de grabación de la actividad cerebral con un Electroencefalograma, el registro de mis constantes vitales y la respuesta galvánica de la piel, la captación de mi actividad ocular y la grabación del experimento en vídeo y fotografía.

Soy consciente de que mi participación es voluntaria y que me puedo retirar en cualquier momento sin dar ninguna razón. Soy consciente de que toda la información dada por mí o los datos grabados de mí será manejada de manera confidencial.

Firma del participante ____

Fecha ____

<u>*Declaración del investigador*</u>

Creo que el participante ha sido plenamente informado sobre el experimento, sobre el procedimiento de registro de EEG al nivel necesario para que dé su consentimiento informado. He analizado todos los aspectos relevantes del procedimiento con el participante, y respondió a todas las preguntas de forma satisfactoria. He observado que el participante ha rellenado todas las secciones correspondientes de este consentimiento para participar en la grabación de EEG.

Firma Investigador ____

Fecha ____

Nombre de la institución ____

Pre-test survey

1. ¿Cuál es tu color favorito?

____

2. ¿A qué te dedicas o qué estudias?

____

3. ¿Consideras que comes saludablemente?

____

4. Si fueras director de una escuela con escasos recursos:

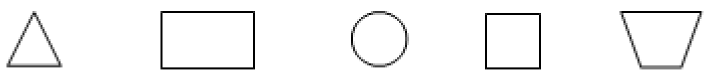
-___Centrarías tu atención y los recursos escasos en los alumnos más brillantes, asegurando que estos pocos reciban la mejor educación posible.

-___Repartirías los recursos en función de la necesidad de los alumnos, de tal manera que todos los alumnos, incluyendo los desfavorecidos o discapacitados, llegaran a un mínimo grado de escolaridad, a pesar de que eso suponga que los alumnos más dotados no exploten al máximo su potencial.

5. ¿Alguna vez has exagerado tus méritos?

____

6. ¿Qué figura te resulta más atractiva visualmente? (Marca con una X)



____ ____ ____ ____ ____

8. ¿Haces deporte? (En caso afirmativo, si lo deseas, específica)

____

9. ¿Qué utilizas más del móvil, llamadas, mensajes, o aplicaciones?

____

10. Imagina que te encuentras un billete de 20€ por la calle, y nadie te ha visto cogerlo:

-___Me quedaría el dinero.

-___Intentaría encontrar a su dueño en las proximidades para devolvérselo.

Cuestionario post-test

1. ¿Te has sentido incómodo en algún momento del experimento?

____

2. ¿Has sufrido algún tipo de dolor de cabeza o en los ojos?

____

3. ¿Te has distraído en algún momento del procedimiento?

____

3. ¿Has visto alguna marca o logo que no conoces?

En caso afirmativo intenta explicarle al asistente qué logo o marca era.

<<relación de imágines de marcas?>>

Informed consent

CONSENTIMIENTO INFORMADO

Título del Estudio: Influencia de una intervención educativa biopsicosocial en el dolor, la disfunción, y las cogniciones del dolor, en pacientes con dolor lumbar crónico en atención primaria. Un enfoque de métodos mixtos.

Investigador: Francesc Valenzuela Pascual, profesor de la Facultad de Enfermería de la UdL. Fisioterapeuta col. Nº 2703

El profesor Valenzuela es un fisioterapeuta especializado en dolor lumbar crónico, que estudia la manera en la que los pacientes perciben este dolor y cómo influye en sus vidas diarias. Los resultados de este estudio nos permitirá construir una herramienta educativa online de la que se podrán beneficiar en un futuro los pacientes con dolor lumbar crónico.

El estudio y sus procedimientos han sido aprobados por el "Comitè Ètic d'Investigació Clínica de l'IDIAP Jordi Gol". El procedimiento del estudio implica que no habrá daños previsibles. El procedimiento consiste en una entrevista personal sobre el dolor lumbar crónico del paciente que será audiograbada. La participación en el estudio va a ocuparle, aproximadamente, 90 minutos.

