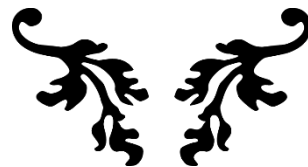# COMPUTER-BASED PAIN DIARY

REPORT SUBMISSION AS A REQUIREMENT FOR THE "MASTER'S PROJECT INVESTIGATION"

MSc DEGREE IN DATA ANALYSIS
AT THE SCHOOL OF COMPUTING
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Supervisor DR. Roger McDermott

Declaration

I confirm that the work contained in this MSc project report has been composed solely by myself and has not been accepted in any previous application for a degree. All sources of information have been specifically acknowledged and all verbatim extracts are distinguished by quotation marks.

Signed: <u>Rafael Castillo</u>   Date:<u>27/05/2021</u>

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I want to thank my supervisor, Dr Roger McDermott, for his support, comfort, patience, and attention he dedicated to me during my first few years at university and during this project; I respect him and am grateful to had him as a teacher at the beginning and as a supervisor at the end of my academic journey at Robert Gordon University.

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Abstract

Chronic pain is one of the most suffered conditions in the world as 1 in 5 people have it. Many problems arise not just for chronic pain patients but also for pain specialists and people around them. There are many existing methods to help chronic pain patients, and the most useful is pain management. The investigation found many pain management solutions, the most popular one being Pain diaries, which record patients' pain episodes and eliminate the memory bias problem. This investigation concluded that computer base diaries are better than paper-based diaries. The investigation found that computer-based solutions addressed the following issues: core functionalities to manage pain, valuable statistics, patient's cultural needs, accessibility and compliance. The investigation also found gaps that have not been addressed by any solution: There is no support for patients and their significant ones or their pain specialists regardless of the many benefits. Also, most of the solutions found on the app's stores are not validates or designed by pain specialists.

This investigation aims to construct a pain management prototype that includes core functionalities and covers one of the gaps found during the investigation.

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Chapter 1

1.1 Introduction

This chapter will discuss the motivation behind this project and the objectives that the project aims to achieve. This section also included the project scope, which contains important information about the limitations of this paper. The research methodologies for this investigation will also be discussed in this section.

A section containing a review of each of the papers read, including citation, relevance and reason for inclusion, can also be found at the end of this section. The last section contains the report structure, which explains the information contained in each chapter of the report.

1.2 Motivation

Chronic pain affects one in every five people and is the primary cause of disability and absence in the workplace. Paper-based and Smartphone solutions exist to deal with pain management, but most of the sources contemplating this topic ask for more research on the field, hence the motivation to review existing systems and find gaps to build a novel prototype for managing chronic pain and contribute to the field.

1.3 Project Objectives

- Research current pain assessment and management techniques; compare and contrast these techniques and find strong features or gaps to improve existing ones.
- Construct a piece of software "prototype" that would allow a user to record subjective numerical levels of pain daily and input subsidiary information such as activity levels, pain location, medication between others.
- Explore UX-HCI techniques to develop an interface to allow a user to input information in an appropriate manner.
- Analyse the data over a specified period and display graphs of data and textual information about user input variables.

1.4 Project Scope

The time constraint for this project investigation is of 6 weeks. Due to the short time, the computer-based solution built during this project will stay at the prototype stage and will not be tested nor published. The prototype is aimed as a phone app, but it will be developed also for computers, this project will take care of the computer version and not the phone app yet.

During this time project will research methodologies to assess and manage chronic pain. The goal is to build enough knowledge to recognise and understand the main problems involved with the topic and potential solutions. Furthermore, existing systems will be analysed, core features and gaps will be identified, and selected problems will be addressed.

This project does not plan on fixing all the problems involved with chronic pain management systems. Instead, the project will select problems based on their complexity in order to build a solution that addresses the selected problems and can be delivered within the deadline of this project.

1.5 Research Methodology

The assessment of chronic pain is one of the most challenging problems in the health care system due to its subjective nature, and there is not much research about the use of phone applications for this topic. Due to this problem, most of the paper found were through citation of other papers. The papers in which citations were explored were found with the following search queries "Methods for chronic pain assessment", "Smartphone chronic pain management", as well as "Smartphone pain diary". In order to label a paper as valuable, the search criteria used are listed below.

1. The paper belongs to a reliable source
2. The number of citations was considered
3. The paper's content has insights or desirable features for pain assessment techniques.
4. The paper contained basic information about pain, chronic pain, pain assessment tools, smartphone solutions for pain management, and paper-based solution for pain management to create a case for the project and back up claims.

The search engine used to find the papers was google scholar. This search engine allows only credible and scholarly material, and the database is a citation index, allowing the search of articles that have been cited multiple times by other people.

The papers were filtered by analysing the paper's abstract, introduction, results and conclusions while incorporating the chosen search criteria and added to the group for complete analysis.

1.6   Reviewed Paper

In this section the research papers obtained will be reviewed to confirm reliability and citations of the papers and also the relevance of the paper towards this project investigation.

1.6.1   A New Perspective on Family Involvement in Chronic Pain Management Programmes

Citations: 15

Reliability: Published by "The Faculty of Health and Environmental Sciences" AUT University. The second-largest university in New Zealand operating for over 120 years under the education (act 1989).

This paper reviews the involvement of significant others in pain management programmes for people with chronic pain. The experiment and data collection took place in a hospital in Auckland, which provides acute, chronic pain management services. The hospital offers a pain management programme covering a wide range of pain conditions. On the final day of the program, the pain patients are allowed to bring significant others; patients and significant others are then interviewed concerning the support of significant others during the pain management programme. The paper concludes with valuable insights for those looking to implement pain management applications for family-based interventions that enhance the quality of life of the "pain patient" and "significant others" around him.

1.6.2   Chronic Pain and Family a Clinical Perspective

Citations: 60

Reliability: Published by "Springer" a recognized company of academic journals and books, focusing on the fields of human health founded in 1950 and written by the author Ranjan Roy a multidisciplinary professor working in clinical health psychology, faculty of medicine in the University of Manitoba Canada known for his extensive work in the field of chronic pain.

The author of the book has conducted a research using the McMaster Model of Family Functioning (MMFF) to analyse the quality of communication between CPS and their significant ones. The result of his research found common patterns, which result in the deterioration of communication between them. This knowledge creates a chance to analyse possible solutions as a feature for the computer-based app that this project aims to develop.

1.6.3 The Influence of Family Support on Chronic Pain

Citations: 250

Reliability: Published by Pergamon press an Oxford-base publishing house for scientific and medical books and journals founded in 1948. The authors Robert N. Jamison is a Ph.D. professor at Harvard medical school and Kitti L. Virts a PhD, Psychologist in Vanderbilt University, both universities are subject to quality control by the United States and Canadian systems.

This paper conducted an experiment at Vanderbilt Pain Control Centre with 521 CPSs, 250 of them had family support and 250 did not. The goal of the experiment was to find out the role family plays in supporting CPS. The paper shows insight in different support techniques which can be considered for the computer-based app if family support features where to be included.

1.6.4 A Pilot Comparison of a Smartphone App with or without 2-Way Messaging Among Chronic Pain Patients: Who Benefits from A Pain App?

Citations: 50

Reliability: Published in The Clinical Journal of Pain. This journal was established in 1985-present in United States and covers every aspect of pain management and has an impact factor of 2.893.

The goal of this paper is to improve the quality of life among CPS. This paper experiments with using a 2-way messaging app to monitor and communicate chronic pain data with healthcare providers and assess its effectiveness. The experiment took place in Brigham and Women's Hospital and Dana Farber Cancer Institute, Boston. Half the patient received only the app, and the other half the "experimental group" had the 2-way messaging system in it. The patients in the experimental group received personal messages relating to changes in data (e.g. "Kamila good news it looks like your pain, mood and activity have gotten better, congratulations"), were as the other group received a standard message "thank you your message has been received". The experiment has limitations due to the limited number of subjects and the brief follow-up period. This paper offers insight into the results and conclusions of novel advantages of obtaining clinical information through an app which could be an added feature for the computer-based diary application for this project.

1.6.5   Essentials of Pain Medicine Chapter 5 - Pain Assessment

Citations: 169

Reliability: The book was published by "Elsevier" a Netherlands-based publishing company specialized in medical content founded in 1880-present with a net worth of 1.922 billion and 8,100 employees.

The chapter of this book offers an overview that critically evaluates pain assessment tools. This chapter is valuable because it defines fundamental concepts about pain and also presents the project with the knowledge to select the pain assessment method that adequately satisfies the objectives of this project.

1.6.6   Pain Diary Pain Management Platform

Citations: 0

Reliability: Published by "UPPSALA UNIVERSITET" founded in 1477-Present the university has a revenue of 7,398 million and 7,387 employees and considers itself a research-intensive university. It is subject to quality control from Sweden academic system.

This paper includes a two-year investigation in designing a chronic pain diary for a smartphone. This paper is valuable because it gathers common knowledge about pain and pain diaries such as who benefits from a pain diary app and pain dairy in the business context. It also conveys an in-depth investigation of the HCI process taken to build a pain diary prototype; these UX techniques need to be considered when creating CPT for CPPs; these insights are required to consider the HCI process of this project.

1.6.7   Contribution of Web Services to Improve Pain Diaries Experience

Citations: 16

Reliability: Published by News wood Limited which focus on the publication of journals, conference proceedings and books. The papers are only published if their source comes from accredited universities. This paper was introduced in the proceedings of the international multiconference of engineers and computer scientists 2021 in Hong Kong. The conference is organized by over three hundred committee members mainly research centre heads professors and research scientists from 30 countries.

This paper gathers basic knowledge of pain and chronic pain, which are valuable for this project background. The project aims to introduce web services as a platform for the development of

chronic pain applications to be able to monitor CPP. This paper is of value because it explains procedures to send and receive alert messages and self-configuration by PS in a CPT to contribute to the healthcare systems. These techniques can be used when developing the prototype for this project.

1.6.8 Evaluation of Self-Management Support Functions in Apps for People with Persistent Pain: Systematic Review

Citations: 27

Reliability: Published by JMIR publications established in 1999-present covering eHealth journals with an impact factor of 5.03 ranking at the top of its categories, written by Hemakumar Devan, BPT, MPhty, PhD in the Centre for Health, Activity and Rehabilitation Research, School of Physiotherapy at the University of Otago. This university was founded in 1869-present and subject to the academic quality system of New Zealand.

This paper performed a systematic search in phone applications for people with chronic pain and evaluated over 939 apps, of which 19 were selected for further evaluation to appraise app quality. The advantages or patterns found in this app investigation are of interest for this project to evaluate the addition of possible features.

1.6.9 Validity, Reliability, Feasibility and Usefulness of Pain Monitor

Citations: 35

Reliability: The source of this paper is "The Clinical Journal of Pain" with reliable impact factor of 2.893. The journal has 37 volumes which are published by Wolters Kluwer a leading provider of information for medicine, nursing and pharmacy professionals and students founded in 1836-present. The company has 19,200 employees and has a revenue of 4.6 billion as of 2021.

