A Mobile Application for Psychological Assessment

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Most people say that it is the intellect which makes a great scientist. They are wrong: it is character.

Albert Einstein

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This thesis is dedicated to my family and friends, specially to my brother, Paulo Filipe.

Abstract

The appearance of a twenty-four hours, seven days a week society in developed countries, lead to an increase in sleep debt among the population. This impairment provokes several physiological and cognitive diseases, such as, obesity, diabetes, cardiovascular and gastrointestinal diseases and other problems associated with cognitive functions, like short-term memory and attention deficits. Thus, early and accurate diagnosis is crucial for the accomplish of suitable treatment.The current tools for psychological assessment need a wide range equipment. From devices for performance tasks to sleep diaries and sleep scales data collection.

In the last few years several innovations in the mobile technologies field lead to an unprecedented evolution in smartphones. The presented work in this thesis purposes an Electronic Psychological Profiler (ePP), an Android application that takes advantage of smartphones capabilities to create an embedded system, easy to use, and available for the general population.

All the information regarding how the application works, along with visual examples for better understanding, are provided. The final result was highly satisfactory, comprising a sleep diary, PVT and n-back tasks, a Karolinska Sleepiness Scale (KSS) and a Samn-Perelli Fatigue Checklist (SFC), along with a new approach for vigilance measurement during a long and continuous period of time. The collected data can easily be accessed and analyzed by physicians, hence, the ePP provides a quicker and friendly interface for psychological assessment.

Keywords

Sleep, Memory, Attention, Application, Android, Psychological

Resumo

O aparecimento de uma sociedade de vinte e quatro horas, sete dias por semana nos países desenvolvidos, levou a um aumento dos casos de débito de sono entre a população. Este dano provoca várias doenças do foro fisiológico e cognitivo, tais como, obesidade, diabetes, doenças cardiovasculares e gastrointestinais e problemas associados a funções cognitivas, tais como, défices de vigilância e memória de curto prazo. Assim, um diagnóstico precoce e preciso é fundamental para um correcto e eficaz tratamento. As actuais ferramentas para avaliação psicológica necessitam de um elevado número de equipamentos, desde dispositivos para realização de tarefas de desempenho até formas de armazenamento de diários e escalas do sono.

Nos últimos anos, várias inovações no campo das tecnologias móveis levaram a uma evolução sem precedentes nos smartphones. O trabalho apresentado nesta tese propõe um Electronic Psychological Profiler (ePP), uma aplicação Android que tira proveito das capacidades dos smartphones para criar um sistema integrado, fácil de usar, e disponível para a população em geral.

Todas as informações a respeito do funcionamento da aplicação, juntamente com exemplos visuais para a sua melhor compreensão, são fornecidas. O resultado final foi altamente satisfatório, contendo um diário do sono, um PVT e um n-back, duas escalas do sono, Karolinska Sleepiness Scale (KSS) e Samn-Perelli Fatigue Checklist (SFC), juntamente com uma nova abordagem para a medição da vigilância durante um longo e contínuo período de tempo. Os dados adquiridos podem ser facilmente obtidos e analisadas pelos profissionais de saúde e assim, o ePP fornece uma interface mais rápida e amigável para avaliação psicológica.

Palavras Chave

Sono, Memória, Atenção, Aplicação, Android, Psicológica

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Abbreviations

ACK Acknowledge

AHR Adjusted Hit Rate

API Application Programming Interface

CENC Centro de Electroencefalografia e Neurologia Clinica

.CSV Comma-Separated Values

dp Density-independent Pixels

DSPS Delayed Sleep Phase Syndrome

EEG Electroencephalography

EMG Electromyogram

EOG Elctrooculogram

ePP Electronic Psychological Profiler

EPS Epworth Sleepiness Scale

fMRI Functional Magnetic Resonance Imaging

KSS Karolinska Sleepiness Scale

NREM Non-rapid Eye Movement

OS Operating Systems

OSAS Obstructive Sleep Apnoea Syndrome

PLMD Periodic Limb Movement Disorder

PSG polysomnography

PVT Psychomotor Vigilance Task

REM Rapid Eye Movement

SCN Suprachiasmatic Nucleus

SFC Samn-Perelli Fatigue Checklist

RLS Restless Legs Syndrom

sp Scale-independent Pixels

SSS Stanford Sleepiness Scale

STM Short-Term Memory

SWS Slow-wave Sleep

SWSD Shift Work Sleep Disorder

UI User Interface

UX User Experience

1

Introduction

Contents

The appearance of a twenty-four hours, seven days a week society in developed countries, lead to an increase in sleep debt among people.[3] Sleep disorders besides causing impairments to the day-to-day routines of people, also contribute to several other diseases, such as, obesity, cardiovascular and gastrointestinal problems and brain neurodegenerative diseases, like Alzheimer. Hence, early and accurate diagnosis is crucial for the accomplish of suitable treatment.[3],[49].

Current methods for diagnosis of sleep problems comprise polysomnography (PSG), actigraphy, oximetry, sleep diaries and performance tasks. PSG is the standard tool for this assessment as it allows a complete analysis of the sleep cycle regarding brain activity during sleep. It is a very powerful resource but with downside of being a costly exam and because of its complexion, must be supervised by a technician, thus being made in laboratory or clinical environments.[35],[17]

Sleep diaries are assessment tools used to perceive the individual sleep routines. These questionnaires are often made by hand, with the need for large volumes of paper to account for long periods of analysis.

