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MSc Interaction Design

POSTURAL HEALTH IN MOBILE INTERACTION

AN ETHNOMETHODOLOGICAL PILOT STUDY

Master thesis

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Abstract

This study presents an investigation for user-centered design, focused on addressing postural health problems in mobile interaction. A review of the relevance of the problem is presented and the risk factors, their possible effects and other related elements are reviewed. The details of a study with an ethnomethodological approach are exposed, the stages of the study, the instruments used, and the results obtained. From this approach, it was possible to identify different elements of the participant's daily routine, not only in her interactions with the smartphone, but also with other devices and some habits of her personal and work life. Results were used in a practical exercise to generate a set of implications for user-centered design, including design opportunities and constraints.

This work aims to become a modest contribution in the continuous transition towards better design practices, exposing a pilot procedure in which a user research process was carried out focused from the beginning on identifying key elements that allow knowing opportunities and restrictions that become relevant when proposing realistic designs and in accordance with the context and user expectations.

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List of Abbreviation

HCI	Human-Computer Interaction
WHO	World Health Organization

1 INTRODUCTION

In the last 10 years the versatility of smartphones has generated a 500% increase in the annual sales of these devices (O'Dea, 2020a). Today there are more than 3.5 billion users in the world (O'Dea, 2020c), and it is estimated that 75% of them use their smartphones daily for at least 3 hours (O'Dea, 2020b). Unfortunately, this growth coincides - especially in the last 5 years - with the increase in medical consultations related to musculoskeletal problems in neck and back mainly (Ahmed, Akter, Pokhrel, & Samuel, 2019; Barrett, McKinnon, & Callaghan, 2020; Ha & Sung, 2020; Mahmoud, Hassan, Abdelmajeed, Moustafa, & Silva, 2019; Soyer & Akarirmak, 2020). Evidence indicates that about 67% of people who use a smartphone for 3 hours or more will experience this condition (D'Anna et al., 2018), health professionals name it Text Neck Syndrome or Forward Head Posture (Gupta, Arora, & Gupta, 2013; Thiyagarajan & Telegbal, 2015; Yeom, Lim, Yoo, & Lee, 2014).

Scientific and academic literature on this topic is extensive, recent, and shows a growing concern. The understanding of the problem seems adequate in terms of medical and biomechanical considerations (Eitivipart, Viriyarojanakul, & Redhead, 2018; Khalaf et al., 2020; Mosaad, Abdel-aziem, Mohamed, Abd-Elaty, & Mohammed, 2020), and some authors have analyzed the variations of bad postures when users use their smartphones in different scenarios (Han, Gwon, Kim, & Shin, 2018; Yoon, Choi, Han, & Shin, 2020). Regarding the proposed interventions, there is an interesting variety of approaches: several developments proposed in academic articles and patents are focused on detecting bad posture and triggering an alert (Elnaffar & El Allam, 2018; Giansanti, Colombaretti, Simeoni, & Maccioni, 2019; Worawat Lawanont, Inoue, Mongkolnam, & Nukoolkit, 2018; H. Lee, 2015; J. Lee, Chee, Bae, Kim, & Kim, 2016; Toda, Nakai, & Liu, 2015; Tothong, 2017; Yeom et al., 2014; Zindahi, Rashmi, Karthik, & Kumar, 2020); others are aimed at promoting exercises and accessories to relax or strengthen the muscles of the neck and back (Arif, 2016; Crossland, 2016; Katz, 2009; Soyer & Akarirmak, 2020; Velame, 2019; Watson & Watson, 2015); and some are focused on proposing a different model of interaction between users and smartphones (Kunze et al., 2015; Liao, 2017; Moberg & Pettersson, 2017; Moeller, 2019; Starner, 2013). It can be noted that for this work not only physical or technological artifacts are understood as interventions, but also the strategies that can help preventing or meeting postural health problems in interaction mobile, even if indirectly.

Without a doubt it is very important to identify and understand that the inappropriate use of smartphones represents a health problem. In this sense, the medical literature is very useful, however it is not enough to avoid the problem. On the other hand, most of the proposed interventions totally evade the relevance of the interaction between the user and the smartphone, and very few approaches that try to modify this interaction to solve the problem are based on conducting user research prior to proposing a design, in which the needs, expectations and wishes of the users have been studied. Because the smartphone has become an object of massive and frequent use (Abbott, 2020; Brown, 2019; Deloitte, 2019), any problem related to the interaction with it requires an approach centered on the users and their daily life. This means that it is not enough to develop interventions that may or may not work, but it is necessary to understand that people's interactions with products can be optimized according to the real use context, in which users have strengths and weaknesses, and they have developed a certain way of doing things (Preece, Sharp, & Rogers, 2015). A gap in existing work can then be noted, as people have not been effectively involved in the design process.

Since in recent years the usefulness of smartphones has captivated users of all ages (Johnson, 2020), the prevalence of musculoskeletal problems in neck and back due to prolonged use of these devices no longer discriminates by age. However, this study focuses on professional mid-adult workers who distribute their time of smartphone use between study, work and entertainment activities, so that a contribution can be made on how to include users in the process of designing a solution that aims to improve behavior and habit. Excluding children and older adults from the study is only a logistical convenience, to minimize the requirements and responsibilities with the use of data, but all the results obtained will surely be useful for decision-making in subsequent studies on the same topic, even if they are focused on children and the elderly.

1.1 RESEARCH PROBLEM

The smartphone has become indispensable tool for many people in the world, there is no doubt about its usefulness, and it is becoming more evident every day. However, it is clear that bad habits of use are generating a worrying prevalence of musculoskeletal problems in users and the proposed interventions do not seem to be enough to counteract them, probably due to the limited user research that supports them. The research problem is the clear lack of user involvement in the design of interventions aimed at minimizing the probability of experiencing postural health problems when interacting with mobile devices, which reduces the probability that these interventions will match users' needs and requirements and will be successfully taken up by users in their everyday routines.

1.2 GOALS

The intent of this study is to present a set of implications for design of interventions that minimize the impact of risk factors on postural health in mobile interaction. Such implications will be based on the findings from user research that will focus on identifying different elements of interest, not only in the user-smartphone interaction, but also in the behavior and daily routine of the user. To achieve this, an ethnomethodological study will be carried out.

1.3 RESEARCH QUESTION

Based on initial observations and a preliminary view at the state of the art related to postural health in mobile interaction, the following research questions that will guide this study have emerged:

- Which risk factors have been identified in literature related to postural health in mobile interaction?
- What are the effects of these risk factors?
- When do risk factors trigger postural health problems in mobile interaction? (time dimension)
- In what circumstances do risk factors trigger postural health problems in mobile interaction? (contextual dimension)
- What kinds of interventions for minimizing the impact of the risk factors on postural health in mobile interactions have been proposed in literature?
- What kinds of interventions are perceived as effective by the users?

1.4 RESEARCH METHODS

A mixed research methods approach will be carried out in which a semi-structured questionnaire will first be deployed to recognize user preferences and knowledge. Based on this information, and in agreement with the user, a diary study will be designed to follow her daily routine. The diary will be complemented with non-invasive photographs (as a partial strategy of *shadowing study*), an interaction log collected from the devices being used during the study and at the end, using all this information, a retrospective interview will be carried out with the user to collect her own impressions and reflections of the data that has been collected in the study. The analysis of the complete data set and the conclusions that arise from there will be relevant for the subsequent formulation of a set of implications for design of possible and realistic user-centered interventions, interaction design concepts or prototype specifications. *Table 1* links the research questions with the methods and the foreseen outcomes, the latter will be better described in the next section.

1.5 FORESEEN OUTCOMES

Reaching the goal proposed for this study implies dividing it into stages, research questions and methods that will contribute to the final result. In this sense, the expected outputs for each task are defined.

First, a review of the literature will provide relevant information about the risk factors associated with postural health problems in mobile interaction, as well as a look at the interventions that have been proposed to solve this problem. The intention is to improve the understanding of the problem space with the data and conclusions obtained by authors from health areas and review the strengths and weaknesses of the proposed solutions.

Data collection instruments will then be designed and implemented to obtain information from a user of smartphone. At this stage it is expected to identify the context of the user and answer some questions about what she says, thinks, does, uses, knows and feels. As it is not easy to obtain these answers in a single turn, it is necessary to have quantitative instruments (questionnaire, interaction log), qualitative (semi-structured interview) and mixed (diary study).

Finally, based on the data collected and analyzed, a set of implications for design of interventions to address or prevent postural health problems in mobile interaction will be presented. Rather than pretending that such implications become a perfect or definitive roadmap, the aim is to expose a process in which the user is the center of research and design in such a way that it can serve as an example for subsequent studies.

Table 1 Research process

Research Question	Research Method	Expected Outcomes
Which risk factors have been identified in literature related to postural health in mobile interaction?	Literature review	Risk factors identified by authors in areas of health, biomechanics, ergonomics, etc.
What are the effects of these risk factors?	Literature review, Interview	Consequences of insufficient treatment on risk factors.
When do risk factors trigger postural health problems in mobile interaction? (time dimension)	Literature review, Interaction logging, Diary study	Occurrence of adverse effects facilitated by risk factors in the time dimension.
In what circumstances do risk factors trigger postural health problems in mobile interaction? (contextual dimension)	Literature review, Diary study	Context in which risk factors occur.
What kinds of interventions for minimizing the impact of the risk factors on postural health in mobile interactions have been proposed in literature?	Literature review	Solutions proposed by other authors.
What kinds of interventions are perceived as effective by the users?	Literature review	Users' opinions on the proposed solutions.

1.6 CONTRIBUTION

After preliminary observations made evident the scarcity of user research in the intervention design processes around postural health problems generated by bad habits in the use of the smartphone, and the consequent low impact that they have generated in this regard, this work aims to become a modest contribution in the continuous transition towards better design practices, exposing a pilot procedure in which a user research process was carried out focused from the beginning on identifying key elements that allow knowing opportunities and restrictions that become relevant when proposing realistic designs and in accordance with the context and user expectations.

A circumstantial contribution, but no less important, has to do with the conditions under which this study was developed in a pandemic scenario, with many social restrictions and limited resources. This work can be seen as an example of taking advantage of the circumstances, because it could be adapted to a very particular and interesting spatial and temporal context, without losing the seriousness neither in terms of the use of the instruments nor the analysis of the data, and demonstrating that creativity is the best tool to counteract the adverse effects of the difficulties that a study like this may face.

2 THEORETICAL FRAMEWORK

Addressing postural health problems in mobile interaction requires the inspection of a set of fundamental concepts from different theoretical frameworks. This study is mainly carried out under the perspectives of Ergonomics and Ethnomethodology. These frameworks seek to cover the elements related to user-smartphone interaction: the user's body and cognition and the context of everyday user-smartphone interactions.

2.1 ERGONOMICS

As the interest of this work is focused on minimizing the adverse effects of mobile interaction on postural health while maintaining the usefulness and versatility of the mobile device, ergonomics and human factors are a highly relevant framework, not only because of their close relationship with HCI, but because it is concerned with understanding the interactions between humans and artifacts in order to maximize human well-being while optimizing the performance of systems (Preece et al., 2015).

An ergonomic approach helps designers increase their awareness of the full scope of knowledge required when designing consumer products and plays an important role in facilitating better performance of consumer products overall. Ergonomics-based product design encompasses a wide variety of consumer references and considers differences in these preferences due to factors such as age, gender, or health issues (Karwowski, Soares, & Stanton, 2011b). Through ergonomics, critical product characteristics such as ease of use, learning, efficiency, comfort, safety and adaptability can be improved, all of which meet user needs and contribute to user satisfaction (Karwowski, Soares, & Stanton, 2011a).

Consistent with the purpose of this work, the domain of ergonomics includes, among others, the human capabilities and limitations, and human-machine interactions (Stanton, Hedge, Brookhuis, Salas, & Hendrick, 2005), which can be used to observe, analyze, and interpret the requirements of the product to create diagnostics and applications which will be used to create health and safety conditions in several contexts (Sáenz, 2005, as cited in Karwowski et al., 2011a).

2.1.1 INJURY RISKS

Many musculoskeletal injuries begin when a user experiences discomfort. If it is ignored, the risk factors contributing to the discomfort will eventually lead to an increase in the severity of symptoms, and what started out as mild discomfort will gradually become more intense and experienced as pain. If left unchecked, pain that indicates some cumulative trauma can eventually result in musculoskeletal injury, such as tendinitis, tenosynovitis, or severe syndromes. Reducing the levels of discomfort decreases the risk of injury occurrence. That is, the levels of discomfort and pain can be used as indicators to measure the success of a product's design (Stanton et al., 2005).

In consumer products - such as smartphones - the user's behavior in front of risks is directly related to the adverse effects that himself may suffer, that is, the user who omits or underestimates the risks of using a smartphone will be the one most likely to make wrong decisions, which can lead to unsafe behavior and more human errors (Rundmo, 2001). Poor risk estimation can be based on ineffective product design, for example when physical characteristics and warnings are not enough to perceive risk. However, when performing routine tasks - as happens with smartphones - it is possible that users do not worry about risks, do not even think about them and consequently the adverse effects may not be attributable to a poor perception of risk (Wagenaar, 1992).

For consumer products the risk of injury is represented as a relationship between an injury rate and a measure of exposure (Weegels & Kanis, 2000), however, to develop safe consumer products, it is essential that designers also recognize the complexity of users, because even if they could calculate risk, it is their subjective perceptions that motivate the behavior (Mitchell, 1999). This does not mean that probabilities are not important, but rather indicates that there are many other subjective factors, beyond the objective measures associated with risk, that are also important for the conceptualization of risk and user behavior. Any consideration of risk in the design process must necessarily incorporate probability and consequence (Bernstein, 1998), that is, the different ways in which risk is conceptualized, as a synonym for danger (subjective risk) or as a statistical value (objective risk) (Oppe, 1988).

2.1.2 RISK MITIGATION

The challenge for consumer product designers is to keep a balance between exposing the user to the lowest possible risk, without depriving them of the best product features (Hecht, 2003). However, there are products that necessarily have risky elements due to their function or purpose and eliminating them is not an option, on the contrary, users must be fully aware to accept the risk, know it and learn to live with it. An excessive intention to eliminate a risk can become counterproductive because, according to Cross (1998, as cited in Williams & Noyes, 2011), it is inevitable that the control of one risk increases the probability of occurrence or the magnitude of the effect of another, this is what is known as risk transference, that is, risk management has a high probability of leading to a redistribution of risk, as in the following cases:

- Alternative solution: The user changes a product with a set of risks A, for another product with a set of risks B.
- Lost benefit: The user prefers not to enjoy an advantage of a product, because that same product represents a risk in another aspect.
- Remediation effort: The management of risk A maximizes risk B.

So, while efforts can be made to reduce risk to users, it is possible that security measures act simply to redistribute risk (Keeney, 1995). Evidence suggests that individuals accept a predetermined level of risk, and when faced with a lower or greater risk they act in such a way as to maintain that predetermined level. A potential consequence of this redistribution of risk is that the effect of any security measure can be nullified (Weegels & Kanis, 2000). Pelzman (1975, as cited in Williams & Noyes, 2011) suggested that when the risks associated with a certain behavior decrease, individuals compensate by assuming greater risks through another behavior.

Eliminating or mitigating a risk is not always possible, even sometimes it is not feasible since it could mean a reduction in the functionality of the product, that is one of the reasons why warning systems are frequently used to notify the users when they are exposed to a potential risk (Lesch, 2005). Although the warnings are important, necessary and easy to implement, it is pertinent to remember that they are only contingency elements to reduce the probability of an adverse effect, but they cannot be assumed as the solution for a poor design (Wogalter, 2006b), that is, risky product defects should be addressed from the design basis to mitigate risk as much as possible and keep the warnings only as a supplement.

2.1.3 WARNINGS

When there is a need for a warning, the product designer must determine the most effective way to get it to the user, selecting the most appropriate channel and the most convenient features to generate the desired effect. The purpose and content of an alert system are not necessarily identical in all cases. For example, some components may be designed with the purpose of capturing attention and directing the user to another component that contains more information for understanding or to affect beliefs and attitudes, or they may be intended for different target audiences (Wogalter, Laughery, & Mayhorn, 2011). If a user does not notice or initially heed a warning, then the warning processing does not go any further. However, even if a warning is noted and heeded, the individual may not understand it, and therefore, no further processing occurs beyond that point. Even if the message is understood, it may not be believed, causing a crash at this point. If the person believes the message, a low motivation (to carry out the behavior indicated in the warning) could cause a block. If all stages are successful, the warning process ends in safety behavior attributable to the warning information (Conzola & Wogalter, 2001). While warning processing may not go all the way to the behavioral compliance stage, it can still be effective at earlier stages. For example, a warning can improve understanding and beliefs, but not change behavior (Wogalter et al., 2011).

When referring to the channel of the warning, it implies two fundamental dimensions: the first refers to the media in which the information is included, for example a label or a video, while the second dimension is the sensory modality of the receiver, normally visual, auditory or tactile (Cohen, Cohen, Mendat, & Wogalter, 2006). On the other hand, the receiver is the user who the warning is directed to. For a warning to effectively communicate information and influence user behavior, the warning must first be delivered (Wogalter, 2006a). Then the focus must be shifted and maintained long enough for the receiver to extract the necessary information. The warning must then be understood and must match the existing beliefs and attitudes of the receiver. Finally, the warning should motivate the receiver to engage in the targeted behavior.

Multimodal warnings are generally more effective than single mode warnings because they provide redundancy. If an individual is not looking at a visual warning, he/she can still hear it (Wogalter & Young, 1991). If the individual is blind or deaf, the information is available in both modalities. Also, if a person sees and hears warning information, there is a greater chance that the message will be delivered to receivers that would otherwise be unreachable.

Shorter and less complex messages presented audibly can be more effective than the same messages presented visually. Presenting an auditory cue is generally better for shifting attention (Wogalter et al., 2011). One implication of this analysis is that a short aural warning, pointing to more detailed information, would be beneficial in attracting attention, as well as allowing longer and more complex information processing.

As the first function of a warning is to attract the attention of the user, it must be sufficiently prominent to be able to compete with other stimuli in the environment, so the more intense the warning, the more effective it will be for that purpose. The context also plays an important role because it is not only the absolute size of the warning, but also its magnitude in relation to the rest of the information that the user receives at a specific moment (David Leonard & Wogalter, 1999). However, prolonged and repeated exposure to a warning can result in the loss of its ability to evoke the user's attention (Thorley, Hellier & Edworthy, 2001, as cited in Wogalter et al., 2011), as it generates an effect similar to "Cry wolf". This habituation process can occur even with well-designed warnings. When possible, changing the appearance of the warning can be helpful in revitalizing the attention switch that was previously missed due to habituation.

2.1.4 Attention and Awareness

A warning should generate an immediate change in the user's level of awareness, either by reminding information that is already in their memory, by activating their instinct for safety, or by inviting them to action. In this sense, a well-designed warning should expose a security problem, invite the user to follow instructions or inform him of the consequences that could result if he does not change his behavior (Wogalter et al., 2011).

At the other end of the channel is the quality of attention of the receiving user. The warning may be well designed and have good characteristics, but it will be insufficient if the user does not have the ability or intention to understand what is being warned, either due to a high level of distraction, a conscious decision to ignore the perception or by an inability to maintain concentration on external stimuli (Mehling et al., 2012). In most cases, all these shortcomings can be overcome through adequate preparation in the active processes of paying attention, which is nothing more than one of the dimensions of body awareness when judging and analyzing sensory information for the purpose of filtering and amplifying those signals that are of priority interest for personal well-being.