This paper developed and tested a multidimensional smartphone app for adults with chronic pain considering clinical guidelines for pain measurement. The paper offer insights regarding which variables are important when measuring pain and best practices for app validity, acceptability and feasibility. The techniques used in the paper prove valuable for the development of this paper's app.

1.6.10 Human-Computer Interaction (HCI)

Citations: N/A

Reliability: This website/school specialized in design and teaches online courses for UX design. The school was founded in 2002; currently, 109,610 students have graduated. Their course certificates are trusted by industry leaders such as IBM and Adobe, who train their teams with their courses. Universities such as MIT and the University of Cambridge include their material in their curricula ("What Is Human-Computer Interaction (HCI)?" 2021).

This website contains a basic explanation of HCI and how HCI helps improve the comprehension of designs; it is a valuable source of information to introduce the basics of HCI to the readers of this paper, to understand why these techniques are essential and why they must be implemented.

1.7 Vocabulary

Significant others or (SO): Refers to people that an individual with chronic pain defines as their key source of social and psychological support.

Chronic pain Patient or CPP: An individual usually a patient of cancer or other chronic pain disease.

Chronic pain tracker or CPT: Technique used to track, log and record chronic pain.

Pain specialist or (PS): Medical personnel involved in pain management such as nurses, doctors, psychologists, care givers, between others.

IMMPACT: Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials (Suso-Ribera et al. 2018).

1.8   Report Structure

Chapter 2 explains basic concepts about pain and chronic pain and the challenges involved. The section also talks about pain assessment tools and chronic pain methodologies for managing pain.

Chapter 3 will review some of the existing problems encountered when building chronic pain systems for pain management. The chapter investigates why these problems need to be addressed, the benefits of solving these problems, and who profits from answering these intricacies.

Chapter 4 perform a research on paper-based and smartphone pain diaries. The intention is to find the core functionalities used in existing systems to understand the essential features found on these systems and find which of the problems discussed in the previous chapter have been addressed. Lastly, this chapter will also cover the features that the pain management system of this paper will include.

Chapter 5 applies HCI methods to reveal insightful characteristics to improve the interaction between the user and the application. The chapter will include a PACT analysis, a conceptual diagram, a mood board user profile and a scenario. As mentioned in the previous chapter, the only "target-user" that will be evaluated on this pact analysis, user profile and scenario is the elderly suffering from chronic pain.

Chapter 6 introduces the methodologies, system requirements and software development tools used to develop the application.

Chapter 7 reviews important LESP concerns, risk issues, the conclusion of this paper and further research work.

Chapter 2

2.1 Pain and Chronic Pain

"Pain is an unpleasant sensory and emotional experience related to past or potential tissue damage" (Pombo et al., 2021, p.1). When the pain is intense but is only experienced through a short period is known as "acute pain", but when the pain lasts over a long period, even after the healing phase is known as chronic pain (Pombo et al., 2021), *chronic pain* is defined as constant pain for more than three months. Chronic pain reduces the quality of life; it affects 1 in 5 people worldwide and is the leading cause of disability to work and perform daily tasks. Chronic pain includes a wide range of conditions *" primary pain, e.g. (low back pain and neck pain), musculoskeletal pain, e.g.(arthritis), migraine, orofacial pain, neuropathic pain and pain following trauma and surgery"* (Devan et al., 2019).

2.1.1 Who Deals with Patients with Chronic Pain

CPP are referred to Pain specialists or (PS); these are medical personnel involved in pain management such as nurses, doctors, psychologists, between others. PS tend to evaluate the CPP progress and prescribe painkillers or other coping strategies to manage the CPP's pain (Bustamante Mirayo, 2012).

People around CPP, such as Family partners or friends, are also involved with the chronic pain of the CPP. For the purpose of this project, we will refer to them as "Significant others" or (SO) for short; these are the individuals whom CPP's consider as their source of social and psychological support.

2.1.2 Challenges of Chronic Pain

"Pain is an internal, subjective experience that cannot be directly observed by others or measured by psychologic markers or bioassays."(Lazaridou et al., 2018, p.39); This makes the study and assessment of pain a problematic task as there are not many ways to interpret or understand the pain. As a result of its incomprehensible nature, chronic pain negatively impacts CPPs and their families causing confusion and anger between CPPs and SOs, affecting the effectiveness of their communication (Roy, 2006).

2.2 Methodologies for Chronic Pain Assessment

This section will discuss the techniques used to assess chronic pain in CPPs and also how these techniques are implemented in paper-base and electronic systems.

2.2.1 Scales

Due to its subjective nature and the inability to verify the pain using objective indicators on behalf of the evaluator, assessing pain relies mainly on self-report, making it prone to biases, so extensive research and experimentation have been done to develop tools for self-assessment that are reliable and valid when communicating pain experience.

Techniques have been developed to quantify the intensity of acute and chronic pain in the form of scales (Lazaridou et al., 2018). "Is common practice to use rating scales as means of measuring pain"(Pombo et al., 2021 p.2). These scales are extensively utilized and have been validated in research and clinical settings. Some of the most common scales used are verbal rating scales (VRSs), visual analogue scales (VASs) and numeric rating scales (NRSs) (Lazaridou et al., 2018).
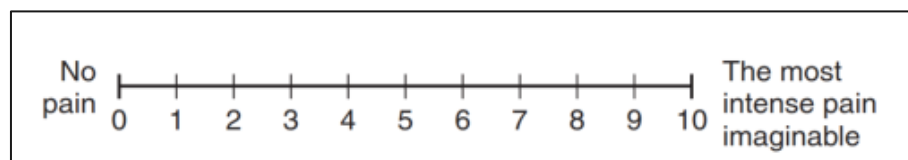
Verbal Rating Scales

"A VRS generally consists of a series of adjectives (or phrases), ordered from least intense (or unpleasant) to most intense (or unpleasant)" (Lazaridou et al., 2018, p. 39). These scales usually included the maximum range of the pain from "no pain" to "worst pain possible." CPS are then asked to choose one of the phrases that best matches their pain level. One of the advantages of this scale is the ease of administration, scoring, and simplicity resulting in a higher compliance rate than other scales. Weaknesses of the VRS scales are the assumption of equal intervals between adjectives making it hard to analyze the data and interpret it; the patient also must be familiar with all the words mentioned in the scale and find one to represent the pain accurately. "VRS is being used less often in pain outcome research than has been the case in the past" (Lazaridou et al., 2018, p. 40). See Figure 4 for an example.

None	0
Mild	1
Moderate	2
Severe	3
Very severe	4

Figure 4Verbal Rating Scale for Pain Intensity

Numerical Rating Scales

An NRS consists of a range of numbers with verbal anchors at each end, signifying the entire range of pain intensity. The scale is usually represented between 0-10 or 0-100, 0 representing no pain and the opposite representing the worst pain imaginable. NRS, just like VRS, has been validated. Advantages of this scale are simplicity, ease of administration and scoring. Weaknesses of this scale are that it statistically does not have ratio qualities meaning that the differences between 1 and 3 and 7 and 9 might not represent equal scaling of the pain intensity. Another problem of this scale is that people contextualize the tag of "the worst pain imaginable" differently making it relative to that person and to a specific time (Lazaridou et al., 2018). See Figure 5 for an example.

Figure 5 Sample numerical rating scale for pain intensity

Visual Analog Scale

VAS is similar to NRS, with the only difference that it has no numbers. VAS is often the measure of choice for assessing pain intensity over NRS and VRS, and there is enough evidence to support its validity. The advantages of VAS are that it is sensitive to treatment effects, and it also correlates well with pain behaviours. Weaknesses of VAS are that it is difficult to apply to patients with perceptual-motor problems and produces higher rates of non-compliance, primarily among people with cognitive limitations such as illiterate or elderly; it is essential to know that most CPPs tend to be elderly or have perceptual-motor problems. Also, this scale cannot be rated verbally meaning patient cannot be blind. In a study 90% of patients report found out that due to memory of past pain being substantially greater than current pain this scale can lead to bias or errors when scoring (Lazaridou et al., 2018). See Figure 6 for an example.
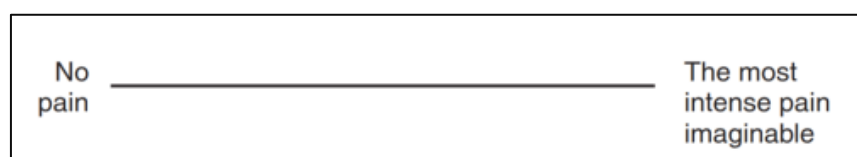
Figure 6 Sample visual analog scale for pain intensity

Conclusions

A review of extensive literature shows VAS, VRS and NRS to have good validity and reliability and concluded that none of these methods are consistently superior to one another. The review specifically concluded "There is no single best tool for pain assessment, and choice of measure should be guided by the needs of the study or the clinical setting" (Lazaridou et al., 2018).

2.3.2 Paper-Base Methods

This section will discuss the techniques used to assess chronic pain in CPPs implemented in paper-base systems such as questionnaires and pain diaries.

McGill Pain Questionnaire and its Short from MPQ

There are many questionnaires for pain management, but the McGill is the most common and widely used; its advantage is its multidimensional approach which queries sensory-discriminative, affective-motivational, and cognitive-evaluative, allowing for the most accurate pain measurement compared to the scales. However, its major weakness is the time it takes to fill in, making it unfeasible for everyday use (Lazaridou et al., 2018). See an example of McGill questionnaire in the Appendix 1.

Pain Diaries

Usually CPPs are reffered to a PSs who can prescribe the right level of painkillers and pain managment strategies; subsequent appointments are scheduled to examine the patient's progress to update prescriptions (Bustamante, Mirayo, 2012). In order to assess the CPP's progress the PS needs to determine a time frame to measure pain intensity; time frames longer than a week are prone to memory biases, so measuring techniques that focus on current pain or pain over the past week are preferred (Lazaridou et al., 2018). Therefore, CPPs are advise to measure their pain over time to analyse the progress and the prescriptions defined by the PS (Pombo et al., 2021).

Pain diaries is an excellent methodology to record pain over time, determine patterns of pain, identify effective pain management methods and improve commincation betwwen CPP and PS. In addition, Pain diaries or (CPT) enables the CPP to contribute to their health care actively (Pombo et al., 2021). CPT allows CPPs to include daily pain entries and record their intensity, location in the body, medication, and activity that triggered the pain. Patients tend to write on

average five entries a day (Bustamante, Mirayo, 2012); logging pain multiple times a day solves the problem of memory biases mentioned before. A disadvantage of paper base solution is the effort that goes in manually filling them and scoring them resulting in low levels of compliance. (Lazaridou et al., 2018). *"Handwritten diaries make it difficult to manage patient's data and analyze it, and doctors discard them for it's complexity of digitalazing the data in order to make statistics. Some patients stop filling their diaries and give up negatively afecting their health and quality of life"* (Bustamante, Mirayo, 2012, p.9). See examples of paper base pain diaries in Apendix 2.