Su participación en el estudio es voluntaria; no tiene ninguna obligación de participar. Tiene derecho a abandonar el estudio cuando quiera.

La información del estudio será codificada para que no pueda relacionarse con usted. Su identidad no se publicará durante la realización del estudio, ni una vez haya sido publicado. Toda la información del estudio será recopilada por el profesor Valenzuela, se mantendrá en un lugar seguro y no será compartida con nadie más sin su permiso.

He leído el formulario de consentimiento y voluntariamente consiento en participar en este estudio.

____

Firma del sujeto Fecha

He explicado el estudio al individuo arriba representado y he confirmado su comprensión para el consentimiento informado.

____

Firma del investigador Fecha

La información recogida durante la investigación será totalmente confidencial. Los datos estarán identificados mediante un código, de forma que nadie pueda asociar la información a su persona. Únicamente los miembros del equipo investigador/colaboradores podrán relacionar dichos datos.

El acceso a su información personal quedará restringido al personal del estudio y colaboradores, autoridades sanitarias, al Comité Ético de Investigación Clínica y personal autorizado por el investigador, cuando lo precisen para comprobar los datos y el procedimiento del estudio, pero siempre manteniendo la confidencialidad de los mismos de acuerdo a la legislación vigente.

Compensación económica.

La financiación de dicho estudio es gestionada por el investigador principal. Su participación en el estudio no le supondrá ningún gasto. La intervención educativa es gratuita.

Por otro lado, tampoco recibirá ninguna compensación económica ya que su participación no supone ningún riesgo para su salud.

Con quien contactar.

En caso de dudas o aparecer problemas o complicaciones durante la realización del estudio puede contactar con la persona responsable de la investigación.

Francesc Valenzuela Pascual, fisioterapeuta. Col. 2703
fvp1969@dif.udl.cat 692864540

Otra información relevante.

Cualquier información que surja durante la investigación y pueda afectar a su participación, le será comunicada por el investigador lo antes posible.

El investigador podrá excluir del estudio si lo considera oportuno a los participantes que no sigan el procedimiento establecido en el estudio. En el caso de ser excluido, usted recibirá una explicación adecuada del motivo que ha ocasionado su retirada del estudio.

Al firmar la hoja de consentimiento adjunta, se compromete a cumplir con los procedimientos del estudio que se le han expuesto.

Cuando acabe su participación no podrá seguir utilizando la plataforma web utilizada en el estudio.

PARTE II: Declaración del paciente.

Declaro que he sido informado/a por el investigador principal del estudio del objetivo del presente proyecto de investigación y que la participación no implica ninguna intervención física, por lo que no se esperan efectos secundarios y/o reacciones adversas; y que sé que, en cualquier momento puedo revocar mi consentimiento.

Estoy satisfecho/a de la información recibida, he podido formular todas las preguntas que he creído conveniente y me han aclarado todas las dudas planteadas.

En consecuencia, doy mi consentimiento.

Nombre:

Apellidos:

____

Firma del sujeto Fecha

He explicado el estudio al individuo arriba representado y he confirmado su comprensión para el consentimiento informado.

CÓDIGO:

____

Firma del investigador Fecha

2nd and 3rd intervention

Informed consent

Se les invita a participar en el siguiente estudio de investigación llevado a cabo por los equipos de investigación de la Facultad de Enfermería y Fisioterapia (FIF) de la Universidad de Lleida (UdL) y Universidad Católica de Valencia (UCV).

Título del estudio: Utilización de las TIC en la mejora de la motivación y de la adquisición de conocimientos sobre la neurofisiología del dolor en los grados en fisioterapia y nutrición / fisioterapia de las facultades de enfermería y fisioterapia.