The quality of attention is closely related to situation awareness, which can be defined as the perception of the elements within an interval of time and space, the understanding of their meaning and the projection of their state in the near future (Endsley, 1995, as cited in Jones & Kaber, 2004). This means that a sensory activation through a stimulus is not enough, but a cognitive activity of reasoning about such stimuli and of prognosis about the consequences of attending or not attending such reasoning is also involved. It can be noted that the definition of situation awareness does not refer to external or internal elements or stimuli, this is so because it does not discriminate them and transcends beyond the senses that can be stimulated from the outside, including also the body awareness, that is defined as the perception of states, processes and bodily actions that originate from internal stimuli that generate proprioceptive sensations (feeling the relative position of the body segments) and interoceptive sensations (sensations that come from the internal organs of the human body) (Mehling et al., 2009) and that many times they can be subjective indicators of pleasure, relaxation, discomfort or pain.

One of the great challenges for designers is to measure, train and stimulate the level of body awareness in users who are exposed to situations that affect their well-being. Making risks evident through warnings is a valid but insufficient strategy in situations in which the user prioritizes the utility or pleasure that a product provides. In the case of mobile interaction, it seems necessary and almost urgent to accompany the warning systems with alternative interaction models that minimize the adverse effects on postural health.

2.2 Ethnomethodology

The literature reviewed during this work showed that there are many gaps in the methodologies for designing solutions to meet or prevent postural health problems in mobile interaction. With few exceptions, the interventions reviewed do not conduct an effective user research or adequate identification and argumentation of design requirements and implications before prototyping solutions. From this finding, it became clear that this work should contribute in this regard, proposing a strategy for integrating the user in the research and design process. With that purpose, the aim is to study the daily life of the user and the interactions in his/her real environment, and since the smartphone today is an artifact of massive, frequent and almost essential use for many users, a research with an ethnomethodological approach emerges as a good option.

Ethnomethodology is not considered in itself as a theory but as an approach that can be adopted within HCI, in fact, it arose in this framework as a reaction against conventional cognitive theories (Rogers, 2012). Garfinkel is recognized as the first reference of ethnomethodology in sociology, and he referred to it as the treatment of practical activities and circumstances as subjects of empirical study, paying more attention to the most common activities of daily life than to extraordinary events, because it is in those daily and common details that learning about the real context and the interactions of people can be achieved (Garfinkel, 1967).

The fundamental hypothesis is that in daily activities there is a rich substrate of information that is normally neglected because it is not very remarkable, but that by making it visible allows knowing relevant details of the context and routine of a user, mainly of his/her domestic and work interactions (Crabtree & Tolmie, 2016; Garfinkel, 1964). Unlike theoretical approaches that claim to reveal the unknown, ethnomethodology says the kinds of things that people cannot disagree with, because it reminds them of things that they already know and recognize as normal and ordinary. Instead, the theory aspires to novelty, to suggest that phenomena are actually different from how people experience them, that is, people's experiences are ignored (Randall, Rouncefield, & Tolmie, 2020).

Observing what people do, places, circumstances and mainly their reasons not only works to overcome a certain indifference to other methodologies, but also helps to develop empathy towards the participants under study, since there is a concern to recognize their meanings, their courses of action (Randall et al., 2020) and some mental models, which may be unique or totally coinciding with the majority, but which in the end may become important in the development of generative tools (Sanders & Stappers, 2013), because finally it is people who shape their actions, rather than their actions being shaped by the environment (Rogers, 2012). In that sense, Crabtree & Tolmie (2016) mention the need to understand the "machinery of interaction", in such a way that those things that had not been studied, because they are considered as simple environments or ordinary contexts, become elements that help to define the implications of the design (Rogers, 2012).

3 LITERATURE REVIEW

A review of literature about postural health problems associated with smartphone use is presented. First, a brief description about the search and selection process of material will be offered, then an overview of the main issues - risk factors and interventions - is presented and supported by relevant works by other authors.

3.1 PROCEDURE

As it is a problem generated by technology that has been developed in the last twenty years, the available literature coincides with that period and shows an increase in publications from 2014, which offers a clue about the period of time that should be consulted. The first decision made in this regard had to do with the answers that the literature review should offer, and according to the research questions posed for this work, this review focused on first identifying the risk factors for health postural in mobile interaction, the moments in which these factors happen, the circumstances that surround them, the effects and the prevalence. Afterwards, the focus shifted to the interventions proposed so far to prevent, minimize or control risk factors and their effects, and finally to the users' perception of such interventions. In this way, two search trends emerged: risk factors and interventions.

3.1.1 PILOT STUDY

Before formally starting the search of material for this review, a pilot was carried out to help to improve the search strategy. Because Scopus allows exploring titles, keywords, abstracts, and other data that facilitate basic analysis, this search engine was chosen to run the pilot. The first step was to refine the search strings, and after several iterations using words related to smartphones, postural health, symptoms, sensors, etc., a set of strings that presented relevant results were reached.

- **Risk factors**: (*smartphone* OR *mobile*) AND (*posture* OR *musculoskeletal*) AND (*pain* OR *complaint* OR *symptom* OR "*risk factor*")

- **Interventions**: (*smartphone* OR *mobile*) AND (*posture* OR *musculoskeletal*) AND (*monitor* OR *tracking* OR *alert* OR *sensor* OR *wearable* OR *support*)

From a quick look at the results offered by these search strings, it was determined that the works published between 2016 and 2021 are consistent with the purpose of this work. In addition, it was possible to identify the most relevant databases for the search: ScienceDirect, SpringerLink, ACM, IEEE, Taylor & Francis and MDPI.

The outcome obtained with the pilot is the first version of a data extraction form fed with the information of 8 papers (4 for each search string). The basic data that make up the form are title, authors, DOI, year of publication and keywords. In addition, it includes the necessary fields to record the contributions offered by each paper to answer the research questions: risk factors, occurrence, circumstances, effects and prevalence, proposed interventions and users' perception. Filling out this form demonstrated that the search strategy was mature enough to begin a formal exploration stage.

3.1.2 KEYWORD SEARCH

Once the search strings were established, a time interval was defined and the most relevant databases were identified, the search was performed based on the keywords. The search string for “risk factors” showed in total - in the 6 selected databases - 19466 results, while the search string for “interventions” showed 25230 results. The main difficulty that arose in this task was related to the differences in the search fields and in the way of managing the search strings in each database. In all cases, an attempt was made to keep the search strategy as similar as possible to the pilot.

Due to the large number offered in the first iteration, an organization based on relevance was chosen and the first 100 results of each database were reviewed, that is, 600 results for each search string. As the first exclusion criterion for this group of publications, all those that were not written in English and those whose full access was not available from the subscription of the Cyprus University of Technology were discarded. The first inclusion criterion was based on finding some relationship between the research questions and the titles, keywords and some abstracts, which allowed selecting 57 publications for the search string of “risk factors”, and 46 for “interventions”.

With 103 pre-selected publications, it was much easier to read all the abstracts and some conclusions to rank the apparent relevance of each one to answer the research questions. From these sections, each paper was awarded a grade between 0 and 5 according to the following scale:

0. Neither the abstract nor the conclusions mention concepts related to risk factors or interventions.
1. Abstract or conclusions mention some concept related to risk factors or interventions, but they are irrelevant to this work.
2. Abstract or conclusions mention some concept related to risk factors or interventions, but they are of little relevance to this work.
3. Abstract or conclusions mention concepts related to risk factors or interventions and could be relevant to this work.
4. Abstract or conclusions mention concepts related to risk factors or interventions and are relevant to this work.
5. Abstract and conclusions mention concepts related to risk factors or interventions and are very relevant to this work.

In the end, those whose grade was equal to or greater than 4 were selected. With this iteration the search based on keywords was completed and 13 papers were obtained for the “risk factors” and 10 for “interventions”. All of them were included in the final data extraction form.

3.1.3 Backward Search

The 23 papers selected in the keyword search were used to perform a backward search, that is, those publications that were cited in those 23 papers. This type of search is used to find out the origin of trends and to identify those papers that have been most relevant and cited on the subject. Keeping the same inclusion and exclusion criteria than the keyword search, in the first iteration of this search, 14 results were obtained for “risk factors” and 18 for “interventions”.

Similarly, all the abstracts and some conclusions of these 32 preselected works were reviewed, each work was given a grade between 0 and 5, and in the end those whose grade was equal to or greater than 4 were selected. With this iteration, the backward search was completed, then 5 papers were obtained for "risk factors" and 7 for "interventions". All of them were included in the final data extraction form.

3.1.4 FORWARD SEARCH

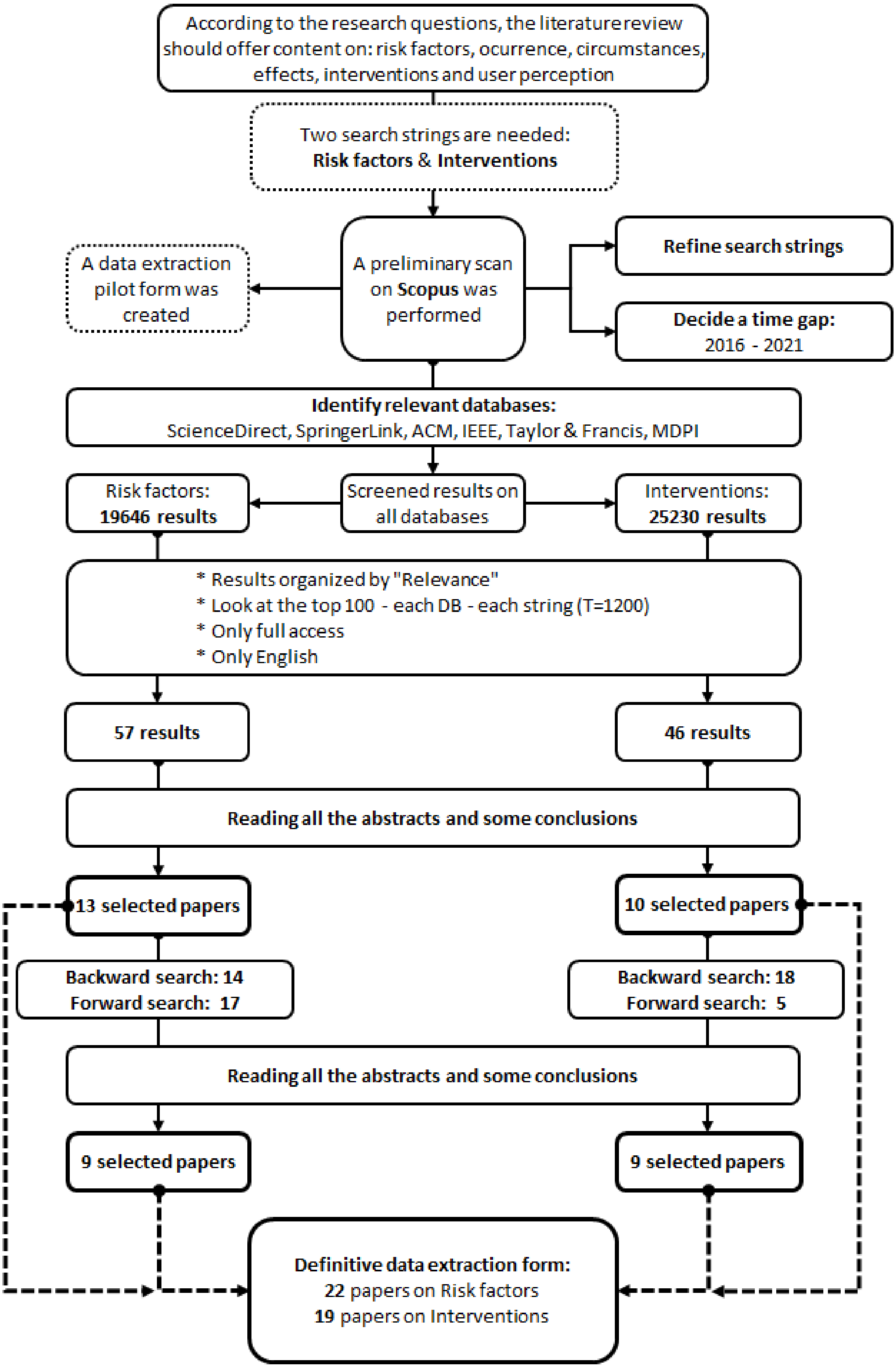
The 23 papers selected in the keyword search were also used to perform a forward search, that is, those publications that have cited any of those 23 papers. This type of search serves to reaffirm the relevance of the results based on the keywords and, since in this exploration the results will be more recent, to identify the trends that have developed in the subject. Keeping the same inclusion and exclusion criteria from the keyword search, in the first iteration of this search, 17 results were obtained for "risk factors" and 5 for "interventions".

Likewise, all the abstracts and some conclusions of those 22 preselected papers were reviewed, each work was awarded a grade between 0 and 5, and in the end those whose grade was equal to or greater than 4 were selected. With this iteration, the forward search was completed, then 4 papers were obtained for "risk factors" and 2 for "interventions". All of them were included in the final data extraction form.

3.2 THE CORPUS

The process of search and selection of material finally yielded a corpus for the writing of the following literature review. In total, 22 papers will be used as references in the categories related to "risk factors", while 19 papers will support the categories related to "interventions". From 41 publications, the definitive data extraction form has been filled out, which will facilitate access to information during the composition of the literature review. *Figure 1* presents a diagram that summarizes the material search and selection process.

Figure 1 Material search and selection process



3.3 FINDINGS

3.3.1 RISK FACTORS

The massification of smartphone use in recent years has coincided with the increase in cases of musculoskeletal discomfort in people who use them (Ahmed et al., 2019; Barrett et al., 2020; Ha & Sung, 2020; Mahmoud et al., 2019; Soyer & Akarirmak, 2020). Due to that, many researchers in areas of health, biomechanics and ergonomics have been interested in identifying the risk factors that increase the probability of suffering discomforts or pathologies associated with mobile interaction. The set of risk factors identified and studied is broad, however, there are some that are much more frequent in the papers and have been the subject of more in-depth studies such as the time of use, the posture during use and the tasks that are made on the smartphone. On the other hand, there are also some risk factors that have not been so studied or, when they have been studied, they have usually been in the background, as has happened with rest and anatomical supports, in both cases related to the absence or the deficiency of these, but when reviewing the set of studies, it can be inferred that their relevance is not less.

3.3.1.1 USAGE TIME

The usage time of smartphones is the risk factor most studied in the available literature, mainly from two points of view: the total time of daily use and the periods of continuous use. While time of use of smartphones has increased in recent years in all age ranges (Johnson, 2020), some studies have reported the average times of use of their participants: about 4 hours (Berolo, Wells, & Amick, 2011), 6 hours (Tapanya, Puntumetakul, Swangnetr Neubert, & Boucaut, 2021; Toh et al., 2020), 8 and 12 hours (Roslizawati & Isyan Farahin, 2021), the last related to cases of smartphone addiction. One of the elements that aggravates the abuse of smartphone use time is the low level of awareness on the possible adverse consequences of this behavior (Woo, White, & Lai, 2016) and the difficulty of training and improving that level of awareness (Liao, 2017).

There are many authors who assure that there is a direct correlation between the number of hours of daily use and the probability of suffering some musculoskeletal discomfort associated with mobile interaction, even Toh et al. (2019) mention that each hour of daily use of the smartphone makes that probability increase by up to 7%. The literature does not show a strong agreement between the authors on a threshold for daily use of the smartphone, but all the studies that mention a time border between a state without discomfort and another with discomfort mention times greater than 1 hour of daily use (Toh et al., 2020; Yang, Chen, Huang, Lin, & Chang, 2017), the highest threshold reported is 6 hours (Tapanya et al., 2021), and other intermediate or nonspecific values (Berolo et al., 2011; Bootsman, Markopoulos, Qi, Wang, & Timmermans, 2019; Cevik, Kaplan, & Katar, 2020; Worawat Lawanont et al., 2018; Nguyen, Dang, Suh, & Chee, 2017; Sahu, Gnana Sundari, & David, 2021; Soyer & Akarirmak, 2020; Toh et al., 2019; Toh, Coenen, Howie, & Straker, 2017; Xie, Szeto, & Dai, 2017; Zirek, Mustafaoglu, Yasaci, & Griffiths, 2020).

There is also no agreement on the duration of the period of continuous use that could signify a border between a relaxed state and another of fatigue, the number of minutes is variable from one study to another. However, those who have studied this aspect usually mention periods longer than 10 minutes (Kim & Koo, 2016; Thorburn, Pope, & Wang, 2021; Toh et al., 2017; Woo et al., 2016).

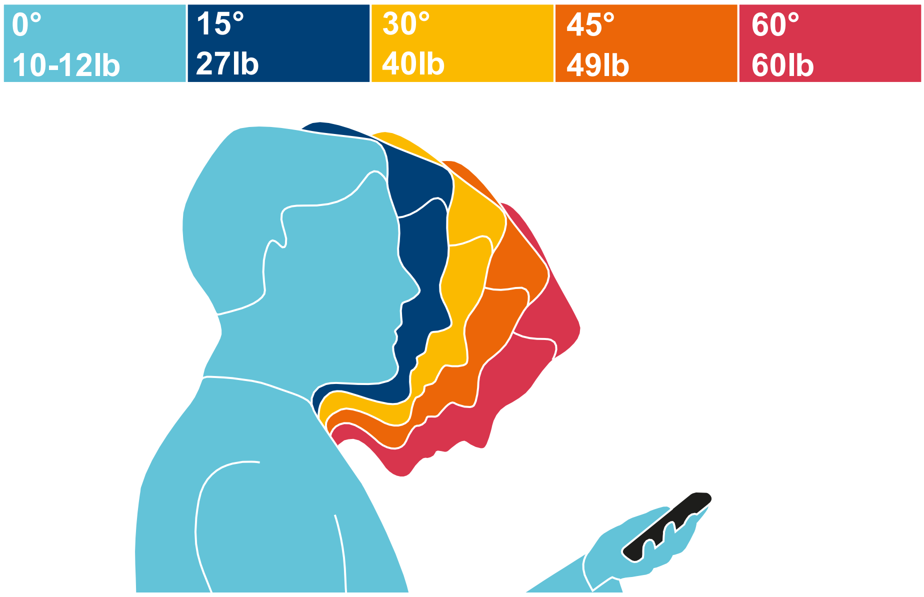
For more details about the specific times reported in different studies see the *Occurrence* section.

3.3.1.2 Posture

The posture that the user adopts while using the smartphone is another widely studied risk factor, mainly due to the postures of the head, neck and upper back, which turn out to be especially vulnerable to discomforts associated with mobile interaction, due to the fact that the load on the structure of the neck increases significantly with the angle of inclination of the head (Kataria, 2018; Ramnaath, Sudharsan, Sanjay Yadhav, Bhanu Priya, & Subramaniyam, 2020; Tapanya et al., 2021; Zindahi et al., 2020), particularly Kataria (2018) mentions a 600% increase when going from 0° to 60° (10lb - 60lb) as seen in *Figure 2*, while Ramnaath et al. (2020) mention an increase of 1400% in the same transition (6.32Kg - 89.19Kg).

Head flexion has been the object of study in many papers as one of the prevalent elements in those users who report musculoskeletal discomforts and pains associated with the use of the smartphone (Worawat Lawanont et al., 2018; S. Lee, Kang, & Shin, 2015; Soyer & Akarirmak, 2020; Syamala, Ailneni, Kim, & Hwang, 2018; Tapanya et al., 2021; Toh et al., 2017; Yoon et al., 2020). Some works mention a dilemma between flexing the head to look down at the smartphone screen versus using the upper limbs to bring the smartphone to eye level (Syamala et al., 2018; Toh et al., 2017). The second option reduces the load on the neck structure but increases the muscle load in all segments of the arms, generating discomforts and pains.

Figure 2 Force on the neck structure according to the inclination angle as stated by Kataria (2018)



Note: *Adapted from Khaleeli (2014).*

Another element recurrently reported in the literature associated with postural errors refers to the static and sometimes asymmetric load on the muscles involved in mobile interaction (Kim & Koo, 2016; M. Lee et al., 2015; Tang et al., 2021; Toh et al., 2017; Xie et al., 2017). Kim & Koo (2016) state that an unvarying posture and continuous muscle contraction bring muscle weakness and fatigue that could develop into chronic pain. It is a situation that is noticeably worsened by prolonged use of the smartphone, low level of awareness and lack of position changes.