2.3.3 Smartphone Methods

It is projected that there are over 7 billion registered users of mobile phones worldwide; It is also estimated that 80% of adults worldwide would own a smartphone by 2020; This phenomenom has lead a considerable increase in apps for tracking health data many of which are for managing chronic pain. Smartphone availability and internet accessibility in most areas have also benefited the health sector, allowing these services to reach more patients (Jamison et al., 2017).

Most services for managing pain on smartphones are pain diaries, which offer general information on pain, strategies for self-management, and the ability to record symptoms such as pain, mood, activity and medications, and setting of reminders when needed (Devan et al., 2019).

2.3.4 Advantages of Pain Diaries on Smartphones over Paper Based

A peper review explains electronic pain diaries help to save time, are more flexible and data can easily be imported and managed (Lazaridou et al., 2018). A similar research concludes that "electronic monitoring available in apps is superior to paper-and-pencil diaries in respect to compliance, user-friendliness, patient satisfaction and test reliability and validity". Furthermore, the research explains that electronic solutions can contain features that enforce reliability, such as date/time, and avoid incorrect data input. These solutions can also provide instant feedback to the CPP through graphs and pain evaluation. Electronic devices allow for a 3D pain mapping of the human body, letting CPP locate the area of pain with greater accuracy, enabling clinicians to interpret the nature of the pain better (Jamison et al., 2017).

2.3.5 Advantages of Web-Based Pain Diaries

Standalone applications are better than paper-based methods because they discard all the problems mentioned in section 2.3.2 and include the advantages mentioned in section 2.3.3, but standalone applications lack the flexibility for real-time PS feedback and data accessibility. Web Services can benefit PS mobility by providing real-time access to the data, reducing PS errors, saving time during CPT progress evaluation, providing 2-way communication, and enhancing PS productivity and quality of care. (Pombo et al., 2021) PS can also adjust their practices in real-time after a CPP's pain episode.

On the other hand, *"Patients want to be better informed of their health options and are, therefore, demanding easy access to relevant health information."* (Pombo et al., 2021, p.1) Web services can assist CPP by providing easy access to their information anytime, anywhere, and the 2-way communication and pain management strategy updates can provide multiple health options for them. (Pombo et al., 2021).

Pain Specialist Interventions

An intervention is when a pain specialist actively addresses the CPP to give advice, ask questions, or prescribe / update / discontinue a treatment. A smartphone web-based solution for pain management can facilitate this interaction by incorporating a 2-way messaging system between the PS and the CPP (Suso-Ribera et al., 2018).

A study explains *that "The current best practice for managing chronic pain involves group-based, multidisciplinary, cognitive behavioural interventions focused on fostering self-management"* (Suso-Ribera et al., 2018).

Most pain services for treating chronic pain such as Cognitive Behavioural Interventions are mainly provided in secondary or tertiary care settings, making them unavailable for most CPP. Some CPP might struggle to physically access these services or struggle with transportation; A web-based solution can deliver these services efficiently (Suso-Ribera et al., 2018).

A study explains, that chronic pain apps that incorporate real-time messages can simulate direct interaction with the therapist or healthcare provider (Jamison et al., 2017). These interventions prove helpful *"in the presence of undesired adverse effects of the medication, non-response to treatment, poor adherence to treatment, or excessive use of rescue medication".* An application flexible enough to share patient progress and have 2-way communication with their therapist and clinician can also help foster healthier behaviours such as self-efficacy and shared decision-making (Suso-Ribera et al., 2018).

Significant-Others Interventions

Chronic pain can negatively impact even well-functioning families due to its incomprehensible nature; This causes confusion and anger between CPP and PS, affecting the effectiveness of their communication.

It is common practice to include significant others in pain management schemes for people with chronic pain, although there is a great variation in how this practice is performed. Some of the most common methods "Partner-assisted intervention and Disorder-specific intervention which tries to teach the significant other how to support their loved one by adopting new behaviours or how to address interpersonal dynamics to maintain or exacerbate an individual's pain".

There is no evidence suggesting that web-based solutions can help address this issue; however, the app can connect the CPPs with SOs and promote communication and support, which can help rehabilitate CPPs (Jamison and Virts 1990).

Reviews of Web-Based Solution for Chronic Pain

There are already many web-based solutions for chronic pain, and studies with CPPs have been made to measure the efficacy of such systems. One of these studies suggests that pain apps are good for collecting data, they are tolerated by chronic pain patients and can be used to communicate daily report status to providers and implemented in clinics (Jamison et al., 2017). Another study concluded *"Smartphone pain apps where found usable, valid, reliable, and easily accepted among CPPs and PSs"* (Jamison et al., 2017).

2.3.6 Human-Computer Interaction

Human-computer interaction (HCI) is a multidisciplinary field which studies how people interact with computer technology to make design interventions maximizing the intercommunication between users and computer. HCI "popularizes the idea that the interaction between a computer and the user should resemble a human-to-human, open-ended dialogue"("What Is Human-Computer Interaction (HCI)?" 2021).

John M. Carrol the founder of HCI explains that "HCI expanded from its initial focus on individual and generic user behaviour to include social and organizational computing, accessibility for the elderly, the cognitively and physically impaired, and for all people, and for the broadest possible spectrum of human experiences and activities" ("What Is Human-Computer Interaction (HCI)?" 2021).

Chapter 3

This chapter will review some of the existing problems when dealing with creating or existing pain management systems, why they need to be addressed, and what or who benefits from solving these problems.

3.1 Why Is a Pain Management System Needed?

As explained in section 2.2, chronic pain affects 1 in 5 people worldwide; due to the large number of people affected, research and novel solutions in this field are needed. This paper will build a proof of concept to address chronic pain, a pain management app prototype. A "Pain Diary" solution has been decided due to the analyses explained in sections 2.3.2 and 2.3.3. Even though this solution's beneficiaries are CPPs with all levels of chronic pain, these solutions should focus mainly on CPPs dealing with high levels of pain. A paper investigation concluded that those who show high levels of pain and disruption of their activity appreciated using an app more as these gained some personal benefit. On the other hand, ironically, patients who are or became more active were least satisfied with an app due to their busy life and pain not being a significant part of their lives (Jamison et al., 2017).

3.2 In Need of a Web-Based Solution

The solution needs to be web-based to be able to exchange information from anywhere and anytime; this approach can improve the pain diary app by improving the ability to monitor chronic pain patience, allow PS intervention and enhance therapeutic assertiveness. Other key features include transferring pain data between systems or devices, pain strategies updates by PS based on current patient progress and sending alert messages to PSs or SOs (Pombo et al., 2021). Web-based solutions also mean that the information can be accessed via phone and computer (Suso-Ribera et al., 2018). As described in section 2.4.5 physical accessibility and transportation is also a known CPP problem which web-based solutions can solve. A web-based solution benefits all CPPs, PSs and SOs with enhanced flow of information between them, information management and accessibility to pain management services.

3.3 Best Tool for Measuring Pain Intensity?

There is also a question about which pain assessment techniques will be used to measure pain intensity; research from section 2.3.1 has shown that the best way to assess pain intensity is through scales; this paper will have to determine the best-suited scale for the needs of the pain diary. This investigation must conclude which user profile will be most common and select a scale which benefits said user group.

3.4 Concerns with App Compliance And HCI

As mentioned earlier, paper-based solutions struggle with compliance, and even though this issue has been considerably decreased using a computer-based solution, there are still problems with compliance reported by many of the papers developing pain management applications (Jamison et al. 2017), (Suso-Ribera et al. 2018). HCI can help understand the user's behaviour to create a solution that will address compliance issues by obtain techniques that can be implemented in a computer-based app to incentivize CPP to use it daily. HCI can also help to deliver a suitable solution to the older, cognitive, or physically impaired users of the app ("What Is Human-Computer Interaction (HCI)?" 2021) and increase their compliance level through a simple and comprehensable app tailored to their needs.

3.4.1 Use Case "The Compliance Problem With The "Pain Monitor" App"

Pain Monitor is an app designed following IMMPACT guidelines to present a validated chronic pain app for adults. Features in the app were validated by reaching a "consensus with a panel of pain experts from the Labpsitec group of the Jaume I University (two psychologists) and the Pain Clinic of the Valld'Hebron Hospital (five physicians, two nurses, and a psychologist)." and selecting the variables recommended by IMMPACT for pain assessment.

Even though this app was carefully built by professionals the problem with apps like "Pain Monitor" is compliance; they had too many variables to record every day. This investigation reported compliance up to 70%, but the length of the experiment was only for a month; there is evidence to suggest that compliance in filling up pain apps goes down as the months go by. The paper admits that the level of compliance decreased after 6 months and suggested that this could be due to the lack of value perceived by the CPP when filling the app daily. Recommendations for keeping a high compliance rate were proposed, the paper explains PSs

integration in the app for guidance and support can increase compliance (Suso-Ribera et al., 2018).

The Commonwealth Fund also concluded through an evaluation of mobile health apps that guidance based on information entered by the user on an app increases user engagement; they also concluded that communication and support between CPPs and PSs on an app increases engagement levels (Jamison et al., 2017).

In conclusion, CPPs and PSs can be benefited by increasing engagement levels through HCI techniques, the collaboration of PSs and a shorter pain record process allowing CPPs to reach higher levels of compliance which supports them and PSs to find better ways to address their specific pain condition.

3.5   Significant-Others and Pain Specialist App Integration

One of the biggest gaps and possible solutions is the involvement of PSs and SOs in apps; thanks to web-based applications, the addition of PSs and SOs in the apps is now possible and there are many advantages as explained in section 2.3.5.

3.5.1 How can Pain Specialists assist CPPs through the App?

As mentioned in section 2.3.5 a 2-way messaging app proves to be a viable solution in the integration of PSs for a CPT. A pilot comparison of smartphone app with or without 2-way messaging explains that patients on average with the 2-way messaging system tended to use the app more, and those with consistent use of the app would be more satisfied using it and had a modest increase in activity levels but did not significantly affect pain intensity, mood, and coping in a direct way (Jamison et al., 2017). The conclusion made by this paper is odd because it has been proven by other papers that increasing usability also increases compliance and as concluded in section 3.4 compliance is a big factor in the improvement of CPPs condition. Since this pilot only lasted 3 months and some patients complained that the 2-way messaging system was disappointing as they expected physicians would be more active in monitoring their progress and intervening with their pain (Jamison et al., 2017) there is still enough room to experiment with this feature, this time the investigation could last more than a few months and CPPs expectations towards PSs collaboration can be negotiated from the start.

The pilot study also requests for future study on how to incentivize clinicians to be more involved (Jamison et al., 2017) which is a good variable to consider. The study also concludes

that CPPs suggested that perceived connection with PSs was beneficial, but also PSs were interview regarding the 2-way messaging system and seven pain management physicians gave feedback on a satisfaction survey. The majority of them reported being satisfied with summary graphs; they also liked receiving pain app summary messages and believed that this would help them in clinical practice and also that it would help improve patient outcome. However, some physicians spoke about the lack of time for checking the app data during working hours (Jamison et al., 2017).

In conclusion, supporting PSs and CPPs to have a better and more collaborative relationship can help both to improve the quality in which the pain is managed (Suso-Ribera et al., 2018). In addition, CPPs benefit from user engagement, motivation, problem-solving and shared decision making. There is not enough research yet to determine whether a 2-way messaging system is a good solution but is a fine gap that could be exploited to expand the knowledge of the field of pain management in a computer-based environment which is expected to yield positive results.