Other useful tools are frequently applied, such as performance tasks, like Psychomotor Vigilance Task (PVT) and n-back tasks. Normally, these procedures need specific devices for each one of them, hence, totalizing a large number of equipments that a patient must carry on with.

With the technological revolution in mobile phones, a new concept may be in the horizon. Nowadays, smartphones are small computers with powerful computational capabilities, thus, being the perfect means to apply all the aforementioned systems.

1.1 Objectives and Motivation

The hereby thesis is purposed in order to overcome the necessity of broad new tools for psychological assessment. To correctly diagnose a patient with a sleep disorder, short-term memory problems or sustained attention deficits, a physician must take benefit of a wide range of tools and equipments.

Besides PSG being the benchmark for sleep studies, several diseases can be diagnosed or screened using other assessment tools, like sleep diaries, performance tasks and visual scales.

Because discomfort appears when a patient must use several different devices, plus a wide number of paper pages, to properly provide the necessary information for an accurate diagnose, it is imperative that new approaches capable of providing the same information with the same accuracy are made.

With the available Operating Systems (OS) for smartphones and subsequent encouragement from their manufacturers for third party application development, a window of opportunities arise. Nowadays, smartphones come with a wide range of sensors and elevated computational power. Therefore, it is possible to give use to all these capabilities in order to create embedded systems capable of multiple chores.

The main objective purposed by this thesis is the creation of an Android application for psychological assessment. This application must include a sleep diary, Psychomotor Vigilance Task (PVT) and n-back tasks.

Furthermore, a new approach for continuous monitorization of a subject attention during a long period of time will also be addressed.

Working in close contact with Centro de Electroencefalografia e Neurologia Clinica (CENC) the application will be improved in order to better suit the current needs. As this project is a joint effort between Instituto Superior Técnico, namely, Instituto de Sistemas e Robótica and CENC, the prototype will be tested by the later.

1.2 Original Contributions

The prototype described in this thesis has been successfully applied to gather information regarding sleep routines and performance values, which lead to the presentation of an abstract, as a poster, in the 6th World Congress on Sleep Medicine in Seoul, Korea, on March 24th, 2015.

- INDIVIDUAL VARIABILITY TO BIOLOGICAL, HORMONAL AND PSYCHOLOGICAL RESPONSES TO SLEEP DEPRIVATION, Reis C., Domingues A., Mestre C.,Ribeiro J., Sanches J., Paiva T.

1.3 Thesis Outline

The present thesis is divided in four chapters. Chapter two gives the necessary background needed to contextualize the problem, where the physiological functions associated with sleep, sleep disorders and assessment tools are portrayed. As the system described uses two performance tasks that evaluate cognitive functions associated with short-term memory and attention, these subjects are also defined. Finally, the chapter ends with a review in the current state of the art for smartphones, where the application will run.

In the following Chapter, the system framework with all the implementations need for the development of the Electronic Psychological Profiler are presented.

Chapter four, presents a detailed step-by-step explanation of the system in the user point of view. In this chapter a visual insight of every feature present in the Electronic Psychological Profiler (ePP) is accompanied by the explanation of their workarounds.

The last chapter contains the conclusions for the hereby presented system, with the necessary suggestions for future developments and possible expansions of the ePP.

2

Background

Contents

The present chapter features the bibliographical review from which this thesis is based. The objective of such review relies on the correct understanding of the problem, and thus, the motivation for this thesis. In developed countries sleep debt as become endemic, result of the 24/7 society. [2] [3] Such debt provokes an increase in the number of sleep disorders, thus, being necessary new approaches to help in the diagnostic and treatment of these conditions. This chapter is divided in six sections. The first section addresses sleep and its subsequent disorders. The second and third sections define two psychological capabilities that became impaired with sleep loss, short-term memory and attention, respectively. The fourth section correlates the previous subjects. Section five presents the different tools used for diagnosis of sleep disorders. Finally, the sixth section introduces the current state of the art for smartphones and its operating systems and how they can become a useful tool for sleep medicine.

2.1 Sleep

Throughout history, several attempts to define sleep were made. It is known that all animals evolved a devision of behavioral states: activity, or adaptive behavior, and rest, or behavioral quiescence. For mammals, specifically, these states are known as wake and sleep. In ancient Greece, Hippocrates defined sleep as the cooling of blood, thus causing a shut down of the body. In turn, Aristotle, described sleep and wakefulness as opposites but necessary processes, controlled by a central organ responsible for sense perception.