Finally, related to the position of the smartphone user, there are many more papers that ensure that there is a direct relationship between discomfort and pain with use during sitting (S. Lee et al., 2015; Soyer & Akarirmak, 2020; Syamala et al., 2018; Thorburn et al., 2021; Toh et al., 2017; Yoon et al., 2020) than standing (E. Gustafsson, Johnson, & Hagberg, 2010) or walking (Tapanya et al., 2021). Observations agree that when sitting, head flexion is greater, especially when the chair does not have an armrest or when the smartphone is placed on the lap.

3.3.1.3 TASKS

The tasks that users perform from their smartphones have also been studied within the framework of risk factors in mobile interaction. Betsch et al. (2021) classify tasks as active or passive according to the demand for interaction between the user and the device, watching videos and listening to music for example are usually passive tasks, while texting and gaming are active tasks. These authors state that the second group of tasks poses a greater risk to postural health.

Most studies agree that typing or texting is the most common interaction in applications (Betsch et al., 2021; S. Lee et al., 2015; Soyer & Akarirmak, 2020; Tapanya et al., 2021; Toh et al., 2017; Xie et al., 2017; Yang et al., 2017; Yoon et al., 2020; Zindahi et al., 2020), promoted especially by social networks, and it is an action that generates such a muscle demand that it can cause pain and discomfort in many body segments: head, neck, back, shoulders, elbow, wrists, hands and thumbs. Gaming is the other activity widely associated with musculoskeletal symptoms, due to repetitive movements, deep immersion, and time spent (Berolo et al., 2011; Soyer & Akarirmak, 2020; Toh et al., 2020, 2017; Xie et al., 2017). Other tasks reported with less relevance in the papers as risk factors are phone calls (Berolo et al., 2011; Soyer & Akarirmak, 2020; Xie et al., 2017), watching videos (Berolo et al., 2011; Toh et al., 2020; Zindahi et al., 2020), browsing (Berolo et al., 2011; Zindahi et al., 2020), listening to music, taking pictures and scheduling (Berolo et al., 2011). Multitasking on the smartphone and with other devices has also been associated with symptoms in neck, shoulders and arms (Toh et al., 2020), and other adverse effects associated with performance (Toh et al., 2019).

3.3.1.4 SUPPORT

The absence or deficiency in body supports constitutes a risk factor highly linked with posture and muscular activity (S. Lee et al., 2015; Soyer & Akarirmak, 2020). Consistent with the higher risk observed in different studies when users manipulate their smartphone while seated, several studies recommend using chairs with armrests (Syamala et al., 2018; Tang et al., 2021; Yoon et al., 2020) and getting the most out of the back of the chair (Syamala et al., 2018; Yoon et al., 2020). Putting the smartphone on a stand also seems to be a good way to reduce the likelihood of musculoskeletal symptoms (Thorburn et al., 2021).

3.3.1.5 Rest

Like support, the absence or deficiency in rest is a factor that worsens the risks associated with poor posture for prolonged periods of time. There are two ways to understand this rest as a beneficial strategy for postural health, the first is to totally shed the use of the smartphone periodically to reduce muscle fatigue (Tang et al., 2021; Xie et al., 2017), and the second is the frequent change of position, preferably every 5 minutes (Thorburn et al., 2021).

3.3.1.6 Other Risk Factors

Here are some risk factors for postural health in mobile interaction that have been studied in various works, although less frequently and usually in less depth: smartphone ***addiction***, closely related to time of use and tasks such as social networks and gaming (Betsch et al., 2021; Roslizawati & Isyan Farahin, 2021; Toh et al., 2017); female ***gender***, related to greater muscular activity (E. Gustafsson et al., 2010) and higher prevalence of symptoms (Toh et al., 2019), although Woo et al. (2016) raises the question whether it is a risk associated with gender or with less physical activity carried out by women; ***age***, the older the users, the more likely they are to suffer from musculoskeletal symptoms (Cevik et al., 2020); the ***grip***, Yoon et al. (2020) affirm that there is a greater risk when handling the smartphone with two hands, while Thorburn et al. (2021), M. Lee et al. (2015) and Chang, L'yi, Koh, & Seo (2015) assure that the risk is less when using two hands; ***repetitive movements***, which can affect all segments of the upper extremities, especially the thumbs (M. Lee et al., 2015; Xie et al., 2017; Yang et al., 2017); the ***size of the screen***, the larger, the greater head flexion (Toh et al., 2017), and the greater flexion and extension of the thumbs (Chang et al., 2015; Sahu et al., 2021; Voelker, Hueber, Corsten, & Remy, 2020); finally, the ***interaction technique***, although it has not been explicitly mentioned, the fact that the user depends mostly on seeing and touching the smartphone screen (Chang et al., 2015; Xie et al., 2017), limits the possibilities and increases the risk factors mentioned in this section.

3.3.1.7 Risk Factor Considerations

The literature review has made it possible to identify a wide group of risk factors for postural health in mobile interaction, some more relevant than others, but all very interesting as an object of study. In this section they have been listed separately, but there are several relationships between them, which have not always been explicitly or deeply studied by the authors, but which can be inferred after reading the canon of this review. For example, a wide head flexion may not mean a significant risk if it is not maintained for a long time; and a user who requires prolonged use of the smartphone could minimize the risk by using appropriate supports and taking regular breaks. Risk factors do not usually appear in isolation and the synergy between them exacerbates the effects.

3.3.2 Effects

When risk factors are not attended, users experience the effects of bad habits in mobile interaction, ranging from mild discomfort to injuries and chronic pathologies. The literature that reports the symptoms that smartphone users subjectively perceive is extensive and some authors supplemented this information with diagnostic instruments (E. Gustafsson et al., 2010; Ramnaath et al., 2020; Yoon et al., 2020). The most frequent and relevant symptoms are ***pain*** (Berolo et al., 2011; Betsch et al., 2021; Cevik et al., 2020; Kim & Koo, 2016; Korpinen, Pääkkönen, & Gobba, 2018; Worawat Lawanont et al., 2018; M. Lee et al., 2015; Sahu et al., 2021; Soyer & Akarirmak, 2020; Syamala et al., 2018; Tapanya et al., 2021; Zindahi et al., 2020; Zirek et al., 2020), ***discomfort*** (M. Lee et al., 2015; Tang et al., 2021; Tapanya et al., 2021; Toh et al., 2020; Woo et al., 2016; Yang et al., 2017), ***muscle fatigue*** (Cevik et al., 2020; Ramnaath et al., 2020; Soyer & Akarirmak, 2020; Tang et al., 2021) and ***numbness*** (Korpinen et al., 2018; Sahu et al., 2021). On the other hand, the most vulnerable body segments to suffer the effects are:

- Neck, up to 89.8% prevalence according to Zirek et al. (2020) and Korpinen et al.(2018).
- Shoulder, up to 78.1% prevalence according to Woo et al. (2016).
- Thumb, up to 53% prevalence according to Zirek et al. (2020).
- Hand and wrist, up to 43.4% prevalence according to Woo et al. (2016).
- Lower back, up to 39.4% prevalence according to Woo et al. (2016).
- Upper back, up to 38.6% prevalence according to Woo et al. (2016).
- Arm, up to 33.3% prevalence according to Toh et al. (2019).
- Elbow, up to 32% prevalence according to Berolo et al. (2011).

If the symptoms are not taken seriously and properly cared for, they can lead to chronic conditions such as computer vision syndrome, cell phone elbow syndrome, blackberry thumb syndrome or text neck syndrome (Worawat Lawanont et al., 2018), lordosis (Betsch et al., 2021), spinal degeneration (Cevik et al., 2020) or tendonitis (Yang et al., 2017; Zirek et al., 2020). Other non-musculoskeletal sequelae of poor smartphone use habits are permanent tiredness, poor sleep quality (Roslizawati & Isyan Farahin, 2021; Yang et al., 2017) and concentration problems (Kim & Koo, 2016).

3.3.3 OCCURRENCE

The time of use was already mentioned as a highly relevant risk factor, however, the review of the selected literature did not allow finding very precise patterns of occurrence or strong coincidences between the authors, perhaps because human groups are usually heterogeneous, because the methodologies and their results present variations or because the perception of discomfort and pain may vary from one person to another. But it has been possible to identify intervals and some interesting elements.

The strongest trend among papers that deal with usage time is about the number of hours of daily use. Yang et al. (2017) and Toh et al. (2020) coincide in having studied groups of adolescents who use their smartphones mainly for leisure activities, both studies establish the threshold for daily use at ***1 hour***, above that time the prevalence rates of musculoskeletal symptoms begin to rise considerably. Two systematic reviews place the daily threshold at ***2 hours***, after which pain and symptoms are more frequent (Toh et al., 2017; Zirek et al., 2020). A study with young adults (20-35) placed the threshold of daily use at ***3 hours***, those who exceeded that border had greater degeneration in some structures of the back. Xie et al. (2017) state in their study that the use of the smartphone for more than ***5 hours*** is significantly associated with pain in the neck and shoulders. The highest threshold reported is ***6 hours*** (Tapanya et al., 2021). Even Toh et al. (2019) mention that each hour of daily use of the smartphone makes the probability of suffering some musculoskeletal symptoms increase by up to 7%.

Regarding the periods of continuous use of the smartphone, the variation is similar. It was found that a ***3-minute*** texting period does not indicate a significant risk of developing neck pain (Tapanya et al., 2021). The lowest prevalence of symptoms happens in people who changed positions every ***5 minutes*** (Thorburn et al., 2021)**.** It has been reported that a period of continuous use greater than ***10 minutes*** can generate discomfort (Toh et al., 2017) and fatigue (Kim & Koo, 2016). In the study with young adults (18-34) of Thorburn et al. (2021) the most of symptomatic users did not begin to experience symptoms until after ***15 minutes*** of device usage. Woo et al. (2016) mention that postures held for more than ***20 minutes*** can lead users to have musculoskeletal problems. Finally, the highest threshold is located at ***30 minutes***, to feel significant fatigue (Kim & Koo, 2016) and a higher prevalence of symptoms among those who do not change position during that period (Thorburn et al., 2021).

Although there is no precise agreement between the authors, it can be noted that discomforts and symptoms begin to be evident in smartphone users after 1 hour of daily use and after 10 minutes of continuous use, and the more these thresholds are exceeded, the greater the prevalence and intensity of musculoskeletal complaints.

3.3.4 CONTRIBUTING FACTORS AND CIRCUMSTANCES

There are some contributing factors and circumstances that feed the context of mobile interaction and that deserve to be reviewed, some because they enhance risk factors and others because they can serve as a reference and inspiration to propose solutions.

The great utility potential of the smartphone and all the advantages it offers - such as portability, computing power, omnipresence, online banking, healthcare, sports monitoring, geolocation, etc. - make it a highly efficient personal assistant (Nath & Mukherjee, 2015) on which the user is increasingly dependent and which he/she must consult much more often and for a longer time. In the same sense, the support that the smartphone offers to the user's cognition, although in principle it can be assumed as a good thing because it allows him/her to discharge cognitive functions such as memory, perception or decision-making, ends up increasing dependence of the user and maximizing usage time (Risko & Gilbert, 2016). Despite the cognitive support, the possibility of working on multiple tasks at the same time and the excessive attractiveness of many of them, can lead the user to a state of almost total immersion in the smartphone and of great distraction in front of the reality that surrounds him/her (Merbah, Gorce, & Jacquier-Bret, 2020), which can reduce proprioceptive ability and lead him/her to a state of unconscious irresponsibility with him/her own postural health (Schabrun, van den Hoorn, Moorcroft, Greenland, & Hodges, 2014).

One of the contributing factors frequently mentioned by some authors is the fact that for many users the greatest use of the smartphone is dedicated to leisure (Berolo et al., 2011; Korpinen et al., 2018; Roslizawati & Isyan Farahin, 2021; Toh et al., 2020; Yang et al., 2017), mainly social media and gaming, but also watching videos, listening to music and taking photos. It is something strongly linked to the categories of risk factors *Usage time* and *Tasks*, which in the case of Roslizawati & Farahin (2021) has been studied from the perspective of the addiction to the smartphone.

Smartphones are no longer a means for verbally connecting people, instead they have become multitasking platforms that allow many activities from a single device, also portable, cheap and very easy to obtain for a wide range of the population. For example, among the papers that indicate the percentage of smartphone use among the participants called to the study, the lowest is the 92% of Toh et al. (2020). A linked fact is that people whose purchasing power allows them to acquire the latest technologies and who can access a greater number of applications tend to abuse the smartphone more, even very close to addiction (Roslizawati & Isyan Farahin, 2021).

Some elements that aggravate the abuse of the smartphone are the low level of awareness on the possible adverse consequences (Woo et al., 2016), the difficulty of training and improving that level of awareness (Liao, 2017) and the limited medical advice or attention in the presence of musculoskeletal symptoms caused by the use of the smartphone (Woo et al., 2016). There is also evidence that a poor physical activity routine (Woo et al., 2016) and the absence of a postural exercise training program (Soyer & Akarirmak, 2020) can make the user more vulnerable to the negative effects the of use of electronic devices.

Smartphones have also become essential tools in work environments, places where people frequently experience stress and other mental health problems, which can predispose a person to suffer from musculoskeletal symptoms more easily (So, Cheng, & Szeto, 2017), sometimes discomforts can be effectively caused by bad habits in the use of the smartphone, but other times they can be the result of the somatization of mental tensions (Winkler, Jeromin, Doering, & Barke, 2020).

On the other hand, the large size of smartphone screens is not only a risk factor (Sahu et al., 2021), but it is also a trend (Voelker et al., 2020) that must be closely watched due to the challenges it implies as it is increasingly difficult to reach some elements on the screen (Chang et al., 2015), the change in the functional areas (Bergstrom-Lehtovirta & Oulasvirta, 2014) and the possibilities that arise to propose new models of interfaces and interactions.

The use of the smartphone accompanied by other electronic devices with a screen and processing capacity is found in the daily routines of the participants in several studies: tablet (Thorburn et al., 2021; Toh et al., 2020), computer (laptop or desktop) (Nguyen et al., 2017; Toh et al., 2017), or both (Woo et al., 2016). This is a neutral factor that can be considered aggravating in cases of addiction to electronic devices or as a possibility to distribute the tasks according to the convenience of the physical characteristics of each device. The use of distributed interfaces allows the user not to depend on a single device, but to control and access functionalities from different places, devices and modes (Khawaja et al., 2020). It can be noted that many alternative forms of interaction seek to reduce, even eliminate, the user's dependence on device screens and take advantage of different sensory and motor channels. Likewise, the interconnectivity between devices and the ubiquity of computer systems generates a complex ecology of interfaces that offers many possibilities (Brudy et al., 2019; Lyle, Korsgaard, & Bødker, 2020) current and potential, to generate new forms of interaction, not only thinking about the postural health in mobile interaction, but also to improving many other aspects of daily life through technology.

3.3.5 Interventions

Literature shows several proposals and approaches with different levels of technological complexity to meet and prevent postural health problems in mobile interactions. However, there are very few interventions directed specifically to this problem and, while a group of proposals for this review was being formed, it was necessary to admit some solutions with different purposes, but very close and consistent with the focus of this work. Unfortunately, and as Sahu et al. (2021) also state, the effects of many of these interventions are neither as effective nor as long-lasting.

It is possible to find two large groups of interventions: the passive ones based on the use of non-electronic accessories, and the active ones based on electronic devices and software applications.

Regarding passive interventions, chairs with adequate supports for arms and back seem to be sufficient to considerably reduce symptoms in neck and upper extremities (Sahu et al., 2021), the purpose is to maintain a neutral and upright position in neck and back while reducing the demand for muscular activity in those segments thanks to the back support and keeping the smartphone at eye level while the elbows rest on the armrests at the correct height for the user (Syamala et al., 2018). On the other hand, Sahu et al. (2021) also mention that the use of prism glasses generates a much lower muscle load on the neck and more neutral postures that tend to produce less discomfort in the neck. This is because the prism glasses deviate the line of sight by 90°, so the seated user can observe the screen of the smartphone placed on his lap while his/her neck is held upright.

Active interventions can also be divided into two groups: those that do not require any complementary physical accessory and those that do.

The first group uses the device's own hardware functionalities - accelerometer, gyroscope, GPS, camera, clock, etc. - together with its processing capacity, that is, those are interventions that seek to take advantage of the smartphone as a platform and avoid the use of additional artifacts. The principle of operation of several proposed solutions is based on the measurement of the neck axis angle relative to the back and triggering an alert when the position is unhealthy. Some designers argue that, since the line of sight is perpendicular to the smartphone screen, it is sufficient to use the smartphone's accelerometer to measure its own tilt angle and indirectly estimate the head tilt angle (Elnaffar & El Allam, 2018; Giansanti et al., 2019; Kunze et al., 2015; Su, Tong, & Ji, 2014; Zindahi et al., 2020). There are also developments that rely on the smartphone camera to obtain an image of the user's face and based on a pattern recognition and classification algorithm, identify the position and tilt of the head (W Lawanont, Mongkolnam, & Nukoolkit, 2015; Worawat Lawanont et al., 2018; H. Lee, 2015; Toda et al., 2015). There are a few proposals focused on changing the postural habits of smartphone users based on different interaction models. For example, when calculating an inappropriate angle, the smartphone distorts the information on the screen as a reminder for the user to improve his/her posture (Clinton, Ira, & Alex, 2018; Kunze et al., 2015; Moeller, 2019). Also there is research that raises the possibility of turning to friends and family to, through a social network, to form a collaborative system in which all members help to take care of their postural health mutually (Liao, 2017); and some interventions are focused on stimulating the user's level of awareness and persuading him/her to reduce the time in front of the smartphone screen (Okeke, Sobolev, Dell, & Estrin, 2018; Pacherazova, 2019; Rooksby, Asadzadeh, Rost, Morrison, & Chalmers, 2016).

The other group of active interventions propose the use of additional accessories or wearables, essentially to place sensors on the user's body and thus take direct measurements of posture. For example, Nguyen et al. (2017) propose the use of a sensor adhered directly to the neck to measure the flexion angle in that segment, while for the same purpose Kunze et al. (2015) propose an accessory type glasses, in such a way that the sensor is discreetly hidden in an artifact of daily use and that does not imply a significant change in the user's routine, and with a principle similar to the previous one, Liao (2017) proposes to place a sensor inside a headset that allows measuring head tilt. Wearable underwear aimed at taking a measurement of the full back tilt have also been proposed (Bootsman et al., 2019; Cajamarca, Rodríguez, Herskovic, & Campos, 2017).

Some of the interventions mentioned generate notifications to warn the users that their behavior in front of the smartphone is not appropriate for their postural health, the way to get the user's attention is through vibrations only (Zindahi et al., 2020), vibrations and sounds (Bootsman et al., 2019), or vibrations and textual feedback (Okeke et al., 2018).

Finally, it is possible to mention that, although many interventions are focused only on smartphone users (Bootsman et al., 2019; Liao, 2017; Okeke et al., 2018; Su et al., 2014; Zindahi et al., 2020), some also have versions for other devices such as tablets, laptops and desktops (Kunze et al., 2015; Rooksby et al., 2016).

3.3.6 User Perception

Preliminary observations to this study made it possible to predict a low user participation in the design and evaluation processes of interventions that seek to meet or prevent postural health problems in mobile interaction. Unfortunately, the literature review confirmed the prediction and revealed little interest from developers to integrate users. Less than half (9/19) of the papers selected about interventions make any mention of the participation or perception of the users, however, fortunately there are some prominent articles whose procedures and results show an interest in working with users.