3.5.2 How can Significant Others support CPPs through the App?

This investigation has been unsuccessful in finding out any SOs support for CPPs in paper-based or computer-based solutions for pain management. The lack of information on this field creates the opportunity to create a real novel solution that relates SOs and CPPs in their pain management journey. Many papers mentioned the lack of research on this topic, meaning that there is not enough evidence to support the success of these features on an app. Nevertheless, there has been enough information to suggest that SOs involvement can help CPP rehabilitation (Jamison, Virts, 1990).

Benefits for Chronic Pain Patients

The biggest problems between CPPs and SOs is communication. A research stated that CPPs said to avoid conversations about their medical condition to avoid hurting their significant other by sounding negative or having the legitimacy of their condition judged. CPPs reported a sense of dependency towards SOs and reluctance to vent their thoughts and feelings freely (Roy, 2006). The app could help address this problem by adding the SO to the CPP pain diary logs as spectators, this would remove the burden of the CPP of expressing every pain episode to their loved one and risk sounding negative. This solution also proves the continuous presence of the pain condition and legitimizes its existence. Since SOs have all the information from

their CPP, they can support them and decrease the number of times that CPPs ask for help, making CPPs feel less needy and more confident towards venting their feelings.

CPP also finds it hard to adapt to different pain levels when overly supported (Jamison, Virts, 1990). Setting up app alarms to notify only when the CPPs needs support can prevent SOs from being overly supportive. Research also reveals that CPPs can adapt better when they have access to an extensive support network or large family; the problem is that "today's society tend to move more frequently and not live near extended family members" (Jamison, Virts, 1990). The app can help them connect from anywhere, enabling SOs to share responsibility, reduce time consumption and support their loved ones.

An interview was done with CPPs after receiving support from their SOs regarding their pain management journey; CPPs said that they wanted a shared understanding of the pain with their relatives. Pain patients often express "concern around the legitimacy of their pain." having their relatives involved helped tackle this issue. They also value showing to others, e.g. (Doctor, acquaintance, or friends) about their relatives' involvement in their pain management. Pain patients also asked for strategies to reduce time consumption for their SO involved in their pain management schemes (Swift, Reed and Hocking, 2014).

Benefits for Significant-Others

Significant-Others also avoid sensitive topics due to the incomprehensible nature of chronic pain and the lack of knowledge about the medical condition underlying pain complaint; consequently, SOs questions if the pain is real (Roy, 2006). In an interview where SOs partake in a programme to support their CPP with their chronic pain, SOs said they wanted access to support and information about the signs that identified their loved ones when being in pain and strategies to manage said pain. They also explained how the involvement allows them to understand and appreciate their loved ones.

The interview concluded that chronic pain affects the entire network of family and friends and being part of a programme ensures everyone is on the same page about the pain and how to tackle it. The consequences of not doing so are relationship tension and pain escalation due to the lack of understanding and actionable strategies towards the pain sufferer (Swift, Reed and Hocking, 2014).

In conclusion, the app offers a different type of communication between SO and CPP, which has not been tested but has the potential to produce positive results. Even though it is reported that clear and direct is the best form of communication between SO and CPP, and the app offers

a visual and indirect form of communication, the report also admits that even clear and direct can lead to unkind or abusive communication (Roy, 2006).

The report concluded with the following facts of CPPs whom SOs supported (Jamison, Virts, 1990).

Non-supportive

- Have liability and work-related injuries.
- Relied on medication
- More pain sites/locations
- Used more pain descriptors when describing the pain
- Show more pain behaviour and emotional distress.

Supportive

- Reported less pain intensity
- Less reliance on medications
- Greater activity levels
- Tended to work

There little to no evidence to support the success of these features on a mobile app, (Jamison, Virts, 1990). This novel solution if included will stay in the prototype face, if it was to be continued, these new aspects must have to be tested to understand if the features are productive or counterproductive.

3.6 What Functionalities Should a Pain Diary App Include?

An investigation and evaluation of existing solutions will be needed in order to find out which are the core pain management features. The app also needs to learn how statistical strategies are being used on inputted pain variables to find correlations with pain frequency and intensity. By including core functionality and important statistical correlations the app can help CPPs, PSs and SOs to understand the CPP condition and develop treatment strategies to better deal with the pain.

3.7   Other Problems

Another problem found by a study was that "no apps provided information tailored to the cultural needs of the user" (Suso-Ribera et al., 2018). Therefore, the solution in this paper will have to be customizable enough to allow for changes, e.g. (scale anchor description or input variables). This solution will benefit a diverse user base from different cultural backgrounds. Furthermore, "Best-practice content items in available pain management apps fostering core self-management skills for self-management support are not known" (Suso-Ribera et al., 2018). Some reviews have indicated that most of the CPT apps were found to have little evidence to support the validity of their content, there is no proof of pain experts involved in the development of the apps, and almost all psychological components of pain are ignored (Suso-Ribera et al., 2018). A paper review three articles that concluded that most pain apps have no healthcare professional involved in creating or managing the app. A paper also explains that "For better integration of apps in clinical practice, concerted efforts are required among app developers, clinicians, and people with persistent pain in developing apps and evaluating for efficacy (Suso-Ribera et al., 2018). Building applications certified and validated by professionals in the field of chronic pain can help make sure the solution is well suited for CPPs.

Moreover, these papers also concluded that the primary functionalities of a chronic pain management app mentioned by professionals are self-monitoring, goal setting, skills training, social support, and pain education (Jamison et al., 2017). Devan et al. (2019) states, that the primary functionalities of a chronic pain app should be skills "pain education, self-efficacy building, self-monitoring, social support, and goal setting". This paper will consider if existing systems have pain education, goal setting, self-monitoring, social support and skills training. then apply all the best methods backed up by research that are sensible and beneficial for PSs, SOs and CPPs.

Chapter 4

This chapter is going to perform a research on paper-based and smartphone pain diaries. The intention is to find the core functionalities used in existing systems to understand the essential features found on these systems and find which of the problems discussed in the previous chapter have been addressed.

4.1 Existing Paper-Based Systems

This project app will not be a paper-based solution, but it is necessary to understand the standard structure and variables used to record these diaries as these have been the only solution used in the past, and most CPPs are used to them. Evaluating these solutions will allow having a smooth transition between paper-based and computer-based hence building a familiar application with a reduced learning curve. A paper review supported these claims by adding that "there is a strong need for the user to feel a direct connection between the previously handwritten task-flow with the new one" and the new solution "must be loyal to the idea of the pain diary as the patients have pictured it so far". (Bustamante, Mirayo, 2012, p.14).

Search Strategy

A search for paper-based pain diaries was performed in the Google search engine on June 17, 2017. The search terms used included pain diary, paper-based pain diary, NHS pain diary.

Inclusion Criteria

Pain diaries were included if (1) the source of the website could be confirmed as reliable, (2) The pain diary was paper based, (3) the pain diary was free and downloadable, (4) Used for general pain conditions, (5) aimed to adults.

Data Extraction

All relevant links from the search results were accessed and screened against the inclusion criteria—next, eligible pain diaries were downloaded for further analysis.

Evaluation

For evaluation, each pain diary and the required variables for each pain entry were added to a table to compare and contrast the results.

Reliability of The Pain Diaries Selected

Pain diary by McMillan cancer support: This organization has millions of supporters, professional, volunteers and campaigners. It is a registered charity with charity number 261017 regulated by England, Wales, Scotland, and the Isle of Man. A sample of this diary can be found in (Appendix C).

Pain diary by American Cancer Society (AMC): A nationwide health organization founded in 1913 and arranged in 250 offices all over the United States. A sample of this diary can be found in (Appendix B).

Pain diary by NPS MedicineWise: An Australian organization that focuses on practical health tools, evidence-based information, and educational activities for providing health support. The organization was founded in 1998; its programs are funded by the national department of health of Australia. A sample of this diary can be found in (Appendix A).

Pain diary by NHS: The United Kingdom National health service founded in 1948, subject to England's quality control for health services. A sample of this diary can be found in (Appendix D).

Pain diary by Turas: Turas is the NHS education hub for Scotland's health and social care professionals working in the public sector. A sample of this diary can be found in (Appendix E).

Figure 4: Paper-based Pain diary – Recorded Variables Table

Diary Name	DT	PI	PL	MD	MS	TT	RS	PW	PB	LP	AA	MA	APS	PPS	HPF
McMillan	+	+	+	+	-	+	-	+	+	-	-	-	-	-	+
AMC	+	+	+	+	+	+	+	+	+	+	-	+	-	-	+
NPS	+	+	+	+	-	-	-	+	+	+	+	+	-	-	+
NHS	+	+	-	+	+	-	+	-	-	-	+	+	-	-	
Turas	+	+	+	+	-	-	-	-	-	+	+	+	+	+	
Count	5	5	4	5	2	2	2	3	3	3	3	4	1	1	3

DT: Date and Time
PI: Pain intensity
PL: Pain location
MD: Medicine and dose taken
MS: Medication side-effects
TT: Treatment or therapy taken
RS: Relief scale after medication treatment or therapy
PW: What made the pain worse
PB: What made the pain better
LP: How long the pain lasted
AA: Did it affected any daily activities
MA: How did it affected your mood
APS: activity you were doing when pain started
PPS: place you were when pain started
HPF: How di the pain feels like

4.1.1 Paper-Based Feature Analysis

The most common features found in paper-based diaries are date & time, pain intensity, the medicine used to relieve the pain, and its dosage; these seem to be the core features found in all paper-based diaries. In addition, the following features were found in most pain diaries, pain location and how the pain affected the CPP mood and seem highly recommended. Other recommended features found through the analysis include what circumstances made the pain worst or better, how long the pain lasted, How did the pain felt like and whether the pain restrained the CPP from completing daily activities. Lastly, the analysis shows medication side effects, treatment or therapies performed to cope with pain, relief assessment one hour after the medication was taken, activity performed while the pain began, and the CPP location when the pain appeared; these last variables seem to be optional as they were only found in two of the diaries.

Some extra recommendations were detected during the analysis. Instructions on how to use the diary were found only in some diaries; without instructions, the CPP is restricted to a PS to have the system explained; The following instruction should be added to any system and the prototype of this project to allow all user to understand the full functionality of the system.

- When should a diary entry be recorded
- A basic explanation of pain
- The benefits of using the diary daily
- Explanation of each variable
- Examples of possible answers for each variable

This analysis is limited due to the time constrain imposed on this project, and a more extensive analysis is recommended. Nevertheless, the current results will be used to choose which core features could be added to the prototype in later sections.

4.2   Existing Smartphone Systems

There has been an increasing number of apps in the latest years used to track health data and change the approach to the management of chronic diseases. "It is now estimated that there are over 14,000 health-related apps for iOS alone" (Jamison et al., 2017, p. 3) a review of these app can reveal essential variables and features that could be added to this project's solution. This section will review the research strategy and core functionalities for smartphone pain diaries found in the Android Google Play Store. The Android operating system has been selected because it is used by more than 85% of smartphones users in Europe (Suso-Ribera et al., 2018).