In the beginning of the 20th century the first scientific explanations for sleep mechanisms arose, nevertheless, only in the 50's, with the evolution of Electroencephalography (EEG) and new anatomical, histochemical and biomolecular methods, was possible to study neuronal networks and brain activity, and start to understand the mechanisms underlying sleep and wakefulness. With EEG was possible to divide sleep in two different stages, Rapid Eye Movement (REM) sleep and Non-rapid Eye Movement (NREM) sleep.[26][16][27]

2.1.1 Neurophysiology of Sleep

The dominant model to characterize sleep was proposed by Borbély, in 1982, and later adapted by Daan, thus being known as *Borbély-Daan Model*. The authors created a model with two interacting mechanisms, Process S, or homeostatic drive for sleep, and Process C, or circadian cycle. Both processes interact, counterbalancing each other and regulating the sleep-wake cycle during the day. Blood-pressure, body temperature and melatonin levels are considered circadian time indicators, hence being very important for sleep studies.[27][39]

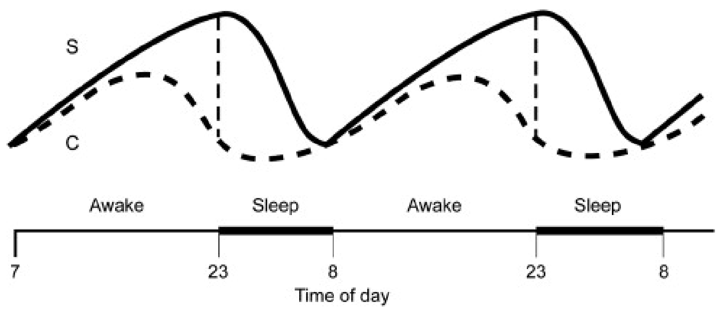


Figure 2.1: Borbély-Daan Model. Interaction between Processes C and S in a two day period. Adapted from [26].

Process S can be characterized as the accumulation of sleep-promoting substances that increase throughout the day. The neurobiological aspects that influence Process S are not fully understood, although, it is hypothesized that genetic factors and adenosine retention may strongly influence this homeostatic process.[13][39][26].

Process C is mainly controlled by the Suprachiasmatic Nucleus (SCN) of the hypothalamus. The first evidence for the importance of the SCN in the control of sleep appeared in early 1920s, as patients with tumors in that region had inconsistent patterns for sleep and wakefulness.[27] Later studies in rats showed that the ablation of the SCN affected the duration of REM and NREM sleep stages. The SCN is known for promoting wakefulness during the day and and sleepiness during the night.[25]

This coordination is made based on light inputs during the day and melatonin secretion during the night. The secretion of this hormone is controlled by the pineal gland. As the neuron firing rate of the SCN decreases in the night, sympathetic activity is stimulated, resulting in melatonin secretion. As melatonin inhibits the neuron firing of the SCN, the circadian drive for wakefulness diminishes even more.

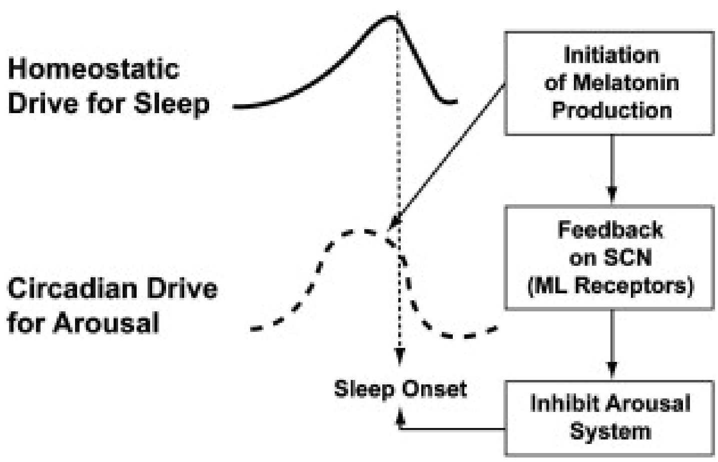


Figure 2.2: Melatonin biofeedback system in the circadian pacemaker. Adapted from [26].

Also synthesized by the pineal gland is the neurotransmitter serotonin, which is intrinsically associated with the sleep-wake cycle. High levels of serotonin are related to wakefullness and lower levels with sleepiness. Studies with rats shown a complete disruption in the sleep-cycle when depletion os serotonin was induced. In humans, deficiencies in serotonorgenic neurotransmission account for REM sleep onset, thus, being an important factor for measuring circadian rhythm disturbances.[28][5]

2.1.2 Sleep Architecture

Before the appearance of EEG it was hypothesized that during sleep the brain was inactive, like the rest of the body. With the introduction of this technology it was possible to characterize sleep in terms of brain activity. Brain wave activity differs between wake and sleep states. During sleep itself, different patterns of neuron potentials can be observed.

In humans a normal sleep period consists of four to five cycles which last for about 90-100 minutes.[27]

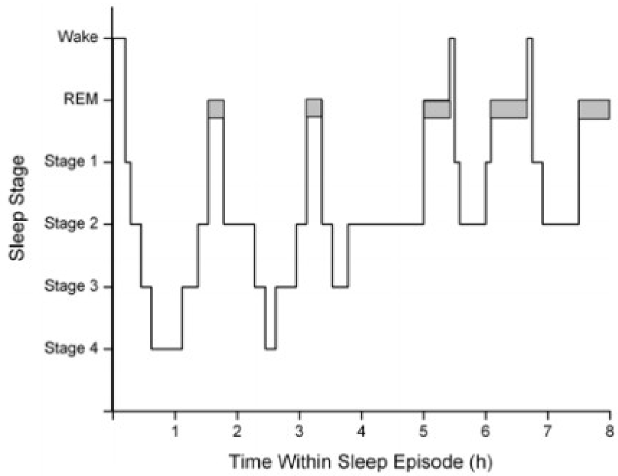


Figure 2.3: Schematic representation for the human sleep cycle. Adapted from [27].