In the descriptions of some interventions, an explicit intention can be noted to promote a behavioral change in the postural hygiene of smartphone users, some seek this change by improving the level of self-awareness in this regard (Okeke et al., 2018), while others resort to also develop a good level of co-awareness in such a way that a change in behavior is collective, supportive and possibly lasting based on the social influence or support provided by the members of a group of people (Bootsman et al., 2019; Liao, 2017). However, and as mentioned by Sahu et al. (2021) and Okeke et al. (2018), the positive effects do not tend to be sustained over time, and much less if the intervention is interrupted or withdrawn.

Those works that show some interest of the designers to integrate the users in the design and evaluation processes of the interventions made use of different information gathering instruments. Questionnaires or surveys were mainly used to collect user perceptions after completing the tests (Cajamarca et al., 2017; Okeke et al., 2018; Voelker et al., 2020); individual interviews were also conducted at the end of the studies (Cajamarca et al., 2017; Rooksby et al., 2016), although Bootsman et al. (2019) used them before, during and after; and Rooksby et al. (2016) also used an interaction log to record events as the user interacts with the tool and to use as research data. By comparing the procedures and results of the papers selected for this phase of the review, it is possible to affirm that few authors committed themselves to researching and understanding user experience, user requirements, cultural context and the usefulness of their interventions (Cajamarca et al., 2017; Bootsman et al., 2019). *Table 2* summarizes the user research methods used in the reviewed papers.

Table 2 User research method used in studies

STUDY	USER RESEARCH METHOD
Wearable technology for posture monitoring (Bootsman et al., 2019)	**Individual interview:** Before, during and after the study
StraightenUp - Spine Posture Wearable (Cajamarca et al., 2017)	**Individual interview:** Post-study **Questionnaire:** Post-study
Good vibrations (Okeke et al., 2018)	**Questionnaire:** Post-study
Tracking screen time (Rooksby et al., 2016)	**Individual interview:** Post-study **Interaction log**
HeadReach: Using Head Tracking (Voelker et al., 2020)	**Questionnaire:** Post-study

Following are some extracts about the interaction of users with those interventions that were the subject of some type of evaluation:

- **Neck posture monitoring system** (Worawat Lawanont et al., 2018)
  - *"System classification provides an easy-to-understand result for the user"*
  - *"Statistical usage record helps a user understand his/her behavior over a certain period"*
- **StraightenUp - Spine Posture Wearable** (Cajamarca et al., 2017)
  - *"User experience, user requirements, cultural context, and aesthetics must be considered as a central factor when designing wearable devices"*
  - *"The most important factor in the acceptance of wearables is their usefulness. Other factors such as ease of use, usability, quality and connectivity affect use rates"*
  - *"The overall user experience was rated as positive"*

  - *"The weakest score was in the hedonic quality category, which means that StraightenUp is perceived as a non-presentable device, it does not have the appearance of a finished product"*
- **Wearable technology for posture monitoring** (Bootsman et al., 2019)
  - *"An iterative process in which we involved nurses as informants in the early exploration phases and later on as test-participants"*
  - *"We interviewed nurses regarding their work and low back pain prevention and regarding their attitudes towards wearable solutions"*
  - *"Based on feedback provided by nurses, physiotherapists, ergonomists and clothes manufacturers we implemented a more refined prototype"*
  - *"Much of postural behavior is habitual and does not necessarily follow conscious and rational reasoning"*
- **Tracking screen time** (Rooksby et al., 2016)
  - *"Several participants felt they ought to be spending more time working. This was generally something that went hand in hand with spending less time on mobile devices"*
- **Good vibrations** (Okeke et al., 2018)
  - *"Participants found the real time feedback useful for keeping track of their own usage, and they correctly perceived the vibration as providing a reminder that encouraged them to spend less time using the target application"*
  - *"Participants who experienced the vibration pulses reported that it increased the awareness of their application usage… They stopped using the application after a few minutes"*
  - *"The usage statistics provided by the persistent notification bar increased their perceived self-awareness of how much time they spent using Facebook every day"*
  - *"Participants enjoyed having the ability to keep track of their daily usage"*
  - *"Real time feedback was useful for participants and it increased their perceived awareness of personal digital habits"*

- *“There is no conclusive evidence that the effect may or may not be sustained after the intervention is removed”*

3.4 CLOSING REMARKS

The available literature allows understanding there is a health problem caused by bad habits in the use of smartphones, health professionals have already identified it and are aware of its magnitude. On the other hand, the proposals aimed at preventing the postural health problems in mobile interaction seem scarce, most of them are limited to triggering an alert and there is little material that shows an effective user research and a proper identification of requirements before prototyping designs. The last point, although it is unfortunate, is also the greatest motivation for this work, as it aims to become a good example of a design process that integrates the users and their context.

Since the smartphone has become an object of massive and frequent use, any problem related to the interaction with it requires an approach centered on the users and their daily life. This means that it is necessary to understand that interactions can be optimized according to the context of real use, in which users have strengths and weaknesses, have a way of doing things, routines, needs, customs, tastes, etc.

In this sense, a research with an ethnomethodological approach seems reasonable and appropriate, since it is not about testing a theory, but about collecting information that allows to identify details that usually go unnoticed precisely because they are so common, normal, natural and ordinary in daily life. These elements can be so inadvertent that the user comes to accept them as an immovable reality, even when they lead him/her to make mistakes and experience uncomfortable situations.

With this work, it is expected to generate a modest contribution to the gaps in the design processes detected in this literature review, better understanding the daily interactions of the user with the smartphone and doing the best to turn those findings into coherent design proposals.

4 ETHNOMETHODOLOGICAL STUDY

To begin with, it is necessary to contextualize the circumstances in which this study was carried out, because in some way those circumstances are also part of the study itself. This document has been written during the Covid-19 health crisis, one year after the declaration of a pandemic by the WHO. This situation led to three relevant events for this research: social isolation, the unprecedented rise of the home office and the rapid digital transformation of companies. Social isolation made it difficult to interact with participants pre-recruited for the study (45), working at home modified the routines of millions of workers around the world, and digital transformation increased the use of electronic devices. Under this scenario, not only was an adaptation to the circumstances necessary, but it also seemed very interesting to do so.

The most relevant decision taken under these conditions was to discard studying a group of participants and instead study a single participant, not only for convenience in terms of logistics, but also because it opened the possibility of doing a closer and more detailed study, now not only on the habits of smartphone use, but also on the daily routines of the participant within a domestic and work context at the same time. Then the researcher had the approval of his wife to be the study subject, who was very consistent because she shared the same home and was greatly influenced by social isolation, home-office and increased use of devices. A small sample, and much more if it is unitary, can be judged as statistically insufficient and unfeasible to generalize a discovery (Baxter, Courage, & Caine, 2015; Randall et al., 2020), it may be true, but that conclusion is not consistent when these are not the objectives from the study. A unit sample can be quite useful, for example, for quickly detecting the major usability and functionality failures of a system (Anderson, McRee, & Wilson, 2010), as the researcher can focus more and for longer on the participant's behavior in different situations (Barzelay, 1993; J. Gustafsson, 2017; Tullis & Albert, 2013), and to recognize minimal aspects of daily life that may become very important but discarded in a study with a larger sample, just at this point the importance of an ethnomethodological approach (Garfinkel, 1967).

In this sense, this study can be considered as exploratory and preliminary. Exploratory because it is an alternative way of obtaining information for design purposes, and preliminary because it presents a basis that can be used in a larger study.

4.1 DATA COLLECTION

To collect data for this study, the use of several complementary methods has been proposed, in such a way that the nature and origin of the information are diverse and help to find key elements from different sources. In the review of the literature, it was possible to appreciate that there were usually few instruments used in user research - as can be seen in *Table 2* - and this study tries to go a little beyond this homogeneity of data. The methods are described below.

4.1.1 STUDY PREPARATION

The purpose is to collect information about the participant's routines, her own perception about the smartphone's use habits and some data related to the devices she uses. With quantitative and qualitative data, it is expected to identify keys that help to better design the diary study and to identify the participant's point of view in such a way that it can be later compared with the data collected with other instruments. Inspired by the *user requirements* of Kujala (2005), a semi-structured questionnaire with several sections was designed to collect different information about the participant:

- Devices and operating systems
- Experience and skills with these technologies
- Times of use, tasks that she performs, objectives
- Physical environment, postures, breaks
- Musculoskeletal symptoms or pathologies
- Possible causes of musculoskeletal problems

Closed questions have formats to help the understanding and facilitate data tabulation. Here are some features:

- With few exceptions, all questions offer four answer options.

- A group of responses are in the format of a discrete scale with an even number of positions: 0, 1, 2 and 3, this in order to avoid a comfortable intermediate value and prevent her from "*sitting on the fence*".
- To measure the expertise of participant with some artifacts and technologies, the following scale was designed:
  - I have used it
  - I haven't used it, but I know it
  - I don't know it, but it seems interesting
  - I don't know it, I'm not interested either

Data collected with the semi-structured preparation questionnaire made it possible to create a much more detailed profile of the participant and to recognize her expertise with some artifacts and technologies.

4.1.1.1 PARTICIPANT PROFILE

Female, 39 years old, professional in marketing, sales manager in a Swiss multinational, she lives in a big city and due to the pandemic has done a year of home office. Reports more than 5 years of experience using a smartphone; she uses it out of necessity, especially as a work and study tool; she feels very competent in its use, but as a non-specialized user; she rates her level of dependence on the smartphone as considerable, especially because of her work; she keeps an eye on her smartphone notifications; she thinks that her iPhone is a great support for her memory and fully relies on its suggestions when making decisions, for example selecting a route or choosing a movie.

Although she usually tries to maintain a good routine of physical activity and good eating habits, she was diagnosed three years ago with cervicalgia (neck pain) and paresthesia in the upper limbs (numbness and pain), probably caused by using smartphone and laptop.

Her work routine changed a lot after the onset of the pandemic. Usually, her job included a lot of field work, frequent travel, and direct contact with several groups of people. At that time the smartphone represented a greater support, while the laptop was only used occasionally. All these activities were replaced with digital communications and virtual meetings, which multiplied the use of the laptop and greatly reduced her physical activity and social life.

Here are some specific data provided by the participant:

- Workplace: comfortable but small desk, some days she works from other places in the apartment (room, living room), prefers to use an external mouse and keyboard, light ring, physical agenda, hands-free and smartphone on desk stand, always has a bottle of water. Her most common position is sitting at the desk.
- Rests: usually she takes one in the morning (5 minutes, low quality), one at lunchtime (1-hour, good quality), and one in the afternoon (30 minutes, excellent quality).
- Stress level: participant considers that she is exposed to a moderately high level of stress because of "I work with people and working with people is complex".
- Symptoms: mainly pain in the back and the right arm, but also in the shoulders and occasionally in the head.
- Possible causes of symptoms: participant attributes the symptoms mainly to posture (long sitting), although she also believes that stress can affect the intensity of the symptoms.
- General use of devices: her working hours are variable but are usually between 8 am and 8 pm Monday through Friday. During those days, she estimates that uses the laptop (14” - Windows 10) and smartphone (4.7” - iOS 12.5) for work by 90% and for leisure by 10%. On weekends she only uses the smartphone, 10% at work and 90% personal use.
- Laptop use: mainly for work, designing and preparing material for training (PowerPoint), giving and attending training (Zoom), answering corporate emails (Outlook), and reducing the use of the smartphone (WhatsApp web).
- Smartphone use: communication with clients and colleagues (WhatsApp and phone), attending talks and meetings (Zoom), reviewing and responding to personal emails (Gmail), and banking transactions.
- Smartphone-related technologies and interactions: a series of questions were focused on identifying the expertise level of the participant with some smartphone-related technologies and interactions:

- Interaction gestures: usually interacts with the smartphone using touch gestures on the screen. When she drives, she prefers to interact with the smartphone through voice commands.
- Wearables: she knows several wearables but has not used any. She thinks she could wear a smart watch.
- Accessories: she frequently uses the hands-free but does not know the possibilities offered by its control to operate some functions of the smartphone.
- Holders: she likes to use the smartphone on holders. She uses one holder for the desk and one for the car.

Using data from the participant profile and in order to express respect and gratitude to the participant (who is not receiving any incentives), she was invited to be a co-designer of a structured diary study - with specific questions - to collect data about her routines and her interactions with the smartphone and other artifacts.

4.1.2 THE STUDY

Data collected during the preparation stage and the willingness of the participant to cooperate designing the study were valuable elements in structuring the action plan. Knowing better the context of the participant, devices she uses and technologies she knows, decisions were made about the most appropriate tools for each instrument and how to use them during seven days of study.

First, a pilot study was carried out to detect potential faults and refine details. For two days, a first protocol design was carried out to verify the viability of the reminders, the response form, the times to do it and the most appropriate way to take the photographs. In the end, only two things changed to the final protocol design: the intention of asking the participant for a screenshot of the smartphone every time she received a reminder was eliminated, because she felt that her privacy was overrun, and a question was added about the stress level that participant felt each time she received a reminder. After the pilot, a study was conducted with the following features:

- Diary study. It provides qualitative and quantitative data without the need for a researcher to be present. It is ideal when you have a limited set of questions to ask participants and the questions are easy to answer (Baxter et al., 2015). However, diaries demand a high degree of commitment and can be very intense for participants, even reminders can be considered invasive. The procedure for this diary study included 3 responses a day (11 am, 3 pm, 7 pm), reminders via WhatsApp, answers recorded in a Google Form and reports of the last two hours about devices used, activities, places, postures, rests, symptoms and stress level.

- Interaction log. The purpose of the interaction log is knowing what the participant does and uses while interacting with the smartphone and laptop during the same days of the diary study. This is a quantitative instrument and allows an indirect observation identifying the applications that participant uses the most and the time she spends on each one.
    - Interaction log on the smartphone. Being an iPhone, Screen Time was used, although it does not allow the information to be exported, it did not represent a greater difficulty to transcribe the information at the end of each day. With this tool, the use of applications, usage trends, frequency of notifications and inquiries were registered.
    - Interaction log on the laptop. the DeskTime application offers some very convenient functions for a study like this, such as tracking the applications used, the web pages visited, and the ability to export the data, even from a remote computer. The use of applications and usage trends were registered with this tool.
- Partial shadowing study. It was important to record the natural and spontaneous postures of the participant for the study, so it was not reasonable to ask herself to take some photos. It was decided that as the researcher was in a privileged position for this task, he would be the one to take the photographs in the least invasive way possible, synchronized with the responses of the diary study.

4.1.3 RETROSPECTIVE INTERVIEW

Diary study and interaction logs offer a large amount of data to identify some routines and behaviors, but due to their own characteristics, they do not allow knowing reasons and circumstances surrounded participant in each situation or decision, and that is precisely why a retrospective interview makes sense. Data collected during the study was exposed sequentially to the participant in order to know her impressions about each one, then a semi-structured interview was carried out and the results of the diary study - including the interaction logs and photographs - were presented visually to the participant from a laptop, while a video of the screen and voices of researcher and participant was recorded. After, the record was reviewed in detail to encode some relevant topics and trends.

4.2 DATA ANALYSIS

The diversity of data collected during the study was significant, since 4 instruments with different characteristics were used, in addition to the post-study retrospective interview. As these are complementary instruments, the need arose to tabulate and analyze some data jointly so that they reached greater consistency and could be better understood. The way in which data was organized and analyzed is explained below.

4.2.1 PARTICIPANT ROUTINES

To understand the participant's routines during the 7 days of the study, only data from the report form was used. The purpose was to identify the recurrence of the participant reporting being somewhere, using a device, performing an activity or experiencing any symptoms. As only 21 reports were collected (3 a day for 7 days), it was enough to generate a spreadsheet with the form data in Google Forms and make a simple count of the data to easily identify the participant's routines, to generate later a diagram that allows to easily observe this information.

4.2.2 APPLICATIONS USAGE

To analyze the use of applications, the data from the interaction log of the smartphone and from the laptop were combined in order to know the way in which the participant used and distributed her tasks between the two devices, that is, those tasks that she only performed in one of the two and those tasks performed in both.

To improve the understanding and visualization of the data, it was necessary to unify the units of time and the formats in units of hours. Later those tasks that were executed in the two devices were unified (although keeping them labeled) and finally they were descending ordered according to the time of use.

4.2.3 Notifications

Notifications were only analyzed from the smartphone interaction log, mainly because notifications on the participant's laptop were almost null and she did not attend to them.

As the data on the number of notifications was collected daily, they were then ordered according to each application and added together to obtain the total number of notifications for each application for a week. Then they were descending ordered.

4.2.4 Daily Use

In order to identify the amount of time the participant used each device per day, the data from the smartphone and laptop interaction logs synchronized for each day of the study were tagged and combined. The average daily use was also calculated for each device.

4.2.5 Time slots

In order to identify the amount of time the participant used each device during each hour of the day, data from the smartphone and laptop interaction logs synchronized for each day of the study were tagged and combined. The average daily use of each device was also calculated for each time slot of the day.

4.2.6 Retrospective Interview analysis

A process inspired by the "affinity diagramming" was carried out, because it is a good tool to analyze qualitative data such as those collected in the retrospective interview, and because there are good precedents when it is used in a diary study (Baxter et al., 2015). Then, from the interview with the participant, key points were obtained and written individually in sticky notes (virtual), in this way there was a visual representation of the data - which is usually very convenient for the researcher - and those notes that mean discoveries or important concepts were grouped around a theme, a category or a trend, which emerged during the process.

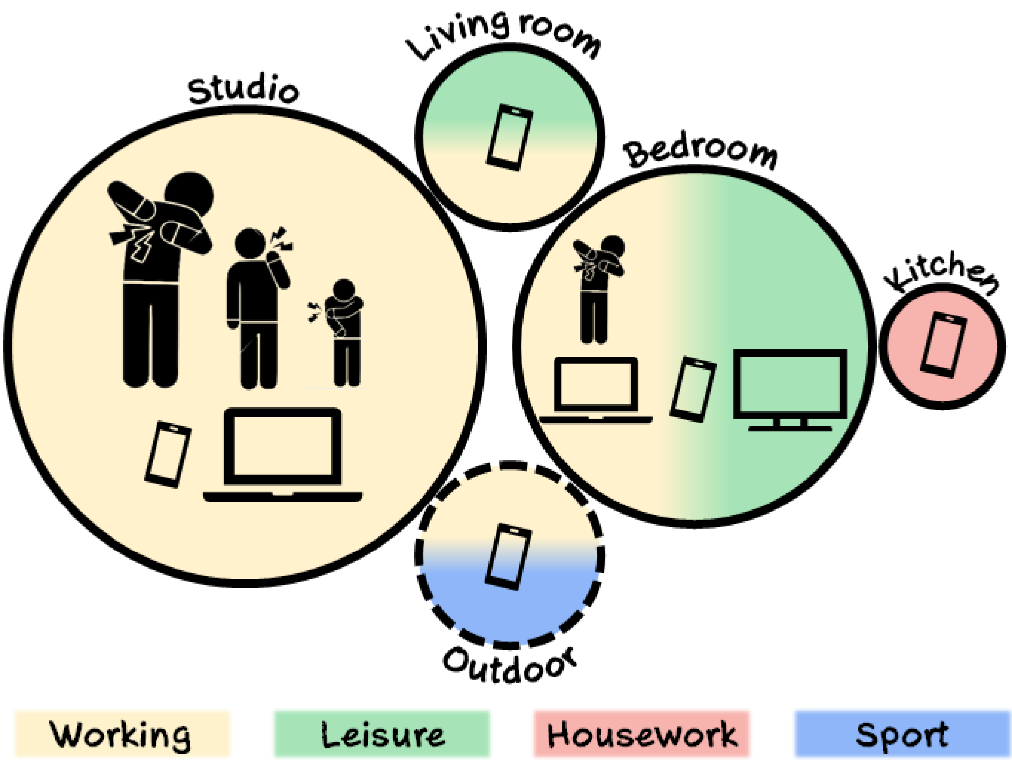
4.3 Results

According to the way the data was organized and analyzed, the results will be presented below. They will not be classified by instruments or tools, but an attempt will be made to show the discoveries in a practical, combined and easy-to-understand way.