Search Strategy

A search for smartphone pain diaries was performed in the United Kingdom Google Play Store on an Android device on June 18, 2017. In order to find existing apps, the following search queries were used (1) pain diary, (2) pain management, and (3) chronic pain (4) pain tracker.

Inclusion Criteria

Pain diaries were included if (1) They were free apps, (2) Available in the UK app store, (3) they could be downloaded from the Google play store, (4) The language of the app was in English, (5) was top-rated by consumers, (6) Included the following essential self-monitoring variables (date and time, pain intensity, pain location, medicine taken), (7) Applicable to all pain conditions.

Data Extraction

Due to the time constraints of this project, only the top 5 consumer rated apps which passed the inclusion criteria were selected. The apps were downloaded and reviewed one by one on an Android device and screened against an evaluation checklist.

Evaluation

"The MARS is a reliable tool for assessing app quality using five sections" (Devan et al. 2019 p. 3); four of the five metrics have been selected for the evaluation of this paper [1] engagement, (2) functionality, (3) aesthetics, (4) information quality. Also, each pain diary and the core variables for each pain entry were added to a table to compare and contrast the results.

Reliability of The Pain Diaries Selected

All the applications screened are subject to the google terms and conditions and are subject to google play store quality control.

Figure 5: Smartphone-based Pain diary – Recorded Variables Table

Diary Name	DT	PI	PL	MD	MS	TT	RS	PW	PB	LP	AA	MA	APS	PPS	HPF
Bearable	+	+	+	+	-	+	-	-	-	-	-	+	+	-	-
Manage my pain	+	+	+	+	-	+	+	+	+	+	-	+	+	-	+
HeealthTrack	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Pain Log: track & analyze your pain	+	+	-	+	-	-	-	+	-	-	-	+	+	-	-
Pain Diary – pain management log	+	+	+	+	+	-	+	+	-	+	-	-	+	+	-
Count	*5*	*5*	*5*	*5*	*1*	*2*	*2*	*3*	*1*	*2*	*0*	*3*	*4*	*1*	*3*

DT: Date and Time
PI: Pain intensity
PL: Pain location
MD: Medicine and dose taken
MS: Medication side-effects
TT: Treatment or therapy taken
RS: Relief scale after medication treatment or therapy
PW: What made the pain worse
PB: What made the pain better
LP: How long the pain lasted
AA: Did it affected any daily activities
MA: How did it affected your mood
APS: activity you were doing when pain started
PPS: place you were when pain started
HPF: How did the pain feels like

4.2.1 Smartphone-Based Feature Analysis

The must-have variables found in Smartphone-based diaries are the same found in paper-based diaries with the addition of pain location. In addition, the activity the CPP was doing the day or when the pain started also seems to be very common and highly recommended. Other recommended features found include the circumstances that made the pain worse, how the pain felt, and how the pain affected the CPPs mood. Moreover, the less essential features shown by the analysis are medication side effects, treatment or therapies performed to cope with pain, relief assessment after medication, how long the pain lasted, What made the pain better and the CPP location when the pain appeared; these last variables seem to be optional as they were only found in two or one of the diaries. Lastly, the variable " did the pain affected any daily activity was not found in any of the apps.

Some extra features were detected during the analysis. These features seem to appear in most apps and will be taken highly considered for this project's solution. The relevant features have been listed below.

- Reminders for medicine and diary entries
- "Extra Notes" section for every diary entry
- The functionality to export the logs or statistics to share with PS
- Optional positive reflection at the end of each entry.
- Customizable variables, i.e. (The diary can be customized with new variables so that they can also be recorded)

- Show meaningful statistics to discover patterns that correlate with the pain.
- Show a log window where all previous logs can be reviewed.
- Include multiple variables in the same section, e.g. (Medicine used, dose, and whether it made the pain better, neutral, or worst; these can be under the same section "Medicine used")
- User guide explaining the functionality of the application.

This analysis is limited to 5 apps due to the time constrain imposed on this project, and a more extensive analysis is recommended. Nevertheless, the current results will be used to choose which core features could be added to the prototype in the following section.

4.3   Pain Diary Variables Selection

This section is going to report on the frequency of variables found in paper-based and smartphone-based research. In addition, this section aims to decide which variables will be selected and implemented in this project's solution. A Table of all variables filtered by frequency in descending order is shown below.

Variable Description	Frequency	Included
1. Date and time	*10*	*Yes*
2. Pain intensity	*10*	*Yes*
3. Medication and dose	*10*	*Yes*
4. Pain location	*9*	*Yes*
5. How was your mood affected	*7*	*No*
6. What made the pain worst (Activities)	*6*	*Maybe*
7. How long did the pain lasted	*5*	*No*
8. What activity triggered the pain	*5*	*No*
9. Treatment or therapy taken	*4*	*Yes*
10. Did Medication or treatment work	*4*	*Yes*
11. How does the pain feel	*4*	*No*
12. What alleviated the pain? (Activities)	*4*	*Maybe*
13. Medication side-effects	*3*	*No*
14. Did it affect any daily activity	*3*	*No*
15. Place you were when pain started	*2*	*No*

Figure 6: Pain Diary Variables Selection

4.3.1 Variable Selection Criteria

This investigation project recognizes the significance of each variable in the table above; each variable helps to create an environment that maximizes the possibilities to find the patterns that can identify the best ways to handle pain. Regardless, due to this project's time constraints, only some of these variables will be selected based on "simplicity of implementation".

Variables 1 - 4 have been included because they are implemented in all systems, and they seem to be the fundamentals of a pain management system. Variable nine can be used to show interesting and simple statistics. Variable ten complements three and nine. Variable seven and is simple to implement.

Variables 6 and 12 can be combined into the same variable, i.e. (a category such as hobbies or weather, which can contain factors like cloudy or rainy); ideally, the user could create these categories and add factors to it in order to create all sorts of combinations. This variable will be included in the project if there is sufficient time.

The variables which were not selected are due to its low significance or complexity of implementation.

4.4 Addressing Problem Specification

This section will contain a problem specification summary from chapter 3 to analyze how and which of the problems have been addressed by current solutions. In addition, this section also aims to recognize the gaps/problems that have not been addressed.

4.4.1 What Functionalities Should a Pain Diary App Include?

There is enough proof that the current solutions contain the fundamental pain management variables needed to record chronic pain; this suggests that problem one has been successfully addressed by existing systems. These systems also show useful statistics that enable CPP to find patterns to problem-solve and find solutions to improve the quality of their pain journey. On the other hand, none of the systems which passed the inclusion criteria has most of the functionalities recommended by professionals from section 3.7. The only functionality met by these systems is self-monitoring. During the app research, many applications containing goal setting, pain education and skill training were not free or did not meet the self-monitoring inclusion criteria. Furthermore, the only application that contained these functionalities, and

including social support, did not work correctly due to bugs and glitches. Therefore, it is fair to conclude that none of the apps reviewed contained all qualities recommended by professionals, and there is a need for solutions that wraps all of these functions.

Due to the time constraints of this project, the only functionality that will be implemented for bearable is self-monitoring which will include the variables discussed in previous sections.

Statistics

In regard to displaying insightful statistics, this investigation concludes that that problem has been solved as all of the apps reviewed displayed graphs and valuable statistics.

Considering the variables included for bearable and the graphs encountered in the reviewed apps, the following statistics are proposed.

- Pain Intensity total average or across time vs past month or year.
- Pain intensity time graph.
- Pain intensity frequency of number selected on the pain scale.
- pain intensity score per time-period (morning, afternoon, night)
- Pain location frequency for every location in percentages.
- Alleviating factors for medication and treatment or therapy in percentages.
- Aggravating factors for medication and treatment or therapy in percentages.
- Ineffective factors for medication and treatment or therapy in percentages.

4.4.2 In Need of a Web-Based Solution

Some of the applications offered a paid subscription in order to safely store their data on the cloud. All applications have the functionality to export the pain information via CSV or PDF files and share it between devices. One of the applications, "Manage My Pain", has phone and computer support, allowing users to choose which device to use. This analysis concludes that the problem from section 3.2 has been solved.

There are plans to include a server to store the information of bearable. However, data export/sharing, and smartphone support will not be implemented in the initial prototype due to time constraints.

4.4.3 Pain Specialist and Significant Others Interventions

Pain Specialists Interventions

There are no applications that include PS interventions problem section 3.5 PS intervention has not yet been solved. As concluded in section 3.5, PS intervention in CPPs progress is a young field yet to be fully explored.

However, a 2-way messaging is a complex system that needs to include various managing options such as special alarms and chat settings; for example, when CPP inputs information, this can trigger an alarm to the PS based on a condition, e.g. (The patient had a level 8 pain episode). In addition, other complexities need to be considered, as mentioned in a paper reviewed on this investigation; the use of alarms could be a burden for clinicians and raise many legal concerns. To minimize this problem, the paper proposes to the PS negotiating the conditions that trigger the alarm with the CPP and remind patients when installing the alarms that this is at the clinicians' discretion, and if there is an emergency, they should seek help their own (Suso-Ribera et al., 2018).

This project will not be implementing the 2-way messaging system due to time constraints. Nevertheless, this paper would like to incentivize others to produce more work towards PSs interventions.

Significant Others Interventions

There are no applications that include SO interventions, problem section 3.5 SO intervention has not yet been solved. As concluded in section 3.5, SO intervention in CPPs progress is still an unexplored field. However, bearable will pioneer and build a novel solution, the first pain diary with SO support which aims to tackle and overcome the obstacles and obtain the benefits mentioned in section 3.5.

4.4.4 Best Tool for Measuring Pain Intensity?

All systems analysed use NRS scales to measure pain intensity except one, a Likert scale type. A study also advises using VRS or NRS when dealing with elderly or cognitive compromise CPP; the study also suggests using behavioural pain indicators to avoid underreporting pain intensity (Lazaridou et al., 2018). Since most pain patients are of advanced age or are cognitively compromised (Public Health England, 2020) and due to most computer-based and paper-based systems use of NRS, the scale used for this project will be an NRS. The study also mentions behavioural indicators, which were encountered in some of the systems reviewed; this makes the scale a hybrid fusing VRS and NRS; values reported less than 2 are considered mild pain, values between 3 and 7 are called moderate pain, and values between 8 and 10 are considered severe pain (Pombo et al., 2021), an example of these scales can be found in Appendix D.

Therefore, the investigation concludes that problem 3.3 has been solved, and a hybrid scale (VRS and NRS) will be implemented for this project solution.

4.4.5 Concerns with App Compliance and HCI

The main problem with compliance is the time and effort it takes to fill in each pain episode entry; as mentioned previously in this report, the average number of entries between CPPs is five a day. Smartphones apps have successfully addressed this issue but created new standards, and now CPPs want a faster process. "CPP reported difficulties in using these apps in the morning, either because answering to the app at work was difficult or because they had limited time to do it before going to work" (Suso-Ribera et al., 2018). Smartphone apps have also addressed this problem by creating customizable components so that the CPP can choose between 1 and up to 20 or more components, allowing the process to take as quick as 20 seconds. Entries can also be partially filled and finished later when the CPP has more time prioritizing the pain scale, which is the factor most affected by memory bias.