Figure 2.3, shows the different states that compose a sleep episode of 8 hours. These states are characterized as *Rapid Eye Movement* (REM) sleep and *Non-rapid Eye Movement* (NREM) sleep.

In a normal subject sleep progresses through the different stages in order. Starting in NREM sleep stage 1 to 4, followed by REM sleep. As the sleep cycle progresses through the night the proportion of each sleep stage changes. the greatest amount of NREM sleep stage 3 and 4 occurs in the first cycle, whereas in the last two may be very brief or even absent.[16]. These two stages are commonly referred as Slow-wave Sleep (SWS) for the slow wave characteristics present in EEG. REM sleep evolves in an opposite way, with higher duration periods occurring in late sleep cycles.[16][27]

In NREM sleep sympathetic activity is low and parasympathetic activity increases. Hence, physiological functions controlled by autonomic activity, such as, blood pressure, heart rate and tidal volume reach there minimum in SWS.[16].

As the name suggests, the main difference between NREM and REM sleep is the presence of rapid movements of the eyes, which can be seen in the electrooculogram. As sympathetic activity is more variable than in NREM sleep, the physiological functions mentioned above have higher fluctuations. REM sleep is associated with dreaming. This process occurs only in this stage of sleep. thus, individuals awaken during REM sleep report vivid sensations. [16].

In the EEG, NREM sleep is characterized by the synchronization in cortical neurons represented by the slowing of EEG frequency and increase in amplitude. SWS is defined as containing over than 20% of delta waves (frquencies between 0.75 and 4.5Hz). NREM sleep stage 1 and 2 is characterized by frequencies between 12-14Hz. REM sleep is characterized mostly by a low voltage and a frequency range between 1-7Hz.[27]

2.1.3 Sleep Disorders

Sleep disorders are conditions which can result from various problems associated with circadian rhythm dysfunctions, inability to initiate and maintain sleep or medical conditions. The American Academy of Sleep Medicine classifies sleep disorders in three major groups. Dyssomnias, characterized by excessive sleepiness or difficulty in initiating and maintain sleep. These are the primary disorders associated with disturbed sleep or impaired wakefulness, they are divided in intrinsic, extrinsic and circadian rhythm disorders. The second category, Parasomnias, are related to arousal disorders and sleep stage disorders, thus being divided in these two groups and REM associated disorders. These conditions do not cause primary complaints of insomnia or excessive sleepiness. The third category comprises the sleep disorders associated with mental, neurological or other medical conditions. [1]

Bellow some of the most common sleep disorders according to the United States National Library of Medicine will be addressed.

2.1.3.A Narcolepsy

Narcolepsy is characterized for excessive sleepiness and repeated episodes of sleep of short duration, i.e., naps and lapses. This disorder affects approximately 0,1% of the population. Narcolepsy is an acquired condition, however, sometimes its possible to find clusters of families where the incidence risk increases 10-40 times.[36] Typically, a narcoleptic patient sleeps 10 to 20 minutes, awakening fully refreshed, within a few hours the process repeats itself. Patients often fall asleep in monotonous or tedious events, i.e., traveling in public transports, attending meetings, watching concerts or movies. In severe cases the patients may fall asleep during important tasks or inconvenient times, thus, being detrimental for their well-being. Because, normally, REM sleep suffers an onset, occurring within 20 minutes after the patient fell asleep, this leads to higher number of awakenings during the normal sleep period.

Narcolepsy is also characterized for cataplexy incidents, whereas the patient is fully aware of its surroundings, with no memory losses, loss of muscle tone occurs (this loss can go from a simple slurred speech to complete posture collapse).[1]

2.1.3.B Obstructive Sleep Apnoea Syndrome (OSAS)

The main feature for this disorder is the presence of apneic episodes, where partial or complete obstruction of the upper airway occurs. This symptom can be observed by others, specially bed partners. Patients with severe episodes can exhibit cyanosis[1].[11] The end of apneic events is often associated with snoring, vocalizations (sighs, moans and murmurs) and whole body movements. This movements can be particularly disturbing for bed partners, hence, being a serious and problematic situation for relationships.[1]

This sleep disorder has a characteristic loud snoring associated. Commonly, this snoring consists of brief gasps followed by 20-30 seconds of silence. The snoring can be so loud that causes disturbances, not only, on the patient sleep but also to bed partners or people in close proximities.[1]

OSAS is defined by the number of episodes per hour of sleep. In mild OSAS about 5 episodes occur per hour, whereas in severe OSAS up to 30 episodes can occur.This sleep disorder induces high sleepiness during the day as the sleep quality is perturbed by the repetitive arousals need to breath.[11]

Patients often report drowsiness, disorientation and incoordination upon wakening. Also headaches that last up to 2 hours after awekening are commonly observed.[1]

2.1.3.C Periodic Limb Movement Disorder (PLMD)

PLMD is characterized by repetitive movements caused by contraction of the muscles during sleep. The typical movements for this disorder are extensions of the big toe in combination with partial flexion of the leg, and similar motions in the upper limbs.[1][31]

Patients often report awekenings due to sudden moves, which deteriorate sleep quality increasing sleepiness during the day.[1]

2.1.3.D Restless Legs Syndrom (RLS)

In RLS patients report sudden urges to move the legs, caused by partial or complete relief of sensations in the limb. Normally, this occurs during sleep onset, hence, patients show difficulties falling asleep, caused by the sudden arousal. Contrary to PLMD where prevalence is not known, RLS was found to have a prevalence of nearly 10%. Patients rarely report the same feelings for the upper limbs, nevertheless, it can also occur.[1][31].