Investigadores principales: María García Escudero, Coordinadora de Innovación Docente (UCV).
Centro: Sede Torrent
C/ Ramiro de Maeztu, 14. 46900 Torrent
Telf. 963637412

Investigadores principales: Francesc Valenzuela Pascual, profesor de la FIF (UdL). Fisioterapeuta col. Nº 2703
Centro: Universitat de Lleida. Facultad de Enfermería y Fisioterapia
C/ Montserrat Roig, 2. 25198 Lleida
Telf. 973702457

Participación voluntaria

Su participación en esta investigación es totalmente voluntaria. Usted puede elegir si quiere o no participar. De aceptar participar, podrá abandonar el estudio en cualquier momento con total libertad, sin necesidad de dar una razón y sin que esta decisión pueda ocasionarle perjuicio alguno.

Descripción general del estudio

Los alumnos serán asignados al azar a los grupos (intervención y control), por lo que, hasta que no se efectúe el sorteo no sabrá a que grupo será asignado. La probabilidad de que se le asigne uno u otro es del 50%.
El objetivo de este estudio es aumentar y mejorar los conocimientos del alumnado de la FIF sobre la neurofisiología del dolor y los mecanismos de cronificación mediante la utilización de las TICs.
Si participa en el estudio deberá seguir las instrucciones que se le indiquen en la página web. Una vez usted haya consentido participar en el estudio, tendrá acceso a la página web mediante un código que se le proporcionará al inicio de la parte de "Fisioterapia en traumatología y reumatología" de la asignatura "Fisioterapia en especialidades clínicas". En el momento de acceder, aparecerá un formulario de solicitud de datos personales y una serie de cuestionarios (2) que tendrá que rellenar siguiendo las instrucciones que se le proporcionarán. Después de haber rellenado todos los cuestionarios por primera vez, aparecerá un mensaje en la pantalla donde se le explicarán los siguientes pasos a seguir.
Pueden darse dos opciones, solamente se le asignará una de ellas:
1. Se le dará acceso a la plataforma web. Este acceso tendrá una duración de 30 días. Durante este tiempo usted se compromete a leer y seguir la información y las instrucciones que aparecerán en dicha plataforma web.
2. Seguirá con las pautas de clases establecidas en su guía docente.
Independientemente del grupo al que haya sido asignado, se le pedirá que repita los cuestionarios (3) después de haber finalizado la intervención. Cada vez que deba volver a rellenar los cuestionarios, dos días antes recibirá un correo electrónico para recordárselo.

Beneficios y riesgos derivados de su participación en el estudio

Debido a que la intervención es de carácter educativo, no existe ningún riesgo derivado del estudio para usted.

Confidencialidad

Reglamento 2016/679 de la Unión Europea, de 27 de abril, relativo a la protección de las personas físicas en relación al tratamiento de sus datos personales. Ley Orgánica 3/2018, de 5 de diciembre, de protección de datos personales y garantía de los derechos digitales.

La información recogida durante la investigación será totalmente confidencial. Los datos estarán identificados mediante un código, de forma que nadie ajeno al estudio pueda asociar la información a su persona. Únicamente los miembros del equipo investigador/colaboradores podrán relacionar dichos datos.

En relación con el tratamiento de estos datos, te informamos que:

- El responsable del tratamiento de estos datos es la Universidad de Lleida - UdL (datos de contacto del representante: Secretaría General. Plaza Víctor Siurana, 1. 25003 Lleida; sg@udl.cat; datos de contacto del delegado de protección de datos: dpd@udl.cat).

2

- La UdL está legitimada para usar la información de este proyecto de innovación docente, sin necesidad de su consentimiento, como ya te informamos en el momento de la automatrícula. La UdL puede hacer uso de datos de los estudiantes con fines estadísticos o cualitativas siempre que sea compatible con los fines iniciales (innovación o mejora docente) y de evaluación, de acuerdo con el Reglamento general de protección de datos.

- La base jurídica para el tratamiento del resto de datos es el consentimiento de la persona interesada de participar en el proyecto de innovación y mejora docentes. Este consentimiento puede ser revocado en cualquier momento.