In another experiment where most patients stopped using a pain app after six months advised the implementation of incorporating a reward system "gamification" to have a competitive sense of winning and improving long-term compliance (Jamison et al., 2017). Unfortunately, none of the systems reviewed used gamification, but it is an interesting factor that could be considered for this project's solution.

Another way of improving compliance is tailoring the application for the most popular user profile. Based on the statistics shown by the UK government, the percentage of people with chronic pain in the UK based on the coming age groups are as follows, (16-34: 18%), (35-44: 29%), (45-54: 39%), (55-64: 43%), (65-74: 49%), (75+: 53%) (Public Health England 2020) this concludes that the majority of CPPs are from advanced age and are not used to using electronic equipment especially smartphones, tablets, and computers (Public Health England 2020). Other user profiles need to be considered, e.g. (cognitively compromised, blind or disabled people), but due to the time constraints on this project, only some HCI techniques for designing solutions for the elderly will be considered.

In conclusion, there are some issues with compliance that existing applications have already addressed, but HCI is a broad science, and there is always a wide variety of techniques that can be implemented.

This project will focus on customizable and short diary entries, which can be edited to maximize compliance, will consider gamification techniques, and apply a few UX techniques to make the application more appealing for the elderly.

4.4.5 Validity and Cultural Needs

Validity

Finding reliable sources for paper-based pain diaries was an easy task, unfortunately, and as section 3.7 explains, *"most pain apps are created without the support of professional pain specialists".* Three out of 5 apps reviewed only contained an email address associated with the app, and the other 2 had websites claiming that their applications are backed by scientific review and have been developed by leading hospitals. These two applications are "Bearable" and "Manage my pain". The quality of these apps is considerably better compared to other options on the google play store.

In conclusion, most applications have indeed been developed without professional pain specialists and considering the small number of apps that claimed and have proved to be backed up by research and professionals is yet too small, making this a prevailing problem.

Since this project is a proof of concept and there will be no deployment or test with real CPPs, the papers solution will not become part of this problem. Furthermore, if this application were to be continued, it is highly recommended to contact pain specialists to validate the application before full deployment.

Cultural Needs

The problem with previous systems was that most of them did not consider cultural needs and were not customizable. In conclusion, building a solution that considers every aspect of every culture is almost impossible, but current solutions offer highly customizable systems that can be considered a reasonable solution to this problem.

This project intends to create a highly customizable application components to address cultural needs.

Chapter 5

This chapter is going to use HCI techniques to reveal insightful characteristics aimed at improving the interaction between user and application. As mentioned in the previous chapter the only target user which will be evaluated on this pact analysis are the elderly suffering from chronic pain.

5.1   PACT analysis

This section will create a PACT analysis to better understand the needs and circumstances of the user, the activities that the user will perform on the system, the context in which the user will use the system and the functional features used.

5.1.1 People

Cognitive and Emotional Characteristics

Most elderly have insufficient attention, memory, perception, learning ability and technology skill and are easily frustrated when dealing with technology. A minimalistic design is proposed; the interface will contain only core functionalities evaluated in this investigation, thus avoiding clustering, and reducing the cognitive load on elderly users.

Physical Abilities and Disabilities

Chronic pain and ageing can affect motor skills, making utilizing a mouse or phone hard to use. The interface components must be large enough to address this deficiency.

Visual

The Elderly usually have weak eyesight due to ageing, but some chronic pains can also affect vision, e.g.(headaches). The interface icons and text must be large enough to address this issue. WCAG also recommends a contrast ratio of 4.5:1 for text under 18px and 3:1 for larger text to improve readability.

Experience and Expectation

The elderly is considered as low skill technology users with slow learning curves. The application will follow a linear / system initiative format so that there is no learning curve for recording a diary entry. Also, Examples and information icons will be placed in each function for user guidance.

Language and Culture

This prototype will only include English speaking users. All variables will be highly customizable so that they can be tailored to any cultural needs. Popular icons, basic jargon and an intuitive workflow will be used to enhance comprehension.

5.1.2 Activities

The CPP fills in the diary 3-5 times a day or depending on the number of pain episodes he had that day, making the interaction with the system constant; there are no diversions while filling up the diary. The time it takes to fill in an entry is less than a minute. The process of filling the entry is linear; the system takes the initiative in asking for the information. The CPP can view useful statistics at anytime and anywhere regardless of internet connection. CPP can choose who can inspect his/her profile.

5.1.3 Context

Any place and at any time that a pain episode might occur. Usually, one hour after a pain episode has occurred.

5.1.4 Technology

The solution will be developed for Computers but design as a web app for phones.

Input: The information inputted on each entry is relatively small and is based on the latest pain episode; the format is given by the system and requires little complexity to fill in.

Usability criteria: The system must be tailored towards this user profile's ability. Due to its frequency, usage must be efficient. The CPP has to feel that his quality of life is being improved by correctly filling in the pain diary. The CPP must know when SO's have received an alert.

Functional support: Must store inputted information on the device's local memory, and this should be then sent to a database on the web to access the information without internet access, prevent data loss, and assure that SOs can access the data. The system must notify the user when alerts to SOs have been sent. The system must show valuable user statistics about their records at all times.

5.2 Conceptual Diagram

The conceptual diagram below shows the different screens, functionalities of each screen, and the information flow between them.
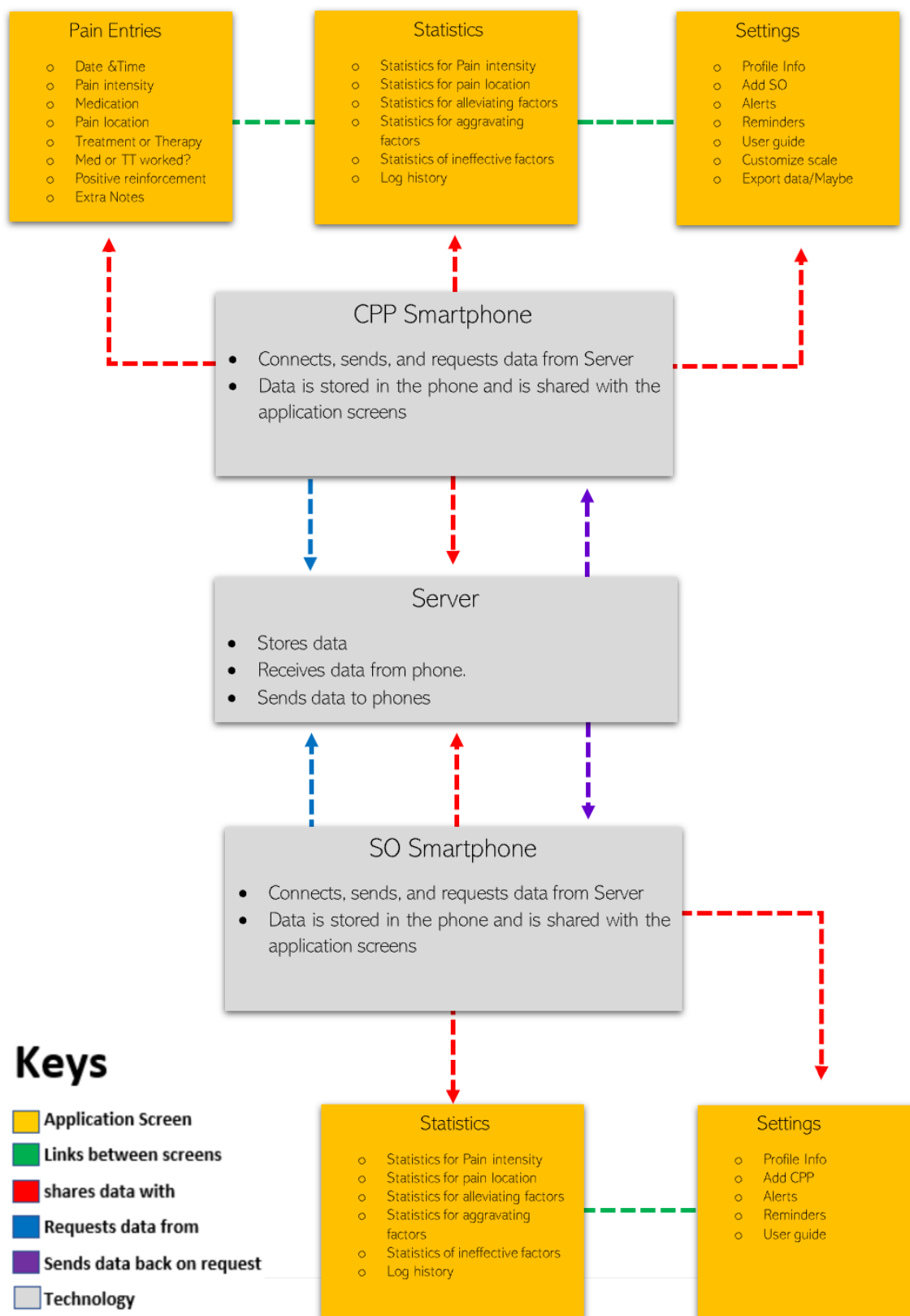

Figure 7: Conceptual diagram

5.2.1 Explanation of Conceptual Diagram

Pain Entries: This screen enables the CPP to record an entry of a pain episode by filling in the variables specified in the diagram.

Statistics: This is the screen that both CPP and SO will share. This screen shows the statistics proposed in section 4.4.1

Settings: This screen will enable the CPP to add SOs in order to spectate their statistics. Further functionality of this page will be decided during the practical stage.

Smartphone: The smartphone will save input data in its local memory. The phone will update the server through its local memory, and the information requested from the server will first be stored in the phone's local memory and then shared to the different screens.

Server: The server will store information about the patient statistics, pain entries, personalized settings, and log in. The server will receive information from the phone and send information on phone request.