4.3.1 Routine Diagram

A diagram summarizing the participant's reports during the seven-day diary study is shown in *Figure 3*:

Figure 3 Report diagram



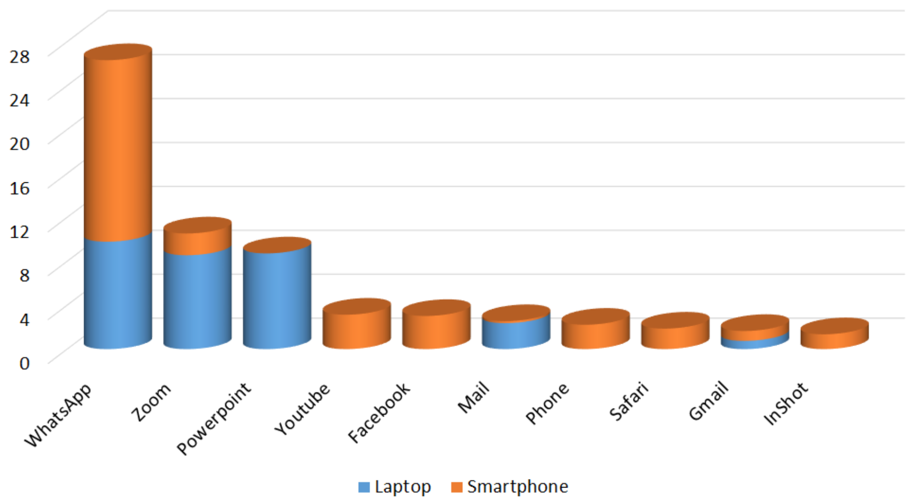
- Each of the circles represents a place from where the participant reported having been (studio, bedroom, living room, kitchen, outdoor).

- Area of each circle represents the recurrence of the reports in that place: 10 times from the studio, 6 from the bedroom, 2 from the living room, 2 from outdoor and 1 time from the kitchen.
- Color represents the activity that she reported in each place: work (yellow), leisure (green), housework (red) and sport (blue).
- Devices icons represent the uses that she reported in each place (smartphone, laptop and smart TV).
- Symptoms icons represent the complaints reported in each place and the size represents the recurrence each one: right arm pain (1 time in the studio), shoulders pain (2 times in the study) and back pain (3 times in the studio and 1 time in the bedroom).

4.3.2 Applications Usage and Notifications

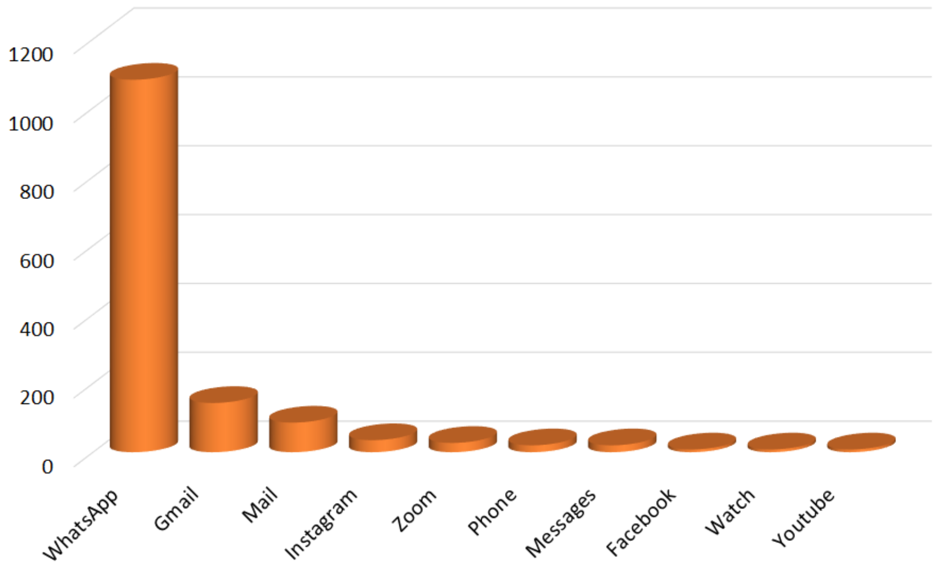
From the interaction logs of the smartphone and the laptop, it was possible to track the use of applications on the two devices for 7 days. *Figure 4* shows the 10 most used applications (in hours) during the study and the relationship of use in each of the devices.

Figure 4 Applications usage (in hours) of the 10 most used applications in smartphone and laptop for a week



On the other hand, *Figure 5* shows the 10 applications that generated the most notifications for 7 days.

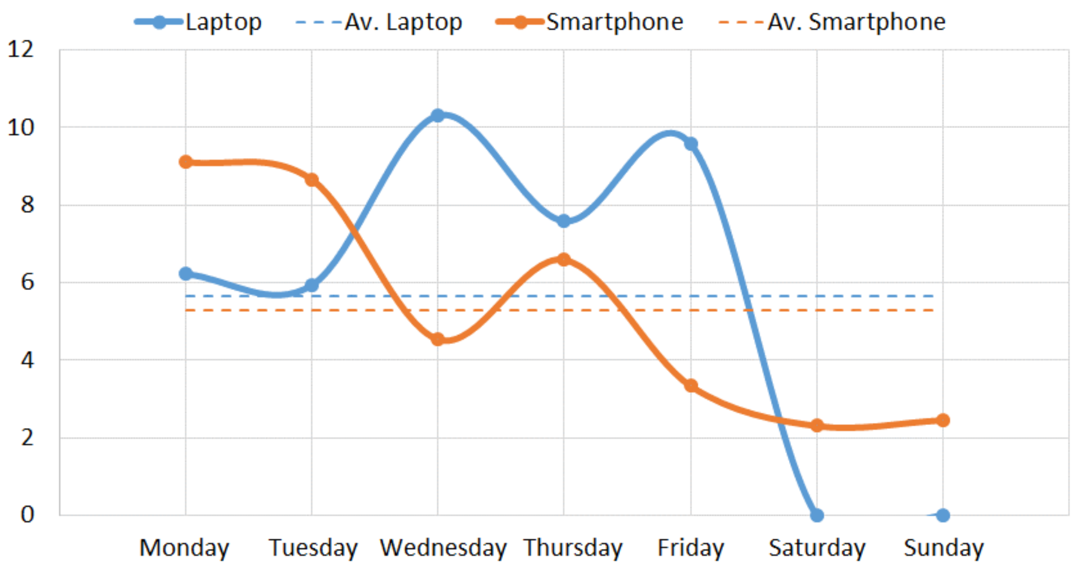
Figure 5 Smartphone applications and number of notifications for a week



4.3.3 Daily Use and Time Slots

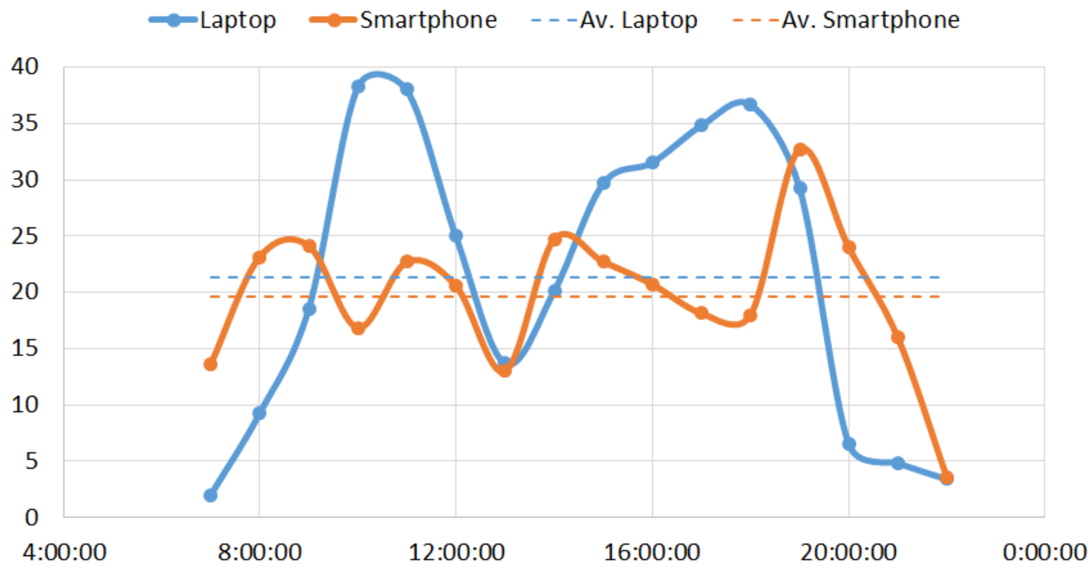
The smartphone and laptop interaction logs allowed to observe usage trends and make a direct comparison between the two devices. *Figure 6* shows the usage trend (in minutes) during the days of the week. A complementary behavior between the devices can be noticed during the working days, that is, when the use of one of them increases, the use of the other falls. On weekends the trend totally changes, but some use of the smartphone remains.

Figure 6 Daily use (in hours) of smartphone and laptop for a week



On the other hand, *Figure 7* shows the average trend of use during time slots. It is possible to notice the beginning of activities around 7 in the morning and ending around 9 at night, with a break at 1 in the afternoon. Also, it is possible to see two slots of laptop use that are much more consistent than the more variable slots of smartphone use.

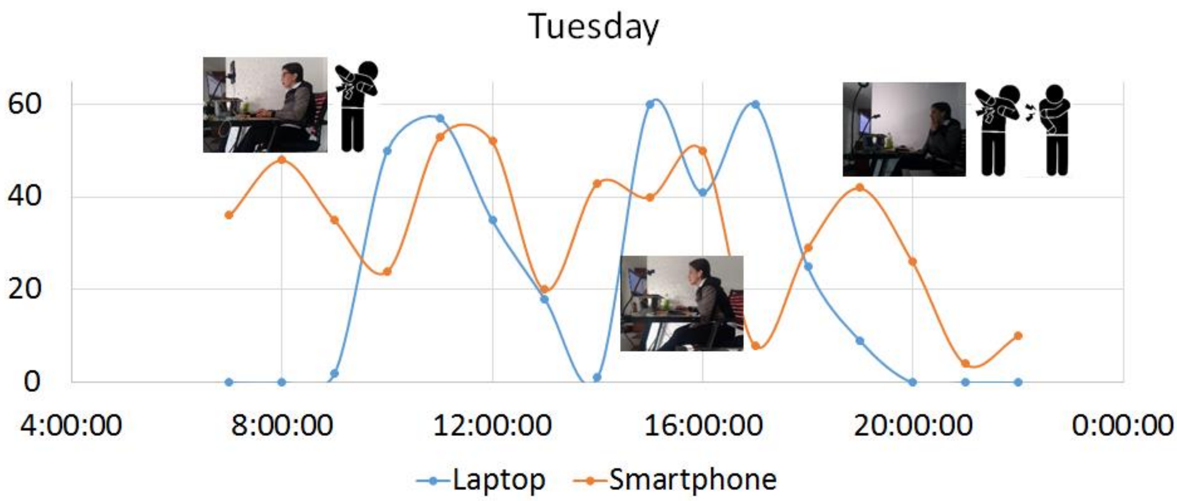
Figure 7 Average trend of use (in minutes) during daytime slots for a week



4.3.4 TIMELINE

A more detailed observation of the interaction logs allows observing the daily behavior of the participant using the smartphone and the laptop. In *Figure 8* it is possible to see a sample of the graphs of this behavior accompanied by the photographs of the participant and the reported symptoms (for the full timeline, see *Appendix A*). Although this timeline allows some trends to be perceived - such as a Tuesday of intense activity and many symptoms, or a weekend of little activity and no symptoms - its main purpose is to work as material for the retrospective interview that will be carried out with the participant.

Figure 8 A sample of the study timeline (Usage in minutes of each device for each time slot)



4.3.5 PRELIMINARY OBSERVATIONS

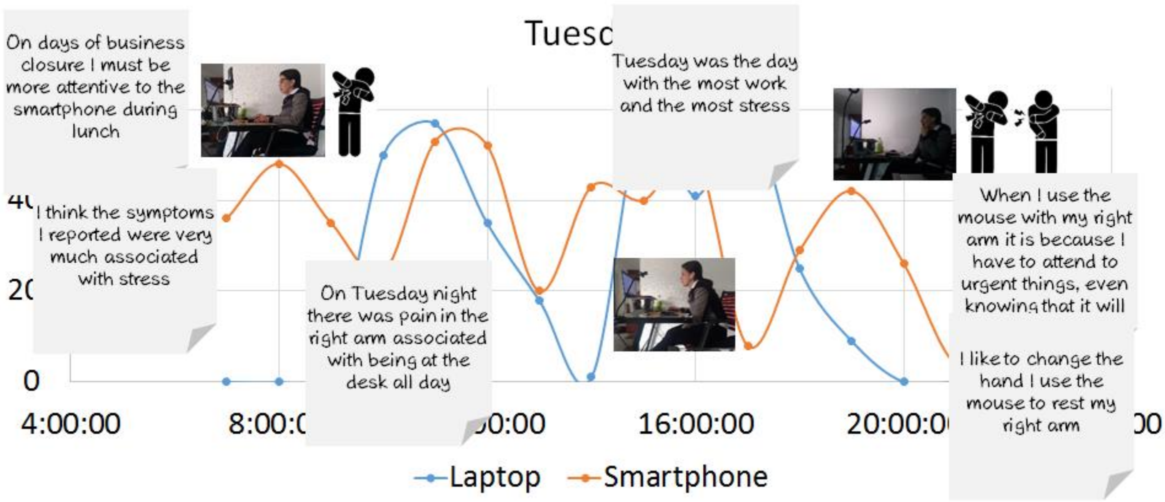
From the data obtained with different instruments and tools of the study, it is possible to reach some preliminary observations that, like the timeline, will serve mainly as material for the retrospective interview with the participant. Although some numbers will be expressed as percentages, it is necessary to reiterate that statistical analysis is not a purpose pursued by this work:

- The use of the laptop is 100% associated with work.
- The use of smart TV is 100% associated with leisure.
- The smartphone was present in all the activities.
- No activity reported without the use of devices.
- Most of the time the participant reported pain, she was sitting in the desk chair working.
- The studio is 100% associated with work.
- There does not seem to be a clear relationship between symptoms, quality of rest, and stress level.
- The stress level and the presence of symptoms increases a little at night.

4.3.6 Retrospective Interview

A semi-structured interview was carried out for 74 minutes. In most cases, the participant agreed with the results and the way in which they were presented, however, during the interview, she made several corrections and clarifications, especially with those data had been collected as numerical data, they did not allow the context and circumstances to be identified. After, about 90 notes were taken and placed in the corresponding screenshot, as can be seen in the sample of *Figure 9* (a collage with all notes on the screenshots can be seen in *Appendix B*).

Figure 9 Collage representing the notes taken from the interview video

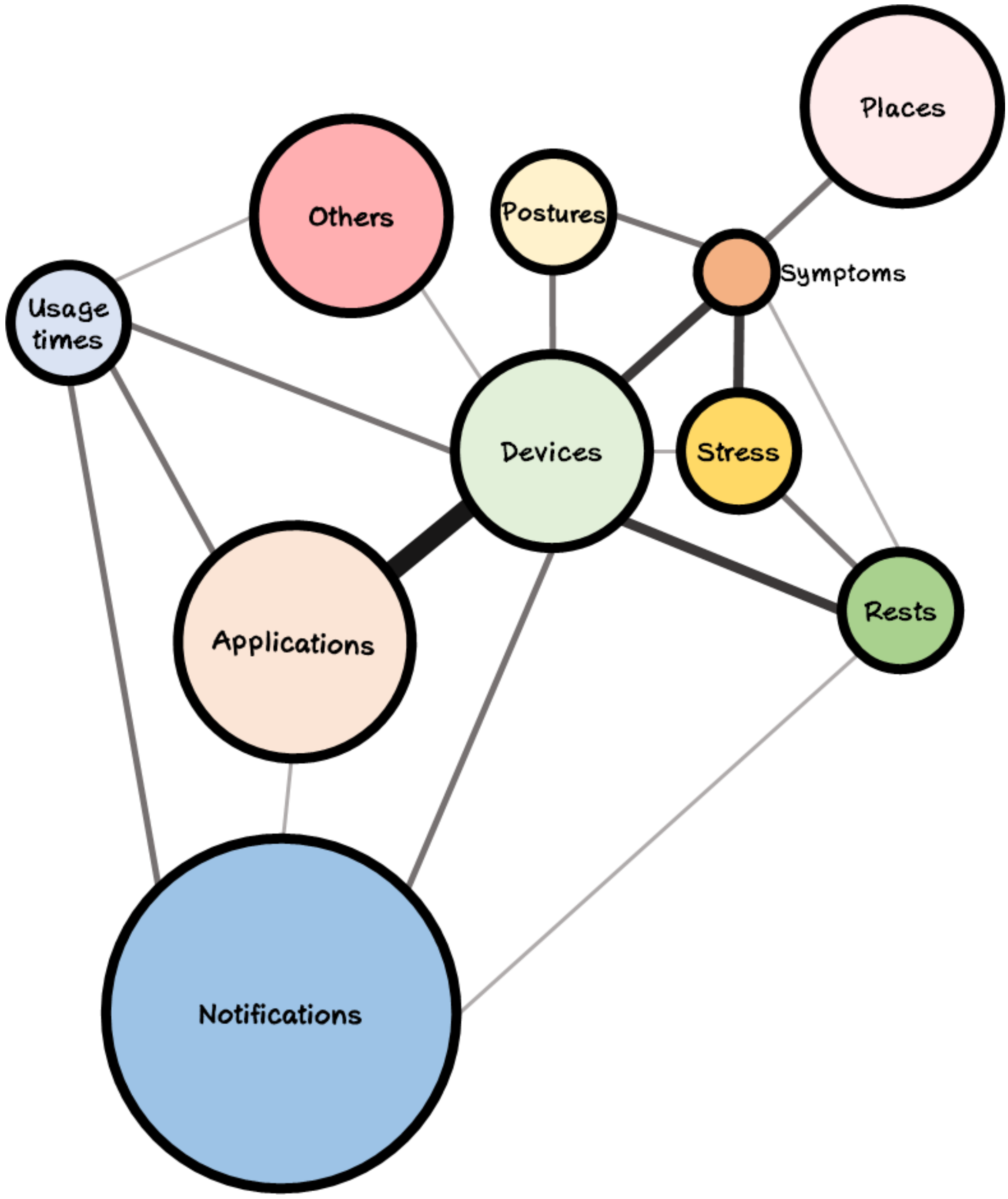


With all these notes, 9 main topics were identified around the interview: devices, times of use, postures, applications, places, rests, notifications, stress and symptoms. A few notes did not fit very well with any of those categories, but they were important and were grouped under the heading “Others”. In total, 10 clusters were created to organize all the notes and each one received a characteristic color and an abbreviation, as can be seen in *Appendix C*.

Once the clusters were assembled, links were searched between them, that is, those notes that were part of a cluster, but had some relationship with another. For this task it was necessary to carefully read each one of the notes, and the one that showed some connection with a cluster different from its, was marked with the abbreviation of that one, as can be seen in *Appendix C.2*.

Clusters and relationships between them made it possible to identify the intensity of topics discussed during the interview, although there was a line drawn by the results presentation, this seems to be a good indicator of the participant's interests since during the interview she had full freedom to express her opinions without time limit. *Figure 10* shows a diagram where it is possible to see the clusters and relationships between them. The cluster size represents the intensity of the topic during the interview, and the density of the connector represents the intensity with which those topics were related during the interview.