2.1.3.E Shift Work Sleep Disorder (SWSD)

SWSD is caused by a sleep pattern misaligned with the cicardian clock. As the name implies, it is recurrent in people who work by shifts, such as, nurses, physicians, policeman, firefighters, bus drivers, etc..Patients with SWSD often develop insomnia, and have a 40% higher risk of developing gastrointestinal and cardiovascular diseases.[38]

Workers report severe difficulties falling asleep, with excessive sleepiness during night shifts. This leads to an unsatisfactory and unrefreshing sleep.[1]

[1] Cyanosis: bluish coloration of the skin and mucus membranes caused by the lack of oxygen in blood[14]

Naps are a useful to countermeasure excessive sleepiness, although poor conditions for napping in work environment may lead to unsatisfying feelings.[38]

2.1.3.F Delayed Sleep Phase Syndrome (DSPS)

DSPS is more commonly seen among young adults and adolescents, caused by recurring delayed bedtimes with early rise time. The urge to correct sleep times during weekends reinforces the problem.[41]

Normally, patients report difficulties falling until 2 to 6 a.m. with increased difficulty awakening at the desired times. Besides the sleep-onset and wake times being later than intended, patients do not report problems maintaining sleep. Excessive sleepiness, mostly during morning hours is observed. [1]

2.2 Short-Term Memory (STM)

STM is an important cognitive function necessary for the execution of tasks that require holding and manipulating information for short periods of time. Baddeley, in 1986 defined STM as ”the temporary storage of information that is being processed in any of a range of cognitive tasks” Contrary to long-term memory there are no structural changes involved[2], hence, being a transient phenomenon.[29][34] We are not conscious aware of every accessible information stored in our STM.[8]

This cognitive process is very important in maintaining the ability to perform day-to-day tasks. When referring to the STM used to plan and carry out behavior its common to use the term working memory, e.g., remembering partial results when doing arithmetic calculations without paper.[12]

There are different types of short-term memory depending on what type of information is stored. It can be visual, spatial, verbal or auditory.[8]

2.3 Attention

There are several ways to characterize the attention depending on the branch of study. Philosopher William James describes attention as the process of taking possession of the mind, in clear and vivid form, of one out of what may seem several simultaneously possible objects or trains of thought. It implies withdrawal from some things in order to deal effectively with others. Zhu *et al.* defines attention as the cognitive process of obtaining and maintaining the alert state, orienting to sensory events, and regulating the conflicts of thoughts and behavior.[48], [18]

On the other hand, attention can be described in physiological terms as the brains areas that influence the operation of other areas. In this case attention is normally divided into three specific areas, called attentional networks. This networks commonly designated as brain circuits relate to: executive control, spatial orienting and alertness. This neural-based systems include the suprachiasmatic nucleus, circadian rhythm, the hypothalamo-pituitary-adrenal axis, and limbic system. Also,

[2] The formation of long-term memories requires new gene expression[7]

alertness may be modulated by metabolic systems and substrates such as thyroid, glucose, oxygen and electrolytes. [32].[33],[24],[46]

The state of attention for every individual correlates with vigilance, which refers to the ability to sustain attention and respond appropriately to demands and changes in the environment. Many studies have been made in this field regarding the identification of personality and ability traits that may relate to performance efficiency in vigilance tasks.[40]

2.4 Sleep, Attention and Short-Term Memory Correlation

Sleep deprivation can significantly impair sustained attention and STM capabilities. Excessive sleepiness and decreased mental performance tend to diminish the ability to retain information and awareness of our surroundings.[21]

EEG and Functional Magnetic Resonance Imaging (fMRI) analysis during performance tasks, both for attention and STM tasks, in subjects under sleep deprivation have shown a decrease in neuron firing and cortex activation.[21][33]

This conclusion indicates a strong relation between sleep and these cognitive functions, where sleep disorders can substantially diminish human cognitive capabilities, hence, being very important to treat patients under such conditions.[21][2]

2.5 Assessment Tools

In order to correctly describe sleep patterns for further diagnosis of sleep disorders, physicians and psychologists need assessment tools capable of providing accurate and relevant information about sleep routines and associated disturbances. Several objective and subjective methods exist for laboratory, hospital and home environments.[35]

The standard diagnostic tool used to assess sleep problems is polysomnography (PSG). This exam consists in a set of three exams that study electrical biosignals, EEG, Electromyogram (EMG) and Elctrooculogram (EOG). Besides giving accurate information about the patients sleep patterns, there are several disadvantages regarding this technology. Normally this exam is conducted in a sleep clinic or laboratory, which alters the patients daily routine by taking him out of his comfort-zone, with the risk of altering the results. The need for several electrodes placed in the patients body, which can cause some discomfort, and the high cost of such exams are also disadvantages.[35][17]