5.3 Mood Board

This section aims to build a design, a proof of concept based on the pain management prototype. This mock-up does not include the UX techniques concluded during the HCI process. Instead, is an initial idea that shows the main functionality of the application and will change. The design includes the main screens workflows "Pain Entry" and "Statistics." The "Settings" scree is dependent on the project's time and will be designed during the practical stage. An application name has been selected "Tangible" as this application will enable intangible subjective pain to be recorded.
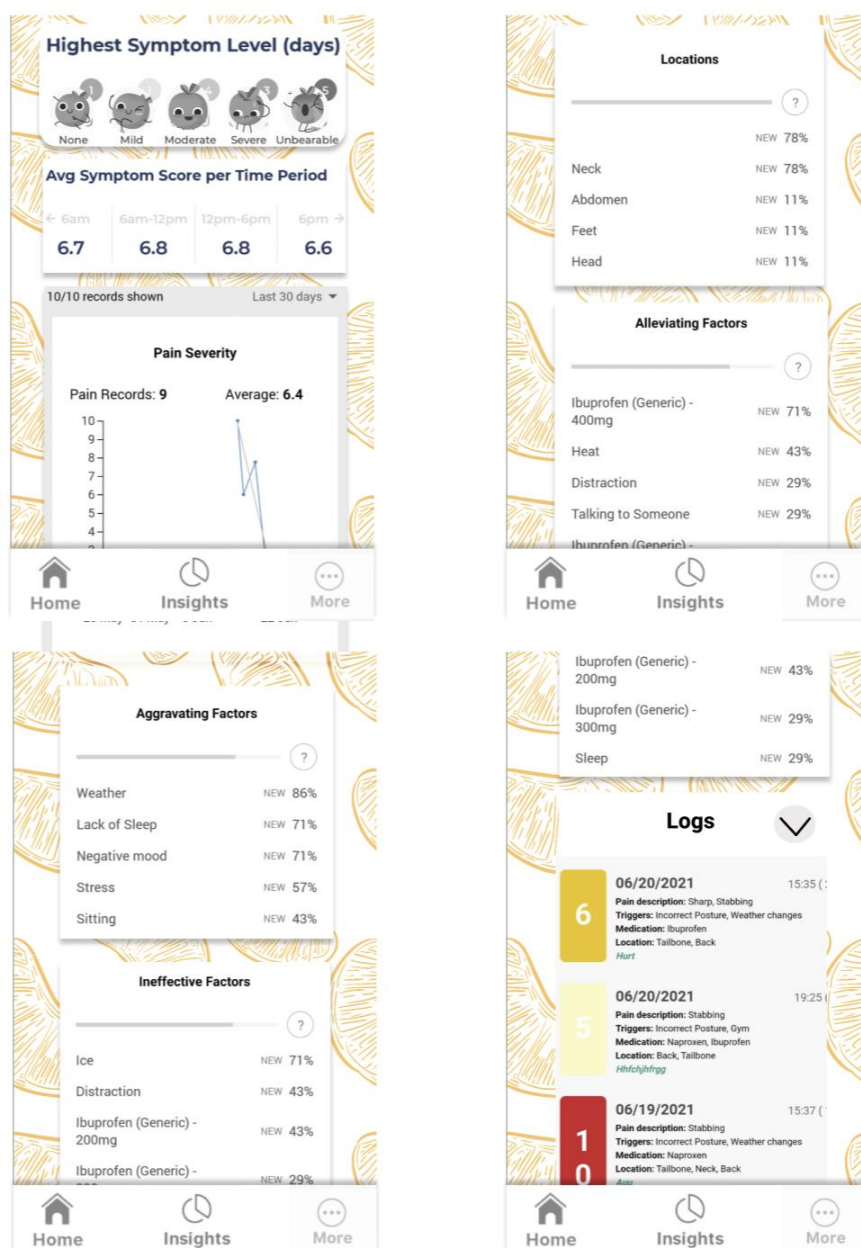
Figure 8: Statistics Screen
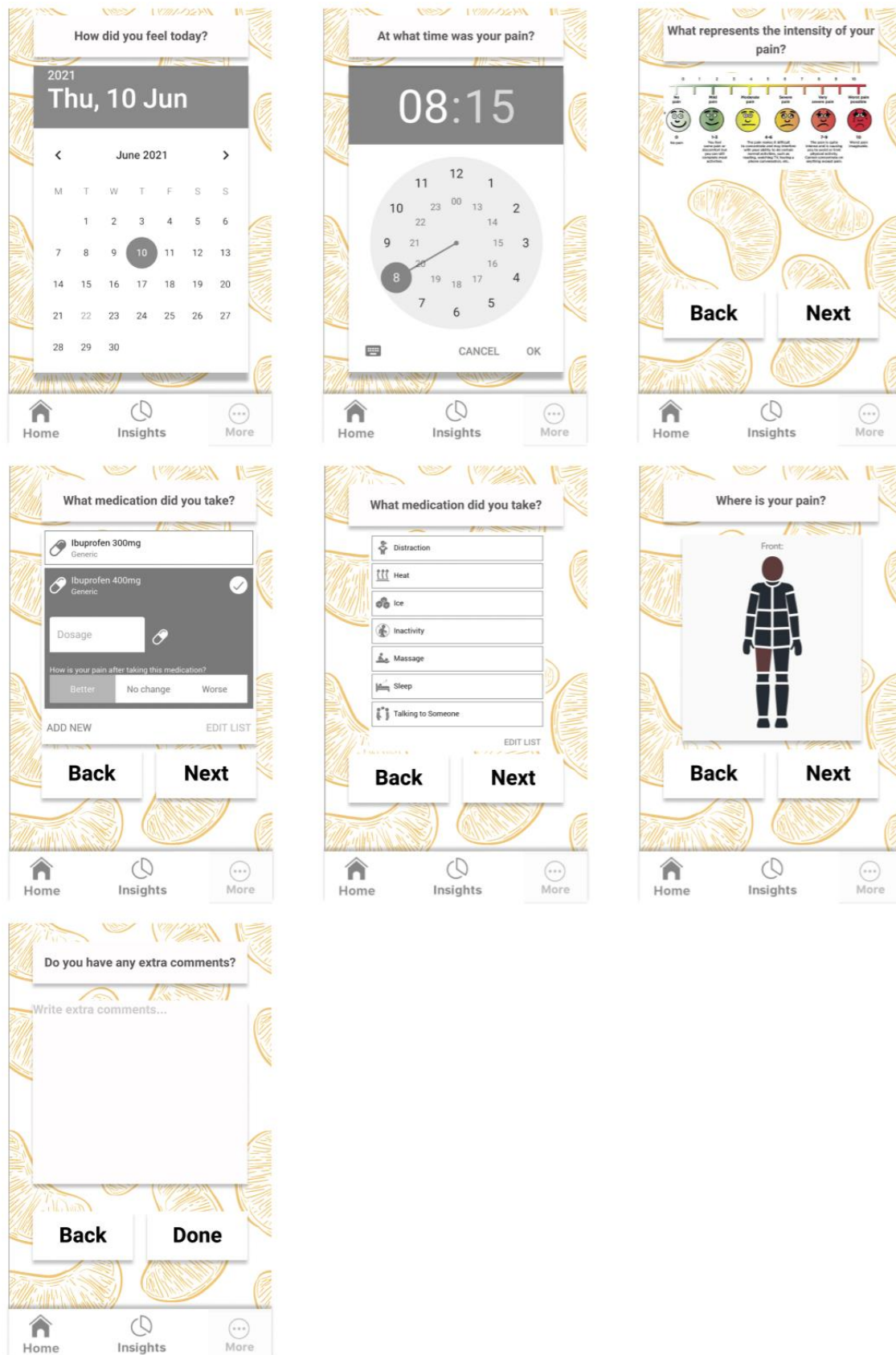
Figure 9: Pain Diary entry / Home

5.3.1 Mood Board Explanation

This section will describe the mock-up in figures 8 and 9.

Home

This screen records each CPP pain episode. The screen is linear, and the system takes the initiative to ask the user about the episode making it simple and eliminating any learning curve. The screen asks date and time, followed by the hybrid VRS-NRS scale for pain intensity assessment. The user can then choose which medications he has consumed with the respective dose and whether the medication worked or not; the user can also edit, remove or add medications. The system then enquires about any treatment and therapy implemented to deal with the pain, and the user can select multiple options and choose whether they worked or not; the user can also edit, add or remove components. The system asks for pain location; the user might have a body map or a list of body parts he can choose to state the location of their pain. Lastly, the system asks for additional comments if the CPP wishes to log any details not included in the recording walkthrough. The screen has "back" and "next" buttons if the user needs to go back to change any options.

Statistics

This screen contains all the statistics proposed in section 4.4.1. On every pain diary entry, this screen will be updated. The user will be able to see the usage statistics and scroll down to see the rest. The graph showing the pain severity will be able to be customized for selected dates. At the end of the statistics screen, the user has the logs component where he will see previous logs and filter them by different variables such as date, time, intensity, medicine or treatments.

Chapter 6

Chapter introduces the methodologies, system requirements and software development tools used to develop the application.

6.1   Methodologies and Software Development Tools

This section will explain the methodologies used to study, design and build the computer-based pain diary "Tangible - Chronic Pain Diary." The section will also include the software development tools used to design and build the system. It also reviews important LESP concerns, risk issues, the conclusion of this paper and further research work.

6.1.1 Methodology

The methodology used for creating Tangible is called "Agile". Agile is a mindset it allows you to approach project development in a way that improves teamwork & client communication and responsiveness towards change. This method is design for a team so only some of the methodologies will be implemented.

The first action to be completed in agile will be "The Backlog", a list of functionalities, features, and requirements called "epics" needed to complete the app. The items in the backlog will need to be organized by priority in descending order.

The second action will be to break down each Epic's product backlog into "user stories". User stories are short narratives of what the app does from the user perspective. The idea is to obtain small portions of work/functionalities that can be finished in hours or a day. Every user story will also be organized by implementation order, i.e. (which one needs to be implemented first so others can be implemented on them.)

The second step is called a sprint; a sprint is a timebox iteration of work intended to deliver a functional portion of the app. every sprint will last one week. At the beginning of each sprint, some of the user stories will be selected enough to represent a week's work. Then the user stories will be placed on a "Kanban board" in order from most important to least. A Kanban board offers a pace where individuals tasks can be placed. Usually contains columns describing what users' stories need to be done, which ones have been completed and which ones are in progress. Finally, at the end of each sprint, there will be a retrospective to review current progress, detect any obstacles or changes and schedule next week's work.

6.1.2 Software Development Tools

Figma: Is a vector graphics editor and prototyping tool. Figma is usually used to create a mock-up for an interface.

React: Is an open-source front-end JavaScript library for building user interfaces or UI components. It can also be used for single-page or mobile applications. It also included JSX which uses HTML to build websites.

FireBase: Is a platform/Database developed by Google for creating mobile and web applications.

Visual Studio Code: Is a source-code editor made by Microsoft for Windows. Features include support for debugging, syntax highlighting, intelligent code completion, snippets, code refactoring, and embedded Git.

Git-Hub: Is a provider of Internet hosting for software development and version control using Git.

Git: Is software for tracking changes in any set of files, usually used for coordinating work among programmers collaboratively developing source code during software development.

6.2   System Requirements

This section is going to review the System requirements for the "Tangible-Chronic Pain Diary"

- Must enable CPPs to record pain episodes by recording all the variables agreed on section 4.3
- Must implement a user interface with the system describe in figure 7: conceptual diagram
- Must include 80% of the components proposed on the statistics screen
- Must enable a CPP to add a SO so that the SO can spectate his pain progress.

- Should have customizable pain scale
- Should have alerts settings to choose if alerts should be sent to SOs or when.
- Should have user Guide explaining the functionality of the application.

- Could have user log in with password change option

- Could have reminders so that the user can schedule medicines or entry recording reminders

- Could have data export functionality allowing the user to share their pain progress with others.

- Could have all the statistical components proposed in section 4.4.1

6.3 LESP and Risks

There are many LESP, and risks related to the testing and deployment of this project, which will need to be dealt with at those stages. Since this project is just a proof of concept and the prototype will not be tested nor published, there will not be any LESP or risk considered at this early stage.