Figure 10 Graphical representation of clusters and their relationships



Next, and according to the intensity of topics and links, a brief conclusion is presented for each of them, summarizing at the same time the findings of the retrospective interview. The number in parentheses represents the number of notes related to this:

- Notifications (9): many notifications are useless but generate distraction and greater use of the smartphone. Disabling them could improve her usage habits a bit.
- Applications (6): WhatsApp is very important in her work and personal life. Recognizes differences between active and passive use of applications.
- Applications & Devices (6): she is very clear about which applications wants to use on each device and, when they are available on both, how to use them on each one.
- Devices (5): willingness to use electronic devices, especially smartphone and laptop. Her willingness to use accessories is low.
- Places (5): pandemic affected her routine of being in many places, she has tried to accommodate herself, but it has not been easy.
- Others (5): Postural health and general well-being are important. The week of the study is a good sample of her current routine, but not her pre-pandemic routine.
- Usage times (3): she is aware of the time she spends working and using devices, but when she saw the results of the study she was a little worried, now she thinks that maybe she should spend less time on that.
- Postures (3): photographs in the study have made her aware of the need to improve her postures.
- Rests (3): although she has well-defined rest periods during the day, considers she should improve her habits in this regard.
- Stress (3): stress level is directly proportional to the intensity of work. Tuesday is the hardest day and Friday the mildest.
- Rests & Devices (3): usually she rests free from devices during her break times. She looks for strategies to rest body segments while uses devices.
- Symptoms & Devices (3): the use of devices and accessories generates musculoskeletal symptoms, although it depends on the situation.

- Symptoms & Stress (3): she is not sure if the stress level is directly associated with the presence of symptoms.
- Symptoms (2): the right arm is the most affected by symptoms. The menstrual period aggravates symptoms.
- Usage time & Devices (2): she is perfectly aware about the usage time of devices.
- Postures & Devices (2): she is more aware of her posture when using the laptop and much less when using the smartphone.
- Notifications & Devices (2): laptop use distracts her attention from smartphone notifications.
- Applications & Usage times (2): time measured for the use of the smartphone in phone calls seems to be poorly measured, it should be longer.
- Notifications & Usage times (2): a period of accumulation of notifications on the smartphone is followed by a prolonged period of use attending those notifications.
- Symptoms & Postures (2): recognizes the influence of posture on symptoms, when conscious, tries to correct it.
- Symptoms & Places (2): considers there is a direct relationship between the presence of symptoms and the place where she works. The desk is an especially awkward place.
- Stress & Rests (2): rest periods are very good for lowering stress levels.
- Stress & Devices (1): there seems to be a direct relationship between smartphone use and stress level.
- Notifications & Applications (1): when possible, she prefers to attend to WhatsApp notifications on the laptop.
- Notifications & Rests (1): turns off notifications at night to sleep better.
- Symptoms & Rests (1): a good rest reduces the likelihood of symptoms.
- Others & Devices (1): smartphone is used as a music player.
- Others and usage times (1): on Monday morning there is a long time of smartphone usage attending to weekend pending things.

4.3.7 CONTRASTING RESULTS

Each stages of the investigation had a different purpose and delivered its own results. Next, *Table 3* presents a brief parallel between these results, classified by stage and by topic, accompanied by a small conclusion about the coherence between them.

Table 3 Parallel between results obtained in each stage

Preparation	Study	Retrospective
Devices		
Mainly laptop and smartphone for work purposes. Little interest in using accessories and technologies.	Exclusive use of the laptop for work. Use of the smartphone associated with various activities. Reduced use of smart TV.	Willingness to use electronic devices, especially smartphone and laptop. Low willingness to use accessories.
Results are consistent, they do not present great differences.		
Places		
Mainly on a desk in the studio. Occasional changes to other parts of the apartment.	Exclusive use of the studio for work. The bedroom and living room are occasionally used as a workplace.	It has not been easy to adjust to working from the apartment. A desk is an especially awkward place.
Results are consistent; however, the retrospective interview shows a complementary emotional element.		
Rests		
One at morning (5 minutes, low quality), one at lunchtime (1-hour, good quality), one at afternoon (30 minutes, excellent quality).	The lunch break is the most punctual and longest duration. The afternoon rest is the best quality.	Need to improve the quality of breaks. Devices and their influence deteriorate the quality of rest.
The results are consistent and complementary. The study shows a more specific result and the retrospective interview shows a practical conclusion.		
Stress		
Exposure to a moderately high level of stress.	The stress level is not very high, but it is a little higher at night.	Stress level is directly proportional to the intensity of work
Results are consistent. The study and the retrospective interview show more specific results.		
Symptoms		
Mainly pain in the back and the right arm, but also in the shoulders and occasionally in the head.	Most of the pains were reported during periods of work at the desk: back, shoulders and right arm.	The right arm is the most affected by symptoms. Using devices and accessories generates musculoskeletal symptoms.
Results are consistent. The study and the retrospective interview show more specific results.		

Workday		
Variable working hours, but usually between 8 am and 8 pm, Monday through Friday.	Working hours between 8 am and 8 pm, Monday through Friday.	Worry about such a long working day.
Results are consistent; however, the retrospective interview shows a complementary emotional element.		

Usage times		
Nonspecific times. Laptop and smartphone on weekdays: 90% work, 10% leisure. Weekends only smartphone: 90% leisure, 10% work	Average daily use: smartphone 5.3 hours, laptop 5.7 hours. Average session time on smartphone: 8 minutes. Smartphone use on working days: 70% work, 30% leisure.	Phone calls seems to be poorly measured; time should be longer. Concern about prolonged use of devices.
Results are not contradictory, but the preparation did not offer very precise data. The retrospective interview shows a limitation in instruments and a complementary emotional element.		

Applications		
Laptop: PowerPoint, Zoom, Outlook, WhatsApp web. Smartphone: WhatsApp, Phone, Zoom, Gmail.	Laptop: WhatsApp web, PowerPoint, Zoom, Outlook. Smartphone: WhatsApp, Youtube, Facebook, Phone, Zoom.	WhatsApp is very important in work and personal life. Clarity about the best device for each application.
Results are consistent, they do not present great differences.		

Postures		
The most common position is sitting at the desk.	The most common position in photographs is sitting at the desk.	More awareness of posture when using the laptop and much less when using the smartphone. Need to improve postures.
Results are consistent. The retrospective interview shows a practical conclusion.		

Notifications		
Remarkable attention to smartphone notifications. Greater perception in visual notifications.	200 notifications on average per day. 75% of notifications are from WhatsApp. Only 5% of notifications are associated with leisure applications.	Many notifications are useless but generate distraction and greater use of the smartphone.
Results are consistent and complementary. The retrospective interview shows a practical conclusion.		

The preparation stage, the study and the retrospective interview offered consistent results between them. However, *Table 3* allowed to note that results of each stage have some particular features:

- In preparation stage, results are not so specific and are closely associated with the participant's perceptions and assumptions.

- The study offered quantifiable and precise results, but with little context.
- Results from the retrospective interview enriched the study data with context and allowed to recognize some concerns and emotions of the participant.

Although a limitation was detected in the instrument used in the smartphone interaction log (poor measurement of telephone call times, probably due to screen off), it is possible to affirm that good decisions were made regarding the investigation stages and the instruments.

4.4 DISCUSSION OF THE RESULTS

The participant selected as study subject has a precedent that made her particularly interesting for the purpose of this research, she had been diagnosed a couple of years ago with cervicalgia and paresthesia in the upper limbs, apparently related to the use of electronic devices, that is, she is directly affected by postural health problems. During the study, the only symptom reported was pain, which has been classified as the most relevant and frequent (Berolo et al., 2011; Betsch et al., 2021; Cevik et al., 2020; Kim & Koo, 2016; Korpinen et al., 2018; Worawat Lawanont et al., 2018; M. Lee et al., 2015; Sahu et al., 2021; Soyer & Akarirmak, 2020; Syamala et al., 2018; Tapanya et al., 2021; Zindahi et al., 2020; Zirek et al., 2020), and the most affected body segments were the back, shoulders and right arm, usually identified with prevalence around 39%, 78% and 33% respectively (Toh et al., 2019; Woo et al., 2016). On the other hand, it was very interesting to observe that physiological effects of the menstrual period aggravated the symptoms, a finding that could be an object of study in another research.

The study showed a participant using the smartphone for more than 9 hours in a day, with a daily average around 5.3 hours, which means a high risk of suffering musculoskeletal pain, especially in the neck and shoulders (Xie et al., 2017), as it happened. However, this risk could be minimized by two adjacent factors: the average time of each session on the smartphone was estimated at 8 minutes, 2 minutes below the thresholds for discomfort (Toh et al., 2017) and fatigue (Kim & Koo, 2016), and the healthy routine of 3 daily breaks, which may still be of higher quality and frequency, but it certainly represents a relief to musculoskeletal overloads (Tang et al., 2021; Xie et al., 2017).

From the participant's reports and photographs, it was evident that her most frequent position is sitting (63%), and more precisely at desk (52%), which represents another risk of suffering discomfort and pain (S. Lee et al., 2015; Soyer & Akarirmak, 2020; Syamala et al., 2018; Thorburn et al., 2021; Toh et al., 2017; Yoon et al., 2020). In fact, from that place and position, she reported most of the symptoms. Although the desk chair seems to have good arm and back support characteristics, the participant acknowledges that she has not used it correctly, which could help her to minimize the negative effects of the sitting position (Syamala et al., 2018; Tang et al., 2021; Yoon et al., 2020). Photographs also show the inclination of her neck with respect to the upper back axis is not the most appropriate and becomes an overload to the neck structure (Kataria, 2018; Ramnaath et al., 2020; Tapanya et al., 2021; Zindahi et al., 2020). However, for this study there were no appropriate instruments to make a precise measurement in this regard, which is why it is included only as an observation.

About the tasks performed by the participant on the smartphone during the study there are several considerations to mention. First, considering the classification made by Betsch et al. (2021) about applications as active or passive according to the demand for user interaction with the smartphone, and taking into account that the passive ones do not represent a musculoskeletal overload, the possibility could be considered for this study of removing the time of use of some applications as a risk factor: YouTube and Zoom, which represent about an hour a day on average, and the participant stated that they are applications that usually do not require significant physical interaction.

On the other hand is WhatsApp, which is undoubtedly the most used application by the participant and which could be considered as a texting task, which is one of the actions that generates such muscular demand that it can cause pain and discomfort in many body segments (Betsch et al., 2021; S. Lee et al., 2015; Soyer & Akarirmak, 2020; Tapanya et al., 2021; Toh et al., 2017; Xie et al., 2017; Yang et al., 2017; Yoon et al., 2020; Zindahi et al., 2020). However, from the photographs and the retrospective interview there are serious indications that the activity on WhatsApp should be measured and classified into different actions: reading, texting, recording and listening to audio messages, reviewing and sharing images and videos, all these tasks require different physical efforts and it does not seem correct to classify the use time of this application as texting time.

Finally, the instrument for measuring user interaction times with the phone has a flaw that ruined the measurements of call times: it only measures while the screen is on and during calls it is usually off. It is not a minor defect if it is considered that attending telephone calls is a risk factor for postural health (Berolo et al., 2011; Soyer & Akarirmak, 2020; Xie et al., 2017) and that, according to the participant's comments, a correct measurement could add almost an hour to the average daily use of the telephone. Although the participant's good habit of always using hands-free during calls could reduce this risk.

The participant thinks the smartphone is a very important tool for her work and this is evident in the study, she not only uses it to communicate by voice and text messages, but also to share information in documents, images, videos, etc., and to attend many video conferences, that is, her level of dependence on the telephone is high, which necessarily implies a prolonged use (Risko & Gilbert, 2016) and greater attention to notifications. It could also be noted that the level of stress is a variable linked to the intensity of work and the time of use of the telephone, although the scope of this study does not allow affirmations about the correlation between all of them, the observations allow to suppose that the intensity of work is the independent variable and the use of the smartphone and the level of stress are the dependent variables. One of the details offered by the study on the participant's initial impressions is that, although it is true that she uses the smartphone mainly for work, her estimate of use for leisure was undervalued by 10% while the interaction log allowed calculating 30%, although it is not disproportionate (Berolo et al., 2011; Korpinen et al., 2018; Roslizawati & Isyan Farahin, 2021; Toh et al., 2020; Yang et al., 2017), this gap should not be viewed with indifference because for Facebook - which is the participant's main leisure application - the average duration of each session is 13 minutes, 3 minutes above the thresholds for discomfort (Toh et al., 2017) and fatigue (Kim & Koo, 2016).

Having received medical attention and advice about her postural health problems has slightly improved the participant's level of postural awareness, but the study reveals that it is not enough, as can be seen mainly in the photographs in which she normally appears in an inappropriate neck and back tilt angles, which could eventually lead to worse symptoms than reported. An important factor so that the participant's symptoms are not more intense and frequent is probably the fact that she maintains a routine of daily physical activity, which improves her body's willingness to tolerate postural overloads (Woo et al., 2016).

Finally, one of the most important results of this study is to have identified the convenience of keeping the participant within her usual environment, in which relevant elements can be recognized that in isolation would go unnoticed. For the purposes of this study, it was valuable to recognize that laptop use is an aggravating factor in postural health problems generated by poor smartphone use habits. Although it was not on purpose, few studies were included in the literature review that cared about incorporating additional devices to smartphones (Thorburn et al., 2021; Toh et al., 2020; Nguyen et al., 2017; Toh et al., 2017; Woo et al., 2016), but fortunately they were enough to contribute to the decisions made for the execution of this study, in whose results it can be seen that an average daily use of the laptop of 5.7 hours represents an important influence. In particular, the participant in this study is not very fond of using many devices and that is the reason why only the laptop and the smart TV are mentioned, but in other scenarios it could represent a huge difference, for example, when studying the isolated use of the smartphone by a user who usually uses a smartphone, tablet, laptop, smart watch, etc. Artifact ecologies are now a reality in user contexts and should be considered in studies like this one.

5 Implication for Design

So far, this thesis has presented a documentary and practical research process that has provided valuable information on postural health problems in mobile interaction. However, the purpose of this work is to synthesize all these findings in a set of implications for design that help to make all these discoveries visible, in such a way that they can contribute effectively in some process of conceptualization and design. It is an idea very close to what some authors call a design opportunity space (Sanders & Stappers, 2013), but this time it will be linked from the beginning to design restrictions, as can be seen in *Table 4*.

5.1 Opportunities and Restrictions

The study allowed to know the context in which the participant uses the smartphone and from this to identify some elements that may be useful when proposing a user-centered intervention. Not only risk factors with the greatest presence in the participant's daily routine were detected, but also some elements that can be used as opportunities for design and some restrictions, without which any good intention of a proposal could crash with user's reality and fall into disuse due to a poor understanding of the context of use. *Table 4* summarizes these findings and works as a first roadmap for a conceptualization and design process.

As can be seen in *Table 4*, of all the risk factors identified in the literature review, only 5 were considered relevant for the study participant, and any intervention proposal should focus on minimizing the impact of these specifically. It is probably not very realistic to aspire to a solution proposal that attempts to attack all the risk factors, but the option that represents the best balance should be sought, neutralizing the adverse effects, making use of the opportunities offered by the participant's context and considering the restrictions such as design limitations.

Data in *Table 4* allows to obtain some keys about the viable alternatives to propose a design:

1. Intervening directly on usage time or posture means facing greater restrictions.

2. An intervention focused on tasks, supports or rests would find fewer restrictions.
3. There are common design opportunities in several risk factors (see common symbols):
    a. Intervening in tasks could result in a reduction in usage time.
    b. Intervening the supports could result in a better posture.

Table 4 Opportunities and restrictions according risk factors.

RISK FACTORS		OPPORTUNITIES		RESTRICTIONS
Usage time	1	❖ Reducing the number of notifications.	1	High dependency due work activities.
	2	➢ Reducing time spent at leisure (Monday to Friday).	2	Alternative device (laptop) with high usage.
			3	Long sessions of continuous work.
Posture	3	○ Photographs improve postural awareness.	4	Low willingness to use body sensors and accessories.
	4	★ Desktop centered.	5	Long work sessions in the same position.
	5	Willingness for physical activity.	6	Few alternatives to change the workplace.
	6	Freedom to change workplace.		
Tasks	7	Willingness to execute the same task from different devices.	7	WhatsApp is indispensable.
	8	❖ Small group of highly important tasks.		
	9	➢ Limiting the use of applications dedicated to leisure.		
Support	10	Preference for chairs with armrests.	8	Limited to one workplace.
	11	★ Desktop centered.		
	12	○ Improving postural awareness		
Rests	13	Willingness to take breaks.	9	Long sessions of continuous work.
	14	Denying the use of devices during break times.		

Keeping restrictions in view always keeps a design team in a state of thought and caution. Many ideas can be interesting, realistic, efficient, etc., but if they are set aside from the reality of the user, they will be in danger of being rejected. The results of this study offer many keys that cannot be ignored if what is intended is to adequately meet the needs of the study subject in improving their postural health:

- Due to her current work-at-home context, the participant is highly dependent on smartphone and laptop use throughout her working day, and there is no realistic alternative to changing the length of the working day or the devices she uses.
- Due to the high use of the laptop, this device does not seem a good option to discharge the use of the smartphone. In fact, several tasks are performed almost simultaneously on the two devices.
- Due to the participant's low preference for using accessories and wearables, any intervention that claims to be efficient and transcendent over time should avoid the use of this type of artifact, or at least consider this restriction to accompany the intervention with some process of training, awareness, adaptation, etc.
- Because the participant must attend many video conferences (usually one hour long), and that limits her possibilities of movement or change of position in those periods of time, an intervention could not be based on the strict requirement of something like this.
- Because her work and social circle uses WhatsApp as the main tool to communicate and share content, any proposed intervention must consider this condition and in no way could affect the fluid and continuous use of that application.

Although some restrictions are stronger than others, they should not be understood as the walls of a fortress that cannot be overcome, it only means that they must be assumed with greater care and in some cases complemented with some pedagogical strategy. Restrictions are often the biggest design challenges. On the other hand, design opportunities cannot be lightly viewed as easy and obvious elements either, because overconfidence can cause a disaster in a design in which all the implications have not been analyzed in detail. Finding the balance seems to be the key point.

6 Discussion

A discussion of the results will not be presented in this section, as it has already been a topic covered. Instead, it will present some reflections on the procedure developed during this study.

Does the sample size matter? It depends. This was the first great question that arose and required the advice of the supervisor of this work and several authors. Although there is no definitive consensus, the answer seems to be that the sample size does matter according to the purpose of the study, that is, when a rigorous statistical analysis is to be carried out, it will be very important to have a sufficiently large sample size so that it allows to find trends and patterns. However, when what is being sought has to do with human behavior, the researcher must be aware that the more he/she wants to inquire about the real context of people, the greater the effort and the necessary resources will be if he/she also wants to maintain a significant size sample. On the other hand, and continuing with human behavior, a small sample, even a unit sample, can become relevant for a pilot or exploratory study - like this one - that aims to achieve findings within the daily routine of people, and much more when resources for research are limited. And that was precisely the reason why an ethnomethodological approach was so convenient for this study, because it did not aim to find results from a statistical analysis, but was aimed at looking for elusive elements that can only become visible when the observation concentrates on the usual and small details of daily life.

About the study, it is possible to mention that the exercise of inviting the participant to co-design it was very enriching. The research had a clear purpose and there were essential requirements that were not negotiable, but there were also elements that allowed some flexibility and it was precisely there where the cooperation of the participant was important. As it was a study based on the follow-up of the participant's behavior for 7 days, 3 times a day, it was absolutely pertinent to have her approval and agreement on the way in which the instruments would be used, in such a way that she would never feel invaded in her privacy, uncomfortable or pressured. Based on the participant's comments during the retrospective interview, the diary study was very appropriate and comfortable for her. Usually, she forgot that she was being studied and never felt the need to change anything in her behavior because of it. She was not aware of the photographs and did not feel uncomfortable knowing that a researcher was monitoring her activities on the smartphone and laptop, however, she claims that it would not have been the case if she had not been confident enough with the observer. She really liked the form design because she was able to answer it quickly, and believes it was a great idea to have previously agreed with her on the study design because she felt integrated, engaged and comfortable. There were no negative comments or suggestions, which also means a success for this study.