Actigraphy and Oxymetry are another widely used tools for sleep assessment. The first consists in a recording device for motor events that allows an evaluation of the sleep-wake cycle, while the second registers the oxygen levels in the blood throughout the day. These two devices are easily found in the market without being very expensive.[35]

In the following sections, the assessment tools used in the prototype described further in this thesis, are addressed. These are sleep diaries, PVT and n-back tasks and visual scales, namely, Karolinska Sleepiness Scale (KSS) and Samn-Perelli Fatigue Checklist (SFC)

2.5.1 Sleep Diaries

A sleep diary is, commonly, a paper questionnaire with the objective of recording the patients sleep habits, latencies, nighttime awakenings and behavioral data. There is no standard sleep diary, instead, sleep clinics and laboratories tend to adapt their own, with the information they find relevant. Cultural differences also contribute to the variability of sleep diaries. Some examples of sleep diaries and questionnaires are *Children's Sleep Status Questionnaire*, *Pittsburgh Sleep Quality Index*, *National Sleep Foundation Sleep Diary*.[30][10]

There is a need for electronic sleep diaries that will allow to stop using extensive paper diaries. The first system with these features was the *NASA Airlog*.[10] With the current development of smartphone applications some electronic diaries appeared.

To facilitate the diagnosis the patients must complete the diary on a daily basis, for at least 8 days, providing information such as *time went to bed, time to fall asleep, wake up time, number of awakenings, number of naps, length of naps, etc.*.[30]

2.5.2 Psychomotor Vigilance Task (PVT)

The objective of this task is to measure the sustained attention of the subject by calculating their reaction time to a visual stimulus.

Normally the standard test has a duration of 5-10 minutes and is done on a portable device of simple use. The user must respond as quick as possible to a visual stimuli by pressing the response button on the device. PVT has become a standard assessment tool for performance in different studies, specially, in sleep disturbs or driving performances.[22]

PVT is a very reliable performance task, although, the duration of the task may not be practical in several situations.

2.5.3 N-back Task

The n-back task is used to measure working memory levels.[20] The concept of the n-back task is quite simple. A series of stimulus appear in order, and the user must always give an answer according to the previous ones. There are different levels of complexity which highly increase cognitive demand according to how many stimulus the user must retain in his memory (low - 1-back, medium 2-back, high - 3-back).[44]

2.5.4 Visual Scales

Visual scales are a very useful way to measure sleepiness and sleep related mental states (like drowsiness). Several scales, for different purposes have been made throughout the years. The most used scales are the *Karolinska Sleepiness Scale* (KSS), *Samn-Perelli Fatigue Checklist* (SFC), *Epworth Sleepiness Scale* (EPS) and *Stanford Sleepiness Scale* (SSS).

Most scales are based on a self-reported subjective assessment, which can lead to errors, nevertheless, this process has shown to be very precise, providing useful information for the assessment of sleep.[19]

When using these scales, the patient must select the corresponding level associated with its own feeling about sleepiness and drowsiness. In the case of the Epworth Sleepiness Scale (EPS), the patient evaluates, in a scale from 0 = would never doze, to 3 = high chance of dozing, eight predetermined statements.

The complete scales can be seen in Appendix A.

2.6 Smartphones

In the last few years a strong technological revolution occurred in the mobile phones industry. The appearence of smaller integrated circuits with higher computational power lead to the appearence of powerful devices that doesn't only serve for simple phone calls and text messaging. Nowadays, with the appearance of smartphones it is possible to have a small computer in our front pockets.

Devices with high speed connection to the internet, built-in sensors like GPS, accelerometers, gyroscopes, cameras, bluetooth 4.0, HD screens with up to 8 inch sizes and much more, are common amongst the general population.

The appearance of new operating systems for this devices lead to an unprecedented evolution in mobile applications. Currently, there are three main OS, namely, Android, IOS and Windows Phone.

Nowadays, companies behind these OS, like Google, Apple and Microsoft, release an Application Programming Interface (API) along with all the necessary developing platforms, hence encouraging the development of applications for each OS. Companies not only enable but also encourage third party development of applications. Each of these OS uses a different programming language. Android, the most widely spread OS, with over 80% market share as of March 2014, uses Java language, although, it is possible to program in native C++. In second place, in terms of market share, is IOS, the OS for Apple smartphones. The programming language for this platform is Swift. Finally, the third OS in market share, Windows Phone, uses C++ as programming language. Anyone with reasonable programming skills can build its own application and take benefit of the small computers that our smartphones are.[9][15][4][47]

Android is the most popular OS, not only for its capabilities but because it was developed based on Linux and under an Apache License, which makes it open-source and free.

Hardware manufactures are thus able to create their own proprietary extensions of Android to differentiate them from competitors. This is no obstacle for developers, as every application made for certain Android version will run in every device that supports it, regardless of manufacturer.[15]

3

System Framework

Contents

This chapter is divided in three sections. The first one provides the definition of the problem where the needs to be solved are presented and the purposed system defined. The second section presents the developed User Interface (UI) with all its components and why these were chosen regarding User Experience (UX). Finally the third section presents the application architecture, with all its elements and functions, always providing visual insights.

3.1 Problem Definition

As seen in the previous chapters there is a need for new approaches to apply the described assessment tools. Psychologists and physicians need a wide range of information to correctly assess a patient psychological profile.