6.4 Conclusions

Chronic pain is a phenomenon affecting many people. There are many solutions implemented to deal with chronic pain; the most widely used in pain management is pain diaries. Many paper-based and computer-based solutions are currently available and have addressed many issues identified with chronic pain. Some of the issues successfully address are the use of core factors to manage chronic pain, the addition of valuable statistics to help PS and CPP's understand the pain better, web-based solutions which allow the CPP to store the data safely, access it from anywhere and share their progress with SO's and PSs, improved compliance rates of pain diaries thanks to the upgrade from paper-based to computer-based pain diaries, UX improvements allowing the applications to be highly customizable and able to adapt to different cultural backgrounds and age ranges.

Not all of the obstacles have been addressed, the investigation was able to detect that most solution does not include PS and SO direct support and it has been demonstrated in this paper that there are possible benefits to this features. Another problem detected is the large number of solutions created that have not been validated by real professionals, some CPPs run the risk to use applications that have not been designed to help them.

This investigation has reviewed the current literature and proposed a computer based-solution that offers greater accessibility is effortlessly configurable and scalable for the chronic pain management field, which includes core functionalities found in most current solutions and a new feature, "SOs support", which will allow chronic pain sufferers and their loved ones to understand each other and be "be on the same page".

6.5 Further Research Work

Further research work will be needed to implement UX techniques and statistical sciences.

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Appendices

Appendix A

NPS MEDICINEWISE — MY PAIN DIARY

DATE AND TIME	DESCRIBE YOUR PAIN (e.g. how long it lasts, where it is, whether it moves, what it feels like – dull, sharp, stabbing)	RATE YOUR PAIN (0-10, see overleaf)	WHAT MADE YOUR PAIN WORSE?	WHAT HELPED YOU GET THROUGH THE DAY? (medicine and non-medicine such as meditation, exercise etc)	DESCRIBE YOUR ACTIVITY LEVEL AND MOOD (Has the pain affected your daily life, including sleep, work social life etc)	COMMENTS (e.g. problems with medicines, how your pain affects your daily life – sleep, mood, work etc.)

MY PAIN DIARY

What is a pain diary?

A pain diary is a written record of how your pain affects your daily activities. It helps you to describe to your healthcare team how your pain has been affecting you over time.

A pain diary also records how medicines, other therapies and your activities affect your pain levels throughout the day.

Why should I keep a pain diary?

A pain diary can help you and your healthcare team:

► understand what makes your pain worse and what helps to relieve your pain

► track your response to your pain management plan, including changes in your medicines or other therapies.

When should I use a pain diary?

Use your pain diary as often as recommended by your doctor or pharmacist. This may include when you have ongoing pain, changes in your activity levels or changes in your medicines.
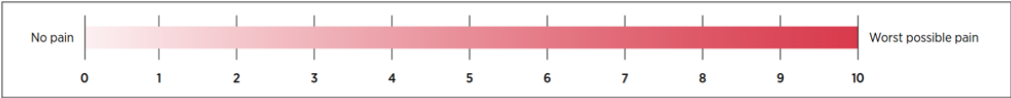
The information that you record will help you and your healthcare team prepare and guide your pain management plan. If your pain is under control you may not need to use the diary as often.

The more information you record in your pain diary, the more helpful it will be for you and your healthcare team.

How do I complete a pain diary?

Record all the information that is relevant to your pain in the diary over the page. You may not need to fill out all columns each time.

To complete the diary use the rating scale (below) to rate your activity. A zero (0) means no pain and a ten (10) means worst possible pain. Select the number that best describes your pain.

No pain											Worst possible pain
0	1	2	3	4	5	6	7	8	9	10	

This leaflet may be printed for patient use.

June 2015

# Appendix B

Daily Pain Diary

Many people with cancer have pain from cancer, cancer treatment, or some other cause. Having pain is *not* a normal part of cancer and cancer treatment. Nearly all cancer pain can be controlled or relieved. Good pain management is part of good cancer care.

Only you know how much pain you have. Your cancer care team and loved ones have no way of knowing about your pain unless you tell them. It helps to use words that clearly describe your pain. Tell your team:

- **Where you feel pain** – be specific, for instance: "the lower left side of my back"
- **What it feels like** – some words to use are:
  - Sharp – like a bad cut
  - Dull – like a sore muscle/muscle ache
  - Throbbing – like a headache
  - Steady – like a toothache or sore throat
  - Burning – like a bad sunburn
- **How severe the pain is** – Use the 0-to-10 pain scale tool described at right.
- **How long the pain lasts** – for example, minutes, hours, days
- **What eases the pain** – for instance, cold compresses, heat, repositioning, medicines
- **What makes the pain worse** – for example, moving, changing positions, it gets worse in the evening, etc.
- **What pain medicines you are taking,** when you take them, and how much relief you get from them

Tools for rating your pain

Using a pain scale helps to describe how much pain you have. For instance, try to put a number from 0 to 10 to your pain level. If you have no pain, use a 0. As the numbers get higher, they mean worse pain. A 10 means it is the worst pain you've ever had. You might say "My pain is a 7 on a 0-to-10 scale" or "a 2 on a 0-to-10 scale."
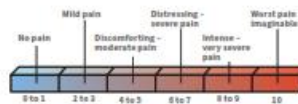
You can use this 0-10 rating scale to describe:

- How bad your pain is at its worst
- How bad your pain is most of the time
- How bad your pain is at its least

It can be hard to remember the details every time you have pain. The diary on the back of this sheet will help you keep track of your pain so you can tell your doctor or nurse exactly how you've been feeling. This will help your cancer care team understand your pain better.

Use this diary to record your pain and what you did to ease it each day. Fill in the chart, and take it with you to your next appointment. In the notes column you may want to write how you felt after taking the medicine, (for example, better able to sleep, eat, be active) and/or side effects causing problems (such as constipation, drowsiness, confusion).

If your pain is not relieved, tell your doctor or nurse. There are many ways to treat cancer pain. Work with your team to find the treatments that work best for you.

American Cancer Society®   cancer.org | 1.800.227.2345

Daily Pain Diary

Date & time	Pain score (0 to 10)	Where pain is and how it feels (ache, sharp, throbbing, shooting, tingling, etc.)	What I was doing when it started	Name and amount of medicine, and time it was taken	Non-drug techniques I tried	How long the pain lasted	Pain score 1 hour after taking the medicine	Other notes

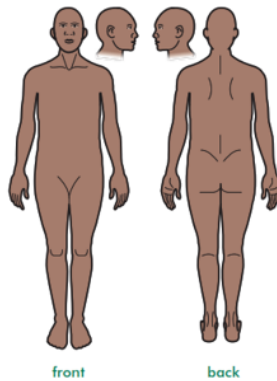American Cancer Society®   cancer.org | 1.800.227.2345

WRITTEN AUGUST 2018

Appendix C

Where is your pain?

Is it in one part of your body or in more than one place?

You can use the diagrams on the right to mark where your pain is.

If you have more than one area of pain, label them A, B, C, and so on (with A being the pain that upsets you the most).

front   back

What is your pain like?

Use any of the following words that best describe your pain:

- aching
- biting
- blunt
- burning
- cold
- comes and goes
- constant
- crushing
- cutting
- dragging
- dull
- excruciating
- frightful
- gnawing
- hot
- intense
- nagging
- nauseating
- niggling
- numb
- penetrating
- piercing
- pins and needles
- pricking
- radiating
- scratchy
- sharp
- shooting
- smarting
- sore
- spreading
- stabbing
- stinging
- tender
- throbbing
- tingling
- tiring
- unbearable.

Numbered pain scale

How bad is your pain? If you measured it on a scale of 0 to 10, how would you rate it? Where 0 is no pain and 10 is the worst pain you've ever had.

PAIN DIARY

WE ARE MACMILLAN. CANCER SUPPORT

How to use your pain diary

You may want to pull out this pain diary and photocopy it, so you can use it more than once. Remember to photocopy both sides.

1. Start by recording when you feel the pain – there's space to note the date and time. You can fill in the diary as often as you need to. If your pain isn't well-controlled, you may want to fill it in every 1 to 2 hours, but if it's better controlled, you can fill it in every 4 to 6 hours.

2. Record where the pain is on your body – you can use the diagrams on the back. It could be in one area or in lots of areas.

3. Describe what the pain feels like. You could use the words on the back to help you.

4. Rate the level of pain on a scale of 0 to 10, where 0 means no pain and 10 means severe pain.

5. Write down the medicines you've used, and any other treatments or therapies that have helped manage your pain. And record anything that made the pain better or worse.

All of this information will help you and your healthcare team find the best way to manage your pain.

Keeping a record of your pain will help you discuss it with your doctors and nurses. Photocopy this diary before you fill it in so that you can use it as often as you need to. If your pain is in more than one place, you may want to use an extra copy of this diary.

You can print more copies of this diary from our website at **macmillan.org.uk/information-and-support/coping/side-effects-and-symptoms/pain**

| Date and time	Where is your pain?	What is your pain like?	Level of pain (0=no pain 10=severe)	What medicines and treatments have you used?	What makes your pain better?	What makes your pain worse?

Appendix D

Pain Diary

Your doctor, nurse or pharmacist will explain to you how to take your pain relief medications.

This diary will help you and your doctor, nurse or pharmacist to decide whether the pain relief medications you take are suitable for you.

Please fill in the pain diary every time you take your pain relief medication or at least twice a day.

When you fill in your pain intensity please use the pain assessment tool below to help you describe the pain you are experiencing.

Record your pain intensity just before taking your pain relief medications, take your medications, then wait 30 – 60 minutes and record your pain intensity again.
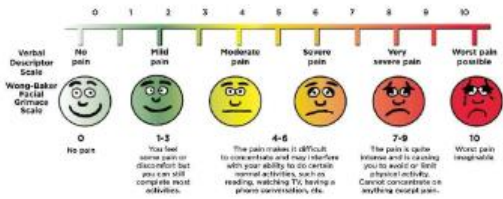

Please keep a note of any side effects that your pain relief medications cause and how the pain is affecting your daily activities such as stopping you doing activities, or limiting how far you can walk.

Please bring the completed pain diary to the next appointment for your pain. You and your doctor, nurse or pharmacist can use the information you record to decide if your pain relief medications are right for you.

Date and time	Name of medication and dose taken	Pain intensity before taking pain relief	Pain intensity after taking pain relief	Any side effects? What are they?	Is your pain affecting daily activity? In what way?	Was my sleep disturbed by pain?
/ / ___am ___pm						
/ / ___am ___pm						
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Appendix E

PAIN DIARY - Please make an entry whenever you experience pain

DAY & TIME	WHERE WERE YOU & WHAT WERE YOU DOING?	HOW LONG DID IT LAST?	WHERE WAS THE PAIN?	HOW SORE WAS IT? RATE USING SCALE BELOW 0-10	HOW DID YOU FEEL?	WHAT WERE YOU THINKING?	HOW DID YOU COPE? WHAT DID YOU DO?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Training in Psychological Skills - Paediatric Healthcare
Pain Module HANDOUT
Promoting Positive Behaviour HANDOUT