- Los datos estadísticos se conservarán durante el tiempo necesario para implementar las mejoras en la docencia que se deriven. Se destruirán en los términos y condiciones previstas en la normativa sobre conservación y eliminación de los documentos administrativos de la UdL, y las tablas de evaluación documental aprobadas por la Generalidad de Cataluña (http://www.udl.cat/ca/serveis/arxiu/).

- Puedes acceder a tus datos cuando se trate de los fines indicados; solicitar su rectificación, supresión o portabilidad; oponerte a este tratamiento, y solicitar la limitación de este tratamiento, mediante un escrito enviado a la dirección dpd@udl.cat. También puedes presentar una reclamación dirigida a la Autoridad Catalana de Protección de Datos, mediante la sede electrónica de la Autoridad (https://seu.apd.cat) o por medios no electrónicos.

Compensación económica

La financiación de dicho estudio es gestionada por el investigador principal. Su participación en el estudio no le supondrá ningún gasto. Por otro lado, tampoco recibirá ninguna compensación económica ya que su participación no supone ningún riesgo para su salud.

Con quien contactar.

En caso de dudas o aparecer problemas o complicaciones durante la realización del estudio puede contactar con la persona responsable de la investigación.

Francesc Valenzuela Pascual, fisioterapeuta. Col. 2703

fran.valenzuela@udl.cat 692864540

Otra información relevante

Cualquier información que surja durante la investigación y pueda afectar a su participación, le será comunicada por el investigador lo antes posible.

El investigador podrá excluir del estudio si lo considera oportuno a los participantes que no sigan el procedimiento establecido en el estudio. En el caso de ser excluido, usted recibirá una explicación adecuada del motivo que ha ocasionado su retirada del estudio.

Usted se compromete a cumplir con los procedimientos del estudio que se le han expuesto.

Cuando acabe su participación no podrá seguir utilizando la plataforma web utilizada en el estudio.

Permission to use IAPS

CSEA IAPS Request Confirmation

1 mensaje

CSEA <media@cseamedia.org> 28 de abril de 2015, 9:22

Responder a: media@cseamedia.org

Para: jorgesolergonzalez@gmail.com

Hello, jorge soler-gonzalez,

Your request has been received. Please read, print out, sign, scan, and email this agreement to media@cseamedia.org if you have not already done so.

IAPS Statement of Use

In accepting the IAPS materials, I agree to not to make the IAPS available to the media (television, magazines, etc.) or to place them on any internet or computer-accessible websites. I also agree not to publish the IAPS in any print format-- including JOURNALS, newspapers, etc. I also agree that I will not provide the IAPS materials to profit making companies or organizations and I agree not to distribute my username and password to unauthorized parties.

Name: jorge soler-gonzalez

Email: jorgesolergonzalez@gmail.com

Date 28/4/2015

Signature

*Important- Access to the downloads is only possible after we have received a signed and scanned copy of the IAPS Statement of Use.

Within 30 days of receiving your signed copy of the IAPS Statement of Use, you will receive a username and password, and the link to download the IAPS. This link should not be shared, distributed, or linked to from another website.

If you have any questions or concerns, please contact us at media@cseamedia.org. Please do not call the CSEA or email other members of our center with matters pertaining to the request and download of the IAPS. Thank you.

Informed consent:

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Consentimiento informado para participar en la investigación de recogida de datos biométricos:

En cumplimiento de la Ley Orgánica 15/1999 de Protección de Datos de Carácter Personal (LOPD), mediante el presente documento acepto que:

Gracias por su interés en participar en este experimento de percepción, donde se recoge actividad cerebral mediante una electroencefalografía (EEG),un dispositivo de lectura de constantes vitales y un eye-tracker que permite detectar el movimiento ocular.

Si tiene alguna duda sobre este experimento consulte al asistente antes de continuar.

Antes de continuar con el experimento, debe rellenar el cuestionario que encontrará más abajo y firmar su autorización para que podamos usar en usted las herramientas que hemos comentado antes: EEG, pulsera de medición de constantes vitales y eye-tracker.