Although the study was very focused on understanding the elements associated with postural health problems in mobile interaction, during the development and obtaining of the results, it was evident that it is not totally correct to isolate the user-smartphone interaction from the rest of the user interactions, especially with other electronic devices. When looking at the results of the interaction log, it was clear that the contribution of the use of the laptop to the musculoskeletal load of the participant is significant. Taking into consideration only the smartphone's interaction log would have provided a reduced view of the participant's reality and would have generated a significant gap in the implications for design. This reflection implies a necessary doubt around the discoveries presented in the papers focused on postural health problems, in whose studies the smartphone was isolated and identified as the only suspect.

7 CONCLUSION

Each of the stages that made up this work offered complementary outputs and conclusions giving cohesion to the final result presented in this thesis.

From the review of the literature, it was possible to understand much more about the existence, prevalence and severity of postural health problems caused by bad habits of smartphone use; the variety of risk factors is very wide, which means most of the users are exposed to several of them and in cases where they are not adequately intervened, the consequences can be severe and regrettable. Some interventions have been proposed from different approaches, but there are really few that have been supported by adequate user research. The latter became a motivation for this study.

Instruments used were divided into three stages that were essential for the successful completion of this work. First, a semi-structured questionnaire helped to have a preliminary understanding of the participant's context and based on this and with the participant's cooperation, the diary study was designed with better support. Then 4 instruments were applied at the same time for 7 days: a form to collect the participant's reports, a smartphone interaction log, a laptop interaction log and, as a partial shadowing study strategy, a photographic record was collected. Finally, a retrospective interview with the participant helped to contextualize all the numerical data that had been collected, but that did not show much about the participant's intentions and emotions.

The nature and variety of the data facilitated the observation of different aspects of the participant's daily routine, not only in her interactions with electronic devices, but also in some of her personal and work life habits.

In the end, all the results were used in a practical exercise to present implications for design, in which the different opportunities and restrictions that should be taken into account to the design of an intervention are considered, according to the risk factors which the participant is exposed.

The procedure carried out demonstrated the relevance of user research to formulate implications that function as guides in the conceptualization and design of interventions aimed at minimizing the adverse impacts of risk factors on postural health in mobile interaction and is presented as an example of research for user-centered design to depart from speculative design processes, devoid of argument and support.

7.1 LIMITATIONS

This study was carried out in its entirety during the health crisis generated by the Covid-19 pandemic, which can be understood as a limitation in itself due to the social restrictions it generated. However, with an optimistic outlook, it could be understood as an opportunity that made it possible to adapt the approach and scope to circumstances that were also very interesting. The same could be said of a unit sample for research, but as it was a pilot, exploratory study with an ethnomethodological approach, the sample size was convenient.

In the instrument used to record the interaction on the smartphone, an important limitation was detected: it only measured the usage times while the screen was on, and since the screen is usually off during calls, this measure has a high degree of uncertainty. This limitation was discovered and counteracted thanks to the clarifications of the participant during the retrospective interview.

7.2 FUTURE WORK

The results of this study showed the potential and importance of an ethnomethodological approach to find particularities in the daily interactions of a person with different electronic devices. The initial goal was focused on the smartphone, but interactions with the laptop ended up being relevant as well.

Based on what was learned in the development of this study, future work should focus on knowing and understanding the elements associated with postural health problems caused by bad habits in the use of electronic devices and the way in which each of them contribute to the problem, assuming that users are now not interacting with isolated devices, but with an increasingly integrated ecology of artifacts and technologies.

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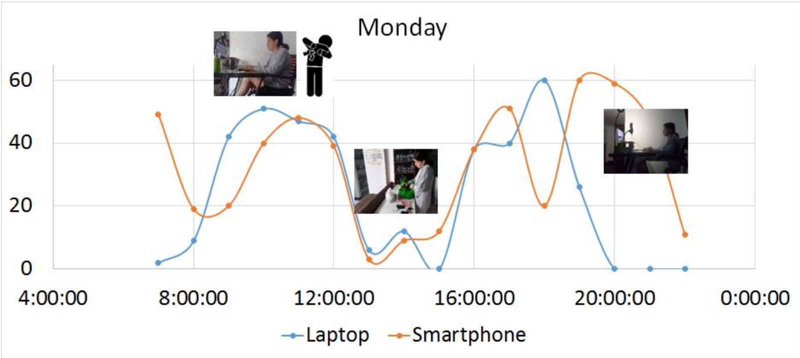
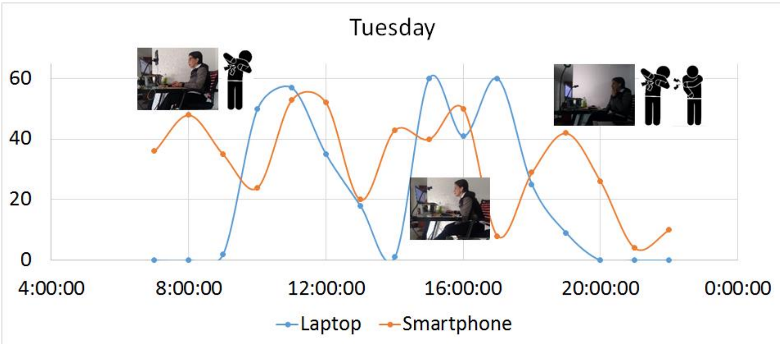
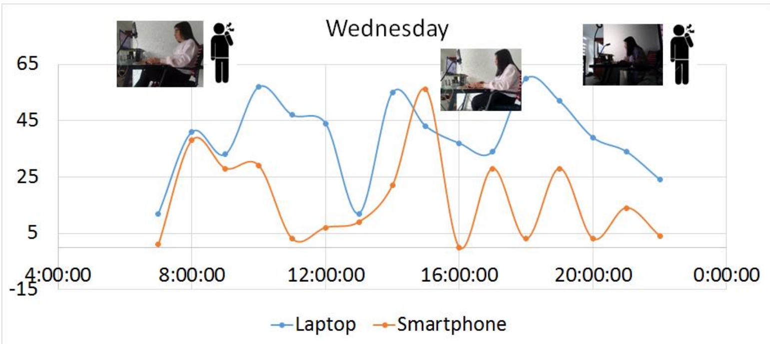
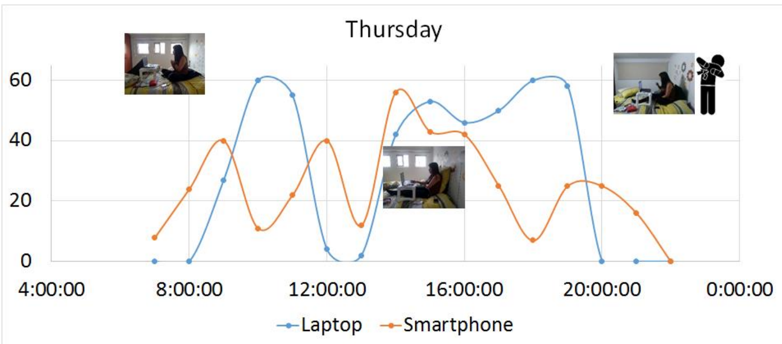
A. APPENDIX A

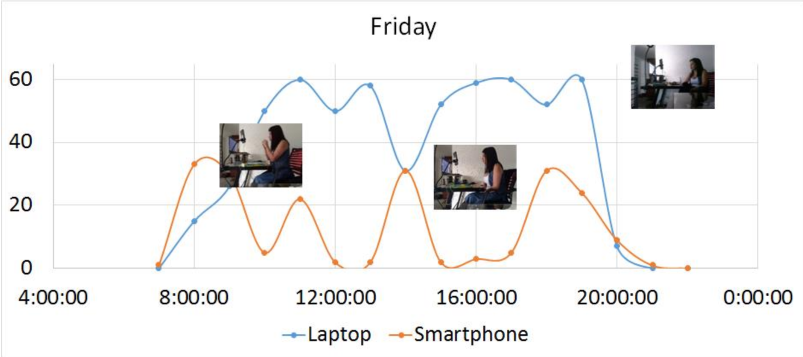
Study timeline

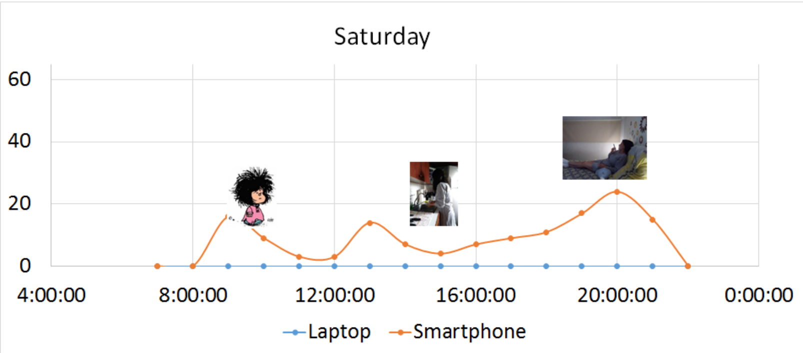


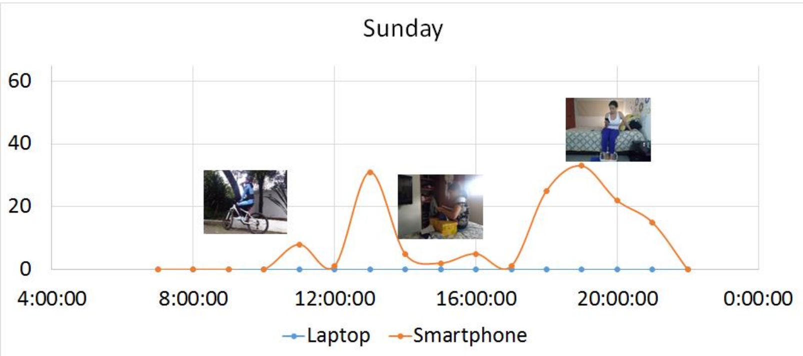






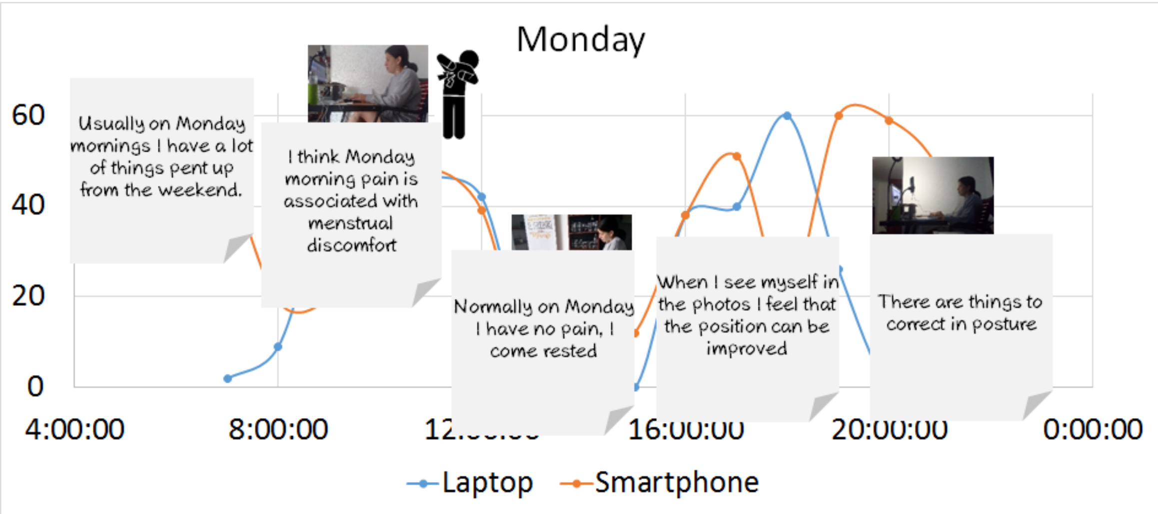

Friday
60
40
20
0
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
Laptop
Smartphone

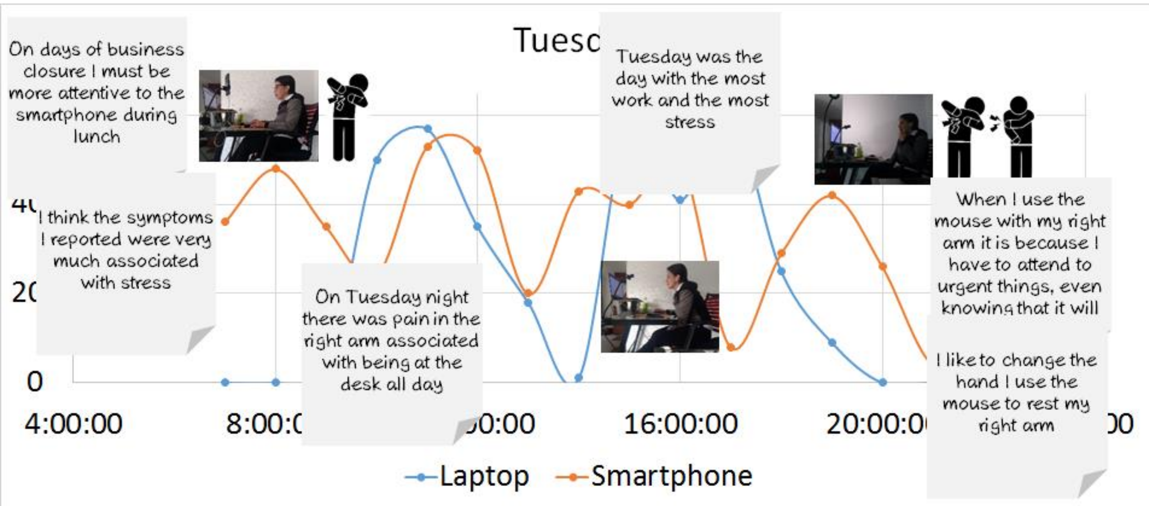

Saturday
60
40
20
0
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
Laptop
Smartphone

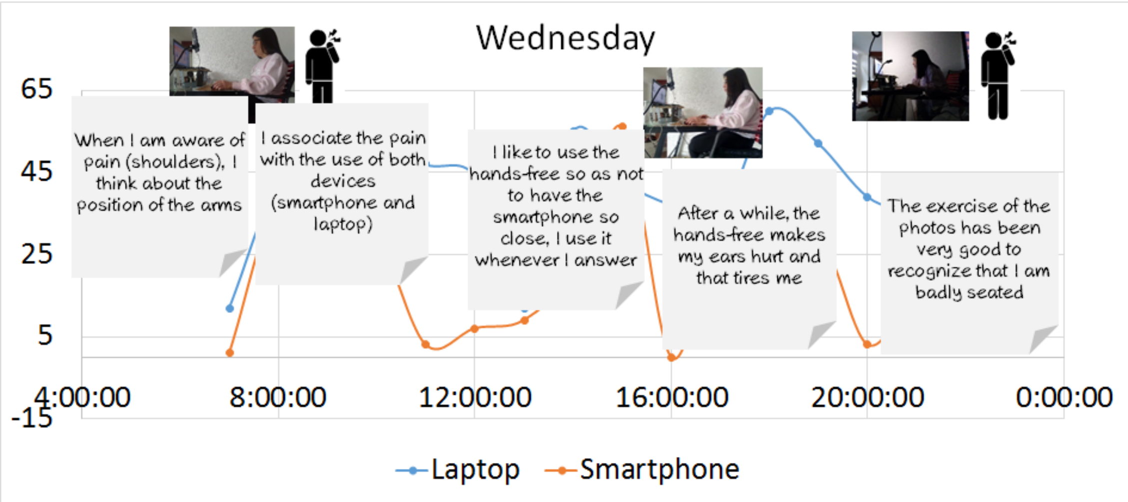

Sunday
60
40
20
0
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
Laptop
Smartphone