The current process needs a diversity of equipments to fulfill the requested diagnosis, e.g., computer software for PVT and N-back tasks, plus a wide number of paper pages containing sleep diaries and visual scales.

Therefore, one way to accomplish this goal may be the creation of an embedded system capable of provide all the needed tools in on single application. the hereby thesis proposes an android application with PVT and n-back tasks, visual scales and a sleep diary. In addition it is purposed a new approach, derived from PVT to assess a subject attention while performing tasks that may be compromised with the reduction of vigilance.

Considering this, the *Electronic Psychological Profiler* (ePP) was created. An android application where the user can have all its sleep diaries and visual scales, with the capability of performing multiple performance tasks. All the data can later be exported and sent to the physician or psychologist responsible for its treatment.

The platform chosen for development was the Android as it is the most widely spread smartphone and tablet operating system, with over 80% of market share as of March 2014. Additionally, this operating system allows greater ease of application development and its subsequent use. The programming language used was Java as it is the official language for Android. Although it is possible to program in Android using C and C++ it is not recommended by Google® as there are some drawbacks, notably, using native code will increase the app complexity without performance improvement.[9][15]

3.2 User Interface

Several studies made in the past few years have shown the importance of the UI in UX, thus making this a major step in the application development.[42],[43],[45]

The UI is the means by which users interact with the application. In this powerful aspect relies the acceptance of an app by the public. Therefore, its very important to achieve an appealing UI that maximizes UX. Thereby, the application was developed according to Google® design guidelines with all the needed adaptations in order to accomplish the best UX possible.[15]

To fulfill all the aforementioned objectives, several aspects were taken into account. Metrics, colors, gestures and the logo itself, were chosen carefully, in order to provide a user friendly environment.

Also, the wide range of screen sizes, from small phones to tablets, implies the need to use an adaptive measure for every dimension. Regarding this, two metrics were applied, *Density-independent Pixels* (dp) and *Scale-independent Pixels* (sp), used for object dimensions and text sizes, respectively.

3.2.1 Metrics

Building an application comfortable is highly detailed. Metrics are very important as the size of every item in the screen must be very precise. Not only it must have a size big enough for the user to see with ease, but also it must not occupy the entire screen. The size of the buttons must be comfortable enough so anyone would press them swimmingly, also, the text size must be big enough to be read with ease.

Type	Dimension	Value
Text Size	Small	18sp
	Medium	20sp
	Large	32sp
Clickable Elements	Width	100dp
	Height	48dp

Table 3.1: Metrics for the different elements used throughout the app.

Besides the metrics for the different elements, one must assure those do not overlap or become to close, also the distance from the screen margins must be enough. In between elements was applied a distance of 16dp, and from the margins a space of 8dp.

3.2.2 Colors

Figure 3.1: Color pallete used throughout the app.

Coherence throughout an application is very important. To maintain it, all the colors used should belong to the same palette, in this case, indigo. This way the user feel more comfortable while using the app, as it shows more consistency. In 2005, researchers from Haas School of Business found that different people from various ethnicities and social backgrounds all find the color indigo an happy color, thus making this a viable choice for our app.[6]

In this context, as seen in Figure 3.2, four different colors were used. With this configuration it was possible to create all the need backgrounds, objects and its functions. The head color, for the logo and the application itself is the Indigo 500, for background the brightest was applied, Indigo 50, while the rest were used to manipulate buttons, i.e., a button has two states, normal and focused, with the colors Indigo 100 and Indigo 200, respectively.

Using the API provided by Google®, through its website, different windows can be used, i.e., alert screens and dialogs, to provide useful information to the user. These stayed with the standard grey-scale colors.

3.2.3 Gestures

In every application there must be a way for the user to interact with it. The android platform provides a wide range of input types so the user can manipulate an app. These inputs can be clicking, sliding, zooming, hovering, dragging and flipping, all these can be done individually or by combination, e.g., hovering and dragging.

The gestures available in the ePP were designed to provide an adequate way of interaction. Its possible to click, hover, slide and zoom throughout the app, This way the user feels more control over the application providing a better UX.

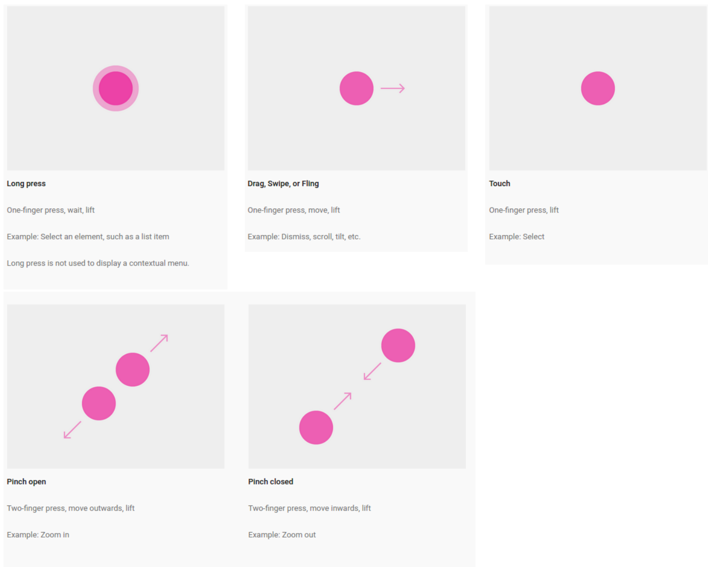


Figure 3.2: Available gestures for interaction throughout the app.[15]

3.2.4 Logo

Figure 3.3: Application logo

The first contact of the user with any application is by its own logo. To improve UX, this aspect must be elaborated carefully. Using the above color palette a simple logo was created.