Al firmar este formulario da su consentimiento a participar en el experimento y a que sea analizada su actividad cerebral mediante una EEG, se recojan sus constantes vitales y la respuesta galvánica de su piel y se registre su actividad ocular.

El investigador asistente que le acompaña le debe explicar todos los detalles que necesite del experimento. Su firma también confirma que ha recibido esta información.

Si usted se siente incómodo o no se encuentra bien, se puede interrumpir el experimento en cualquier momento.

Con su firma, reconoce saber que el uso de los electrodos puede provocar algunas marcas en la cara que se desvanecen de manera natural en algunos minutos; su pelo puede quedar húmedo después del procedimiento a causa del uso de la solución salina de la EEG.

El experimento solo dura unos minutos, en cualquier caso menos de media hora.

Lea detenidamente las siguientes preguntas médicas.

Si la respuesta a cualquier pregunta es "sí", debe indicarlo al investigador asistente para evaluar si puede participar en este estudio.

- *¿Está tomando o ha tomado recientemente, cualquier medicamentos de venta libres?*
- *¿Existe algún motivo que impida su visión normal, con o sin corrección?*
- *¿Alguna vez ha sufrido de epilepsia?*
- *¿Ha tenido alguna cirugía en la que se haya colocado elementos metálicos han en su cabeza?*
- *¿Tiene usted un marcapasos instalado?*
- *¿Utiliza algún otro dispositivo médico?*
- *¿Se ha sentido mal durante los últimos días?*
- *¿Sufre de cualquier enfermedad crónica de la piel (por ejemplo, eczema, soriasis) ?*

• *¿Ha consumido alcohol o drogas en las últimas 24 horas?*

• *¿Actualmente tiene algún corte o abrasiones en la cabeza?*

Declaración del Participante

Doy mi consentimiento informado para participar en este experimento de investigación que supone una sesión de grabación de la actividad cerebral con un Electroencefalograma, el registro de mis constantes vitales y la respuesta galvánica de la piel, la captación de mi actividad ocular y la grabación del experimento en video y fotografía.

Soy consciente de que mi participación es voluntaria y que me puedo retirar en cualquier momento sin dar ninguna razón. Soy consciente de que toda la información dada por mí o los datos grabados de mí será manejada de manera confidencial.

Firma del participante [redacted]

Fecha [redacted]

Declaración del investigador

Creo que el participante ha sido plenamente informado sobre el experimento, sobre el procedimiento de registro de EEG al nivel necesario para que dé su consentimiento informado. He analizado todos los aspectos relevantes del procedimiento con el participante, y respondió a todas las preguntas de forma satisfactoria. He observado que el participante ha rellenado todas las secciones correspondientes de este consentimiento para participar en la grabación de EEG.

Firma Investigador [redacted]

Fecha [redacted]

Nombre de la institución [redacted]

CEIC Approval

Institut Català de la Salut
Hospital Universitari
Arnau de Vilanova

El Comité Ético de Investigación Clínica en la reunión de 30 de septiembre de 2015, acta 9/2015, informó favorablemente la solicitud del proyecto de investigación titulado: **"Empatía médica: intervención psicoeducativa y correlaciones biométricas en estudiantes de 6º de medicina"**, con la Dra. Teresa Guilera Llados como investigadora en el Hospital Santa Maria, y consideró que:

- Se cumplen los requisitos necesarios de idoneidad del protocolo en relación a los objetivos del estudio y que están justificados los riesgos y molestias previsibles para los sujetos participantes.
- La capacitad del investigador y los medios de que dispone son apropiados para llevar a cabo el estudio.
- Es adecuado el procedimiento para obtener el consentimiento informado de los sujetos que participan en el estudio.

Lleida, 7 de octubre de 2015

Joan Antoni Schoenenberger
Presidente

Generalitat de Catalunya
Departament de Salut