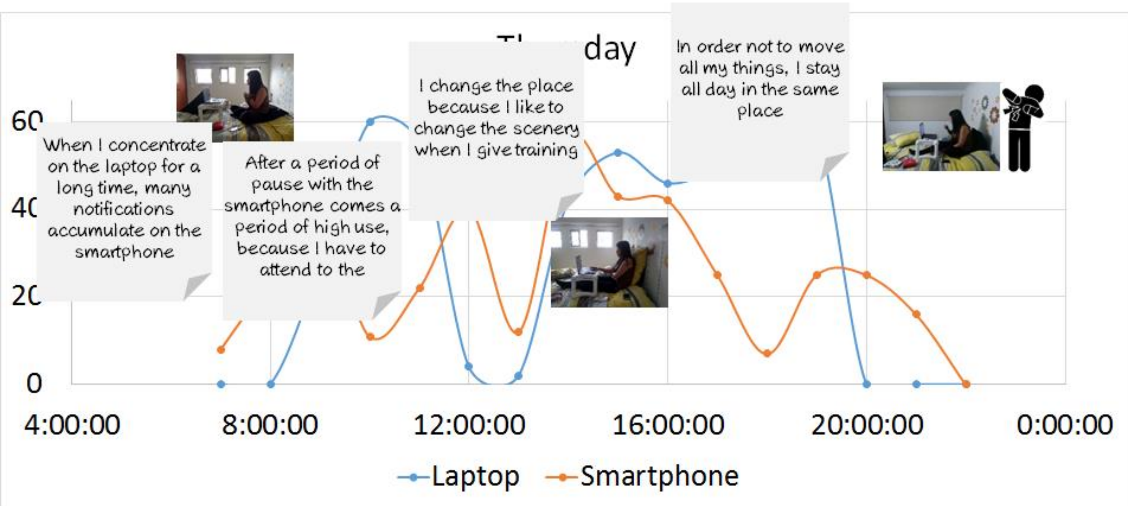
B. APPENDIX B

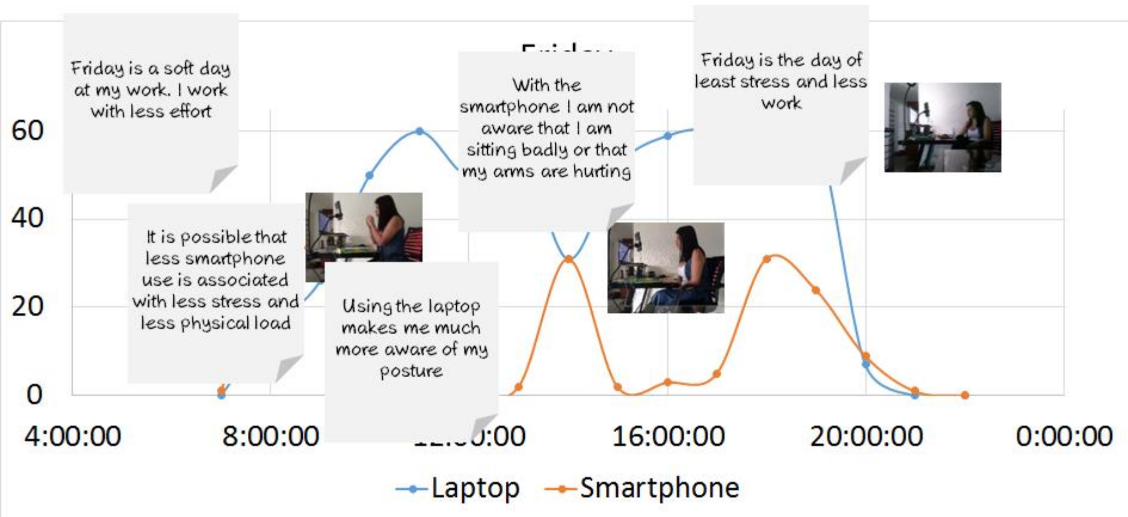
Collages with notes on screenshots

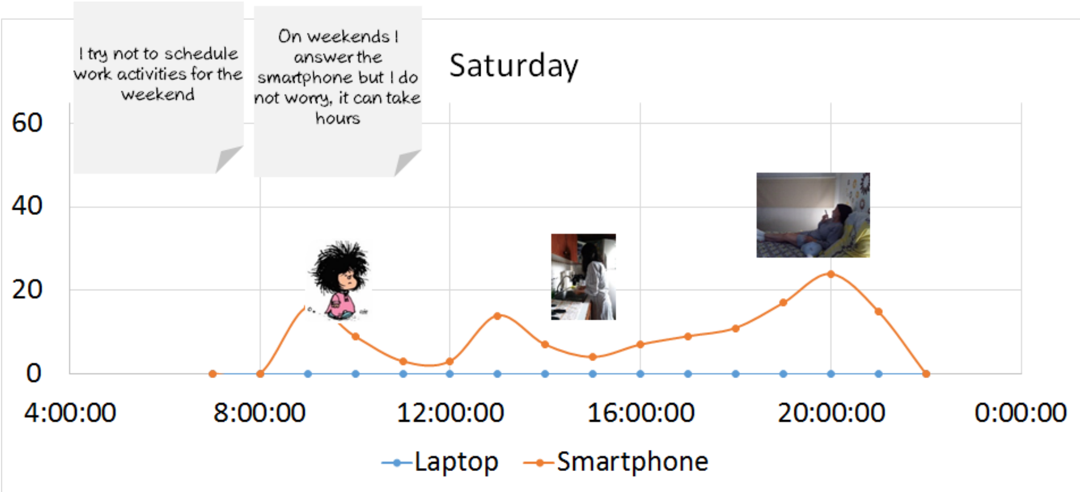


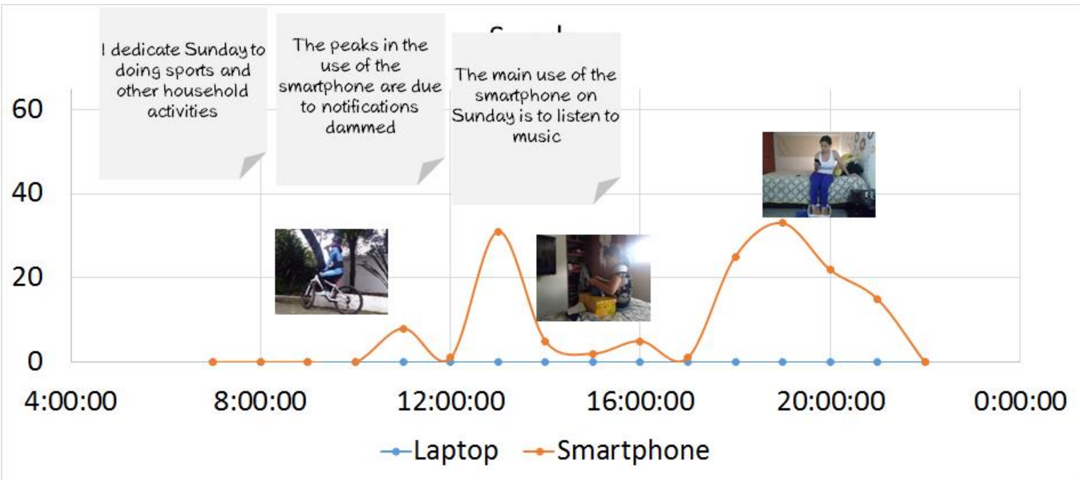


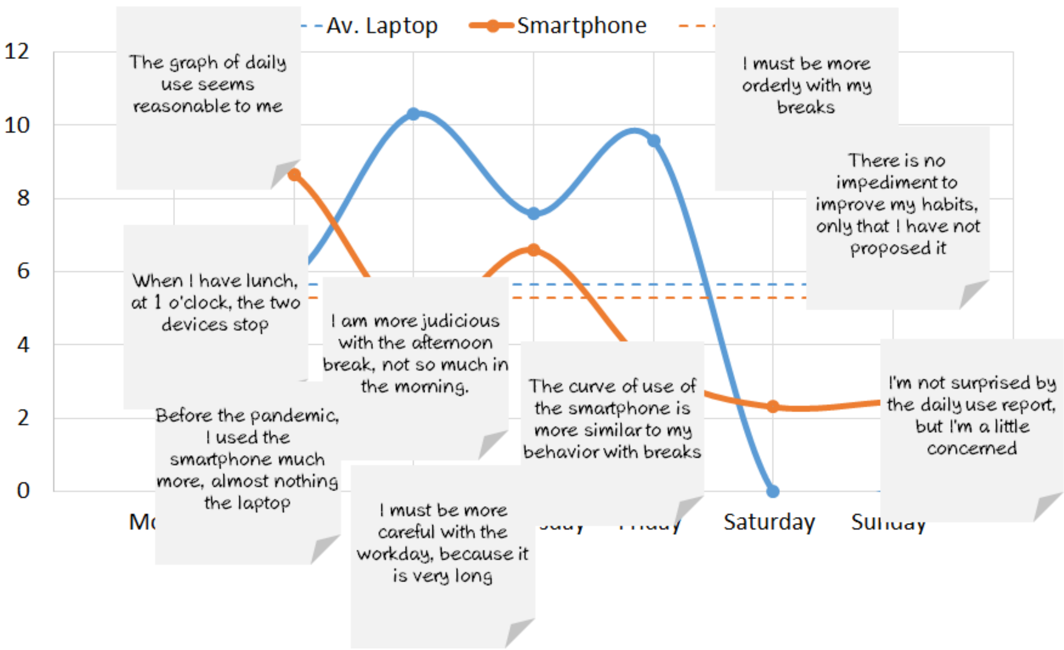

Wednesday
65
45
25
5
-15
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
When I am aware of pain (shoulders), I think about the position of the arms
I associate the pain with the use of both devices (smartphone and laptop)
I like to use the hands-free so as not to have the smartphone so close, I use it whenever I answer
After a while, the hands-free makes my ears hurt and that tires me
The exercise of the photos has been very good to recognize that I am badly seated
Laptop
Smartphone

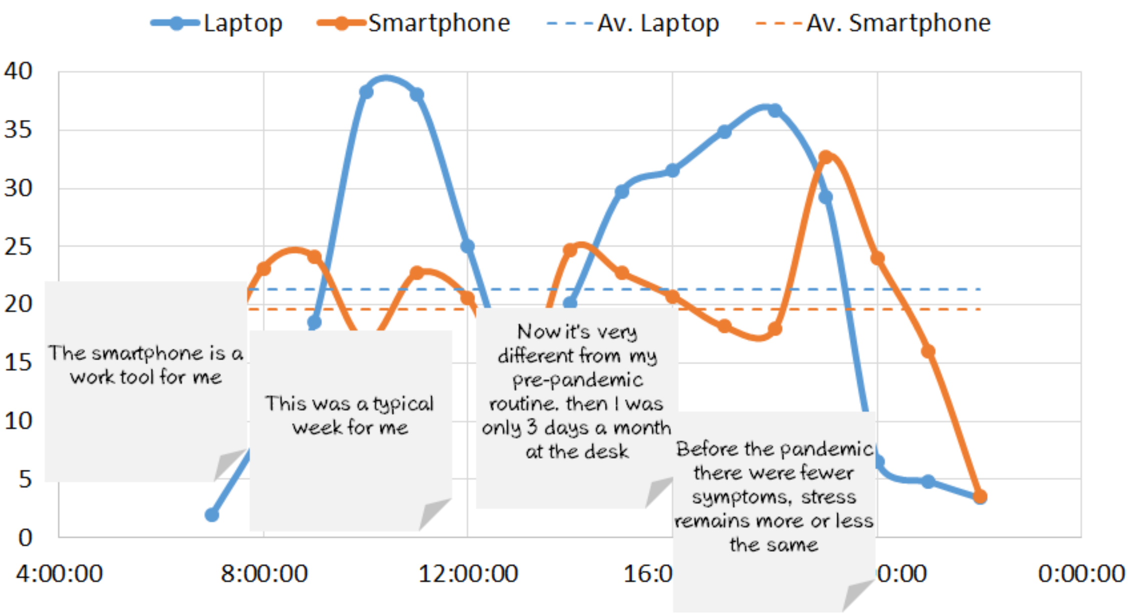

60
40
20
0
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
When I concentrate on the laptop for a long time, many notifications accumulate on the smartphone
After a period of pause with the smartphone comes a period of high use, because I have to attend to the
I change the place because I like to change the scenery when I give training
In order not to move all my things, I stay all day in the same place
Laptop
Smartphone

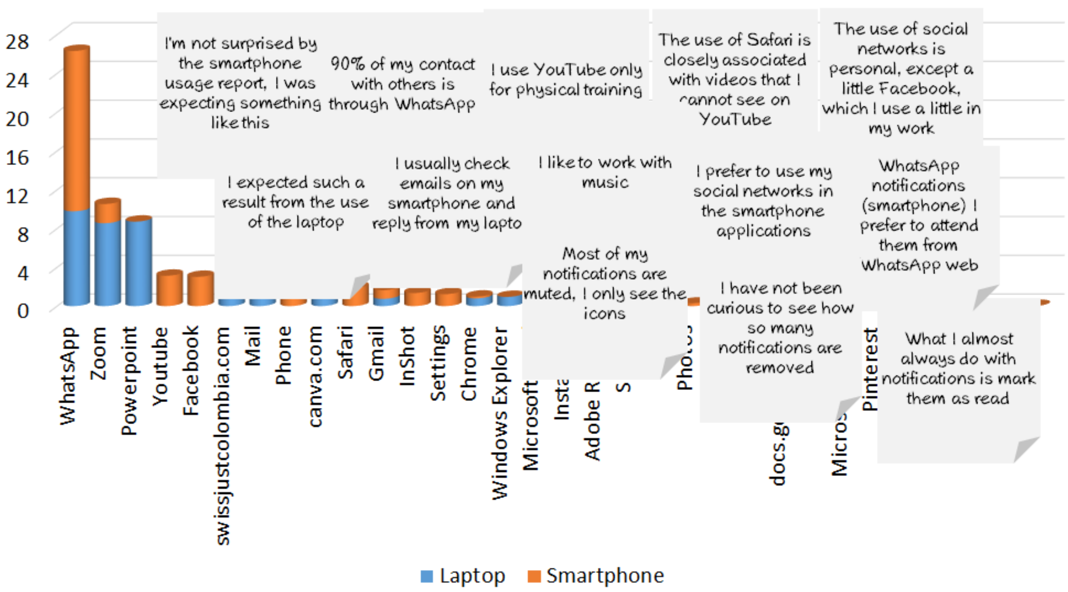

60
40
20
0
4:00:00
8:00:00
16:00:00
20:00:00
0:00:00
Friday is a soft day at my work. I work with less effort
It is possible that less smartphone use is associated with less stress and less physical load
Using the laptop makes me much more aware of my posture
With the smartphone I am not aware that I am sitting badly or that my arms are hurting
Friday is the day of least stress and less work
Laptop
Smartphone

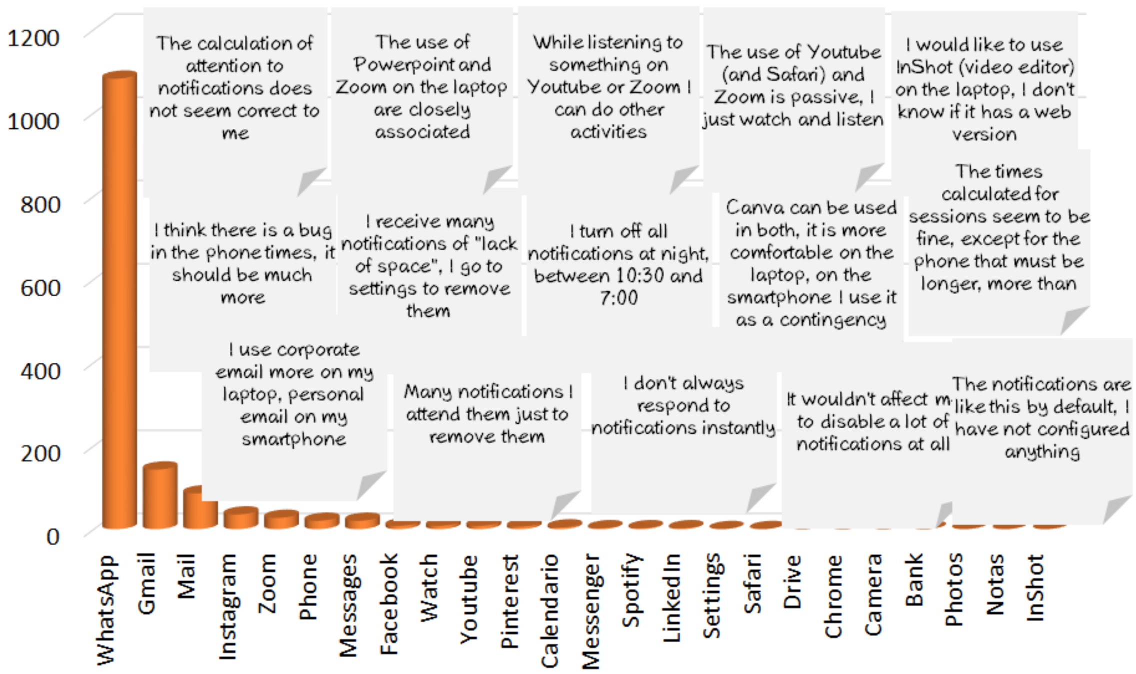

I try not to schedule work activities for the weekend
On weekends I answer the smartphone but I do not worry, it can take hours
Saturday
60
40
20
0
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
Laptop
Smartphone


I dedicate Sunday to doing sports and other household activities
The peaks in the use of the smartphone are due to notifications dammed
The main use of the smartphone on Sunday is to listen to music
60
40
20
0
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
Laptop
Smartphone

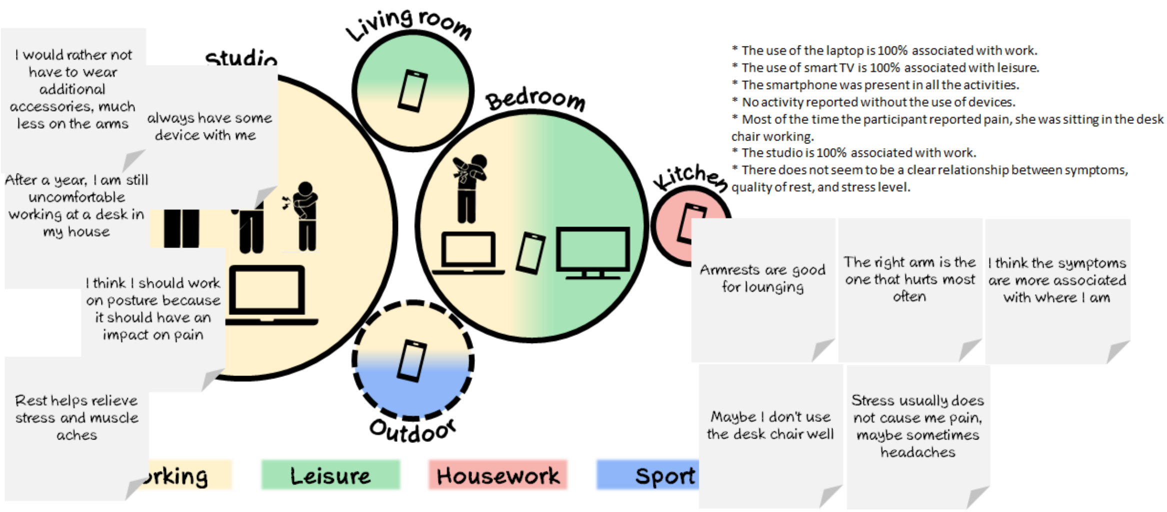

Av. Laptop
Smartphone
12
10
8
6
4
2
0
The graph of daily use seems reasonable to me
I must be more orderly with my breaks
There is no impediment to improve my habits, only that I have not proposed it
When I have lunch, at 1 o'clock, the two devices stop
I am more judicious with the afternoon break, not so much in the morning.
The curve of use of the smartphone is more similar to my behavior with breaks
I'm not surprised by the daily use report, but I'm a little concerned
Before the pandemic, I used the smartphone much more, almost nothing the laptop
I must be more careful with the workday, because it is very long
Saturday


Laptop
Smartphone
Av. Laptop
Av. Smartphone
40
35
30
25
20
15
10
5
0
4:00:00
8:00:00
12:00:00
16:0
0:00
0:00:00
The smartphone is a work tool for me
This was a typical week for me
Now it's very different from my pre-pandemic routine. then I was only 3 days a month at the desk
Before the pandemic there were fewer symptoms, stress remains more or less the same


28
24
20
16
12
8
4
0
WhatsApp
Zoom
Powerpoint
Youtube
Facebook
swissjustcolombia.com
Mail
Phone
canva.com
Safari
Gmail
InShot
Settings
Chrome
Windows Explorer
Microsoft
Insta
Adobe R
docs.g
Pinterest
I'm not surprised by the smartphone usage report, I was expecting something like this
90% of my contact with others is through WhatsApp
I use YouTube only for physical training
The use of Safari is closely associated with videos that I cannot see on YouTube
The use of social networks is personal, except a little Facebook, which I use a little in my work
I expected such a result from the use of the laptop
I usually check emails on my smartphone and reply from my lapto
I like to work with music
I prefer to use my social networks in the smartphone applications
WhatsApp notifications (smartphone) I prefer to attend them from WhatsApp web
Most of my notifications are muted, I only see the icons
I have not been curious to see how so many notifications are removed
What I almost always do with notifications is mark them as read
Laptop
Smartphone



1200
1000
800
600
400
200
0
WhatsApp
Gmail
Mail
Instagram
Zoom
Phone
Messages
Facebook
Watch
Youtube
Pinterest
Calendario
Messenger
Spotify
LinkedIn
Settings
Safari
Drive
Chrome
Camera
Bank
Photos
Notas
InShot
The calculation of attention to notifications does not seem correct to me
The use of Powerpoint and Zoom on the laptop are closely associated
While listening to something on Youtube or Zoom I can do other activities
The use of Youtube (and Safari) and Zoom is passive, I just watch and listen
I would like to use InShot (video editor) on the laptop, I don't know if it has a web version
I think there is a bug in the phone times, it should be much more
I receive many notifications of "lack of space", I go to settings to remove them
I turn off all notifications at night, between 10:30 and 7:00
Canva can be used in both, it is more comfortable on the laptop, on the smartphone I use it as a contingency
The times calculated for sessions seem to be fine, except for the phone that must be longer, more than
I use corporate email more on my laptop, personal email on my smartphone
Many notifications I attend them just to remove them
I don't always respond to notifications instantly
to disable a lot of notifications at all
The notifications are like this by default, I have not configured anything



Living room
Studio
Bedroom
Kitchen
Outdoor
Leisure
Housework
Sport
I would rather not have to wear additional accessories, much less on the arms
always have some device with me
After a year, I am still uncomfortable working at a desk in my house
I think I should work on posture because it should have an impact on pain
Rest helps relieve stress and muscle aches
* The use of the laptop is 100% associated with work.
* The use of smart TV is 100% associated with leisure.
* The smartphone was present in all the activities.
* No activity reported without the use of devices.
* Most of the time the participant reported pain, she was sitting in the desk chair working.
* The studio is 100% associated with work.
* There does not seem to be a clear relationship between symptoms, quality of rest, and stress level.
Armrests are good for lounging
The right arm is the one that hurts most often
I think the symptoms are more associated with where I am
Maybe I don't use the desk chair well
Stress usually does not cause me pain, maybe sometimes headaches

C. APPENDIX C

Clusters

C.1 CLUSTERS FORMED WITH THE INTERVIEW NOTES

C.2 Links Between Clusters