Figure 3.3 represents the ePP logo. It contains three different elements strictly related to the application features, an alarm clock, a book and the letters *z*. The logo was elaborated using CorelDRAW®X7, a vector graphics editor.

3.2.4.A Clock

The main element in the logo is a clock. This specific symbol was chosen because it relates to almost every feature present in the ePP. Not only it has a sleep diary, where its possible to relate the clock to an alarmclock, but also has performance tasks that measure response times, therefore relating to a stopwatch. Also, as the performance tasks and visual scales should be done ate specific times, prescribed by the psychologist or physician, the symbol can be related to a calender alarm.

Figure 3.4: Clock element from the logo.

3.2.4.B Books

The second part of the logo is an opened book. This symbol relates to different elements,i.e., the electronic sleep diary and visual scales, which are normally handmade in paper format, and the database where all the data is stored. As the diary plays a major role in the application, it was consider it should have a reference in the logo.

Figure 3.5: Books element from the logo.

3.2.4.C Zzz

The last component of the logo are two letters *z*. This is a specific reference to sleep, as it is a major component in this psychological profiler.

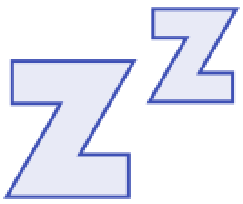


Figure 3.6: ”zz” element of the logo.

3.3 System Architecture

This section will describe how every feature in the application was implemented and the reason certain choices were made. Designing an application is a process that can be divided in three major steps.[42]

1. *Requirement Analysis*, where target users are defined, the demands collected and all the needed functions specified.
2. *Designing the UI*, the process where the position of every element in each window is determined.
3. *Implementation*, the main step, where the actual coding happens. This is the longest step where all the interactions between inputs and background actions are defined.

The collaboration with CENC was crucial in the development of the ePP. Throughout the entire process a close contact was maintained, allowing constant improvements to best serve the needs and objectives, which allowed the maximum improvement of the system.

3.3.1 Diary

The main feature in the ePP is the electronic sleep diary. To build the diary, the standard sleep diary from U.S. National Library of Medicine was used as base model. The necessary changes were made with the continuous support of CENC in order to address optimally to the current needs.[30]

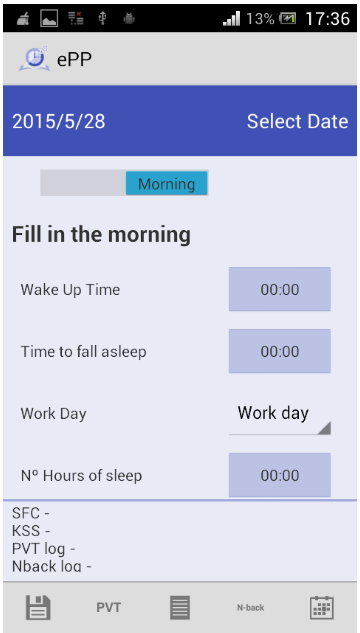


Figure 3.7: Screenshot of the Diary feature.

Figure 3.7 shows the screen for the electronic sleep diary. On the applications first run, the help dialog appears as it contains important information regarding how to complete the form. From here the user can access the help by taping the help icon.

The diary can be divided in two sections. the main area, where the actual diary is located and the action bar, which can appear split in top and bottom, as seen in Figure 3.7, or only on top, depending on the screen size.

The main area is where the information to be filled is placed. this info is divided in *Evening* and *Morning* info, according to the time of the day the user should fill it. To navigate into the specific part of the day the user wants, a switch button on the top of the screen must be selected accordingly. The corresponding fields to be completed are shown in the next table.

Table 3.2: Sleep diary elements for user completion

Fill in the Morning		
Wake up Time	Time to fall asleep	Type of day
Nº hours of sleep	Nº of awakenings	Total time awake
Fill in the Evening		
Time went to bed	Time felt asleep	Nap length
Number of naps	Exercise time	Intensity
Lunch time	Dinner time	Nº of alcoholic drinks
Nº of caffeinated drinks	Complaints	Other

The lower part of the diary is a log containing all the data for the visual scales, PVT and N-back tasks, thus, providing all the information for that specific date. This way the user can check its performance levels and analyze their routine.

When the user opens this feature it will be displayed the diary for the current day. To improve UX, it is possible to navigate throughout the different days. Swiping left or right allows the user to go back one day or advance one, respectively. There is also the possibility of specifying the date by pressing the *Select Date* button.

The second section, the action bar, is composed by several buttons, i.e., *Save, PVT and N-back tasks, Visual Scales, Go to present day, Export and Help*. These buttons allow the user to:

- *Save* - Save the inserted data into the database[1]
- *PVT* - Access the PVT feature.
- *N-back* - Access the N-back feature.
- *Visual Scales* - Access the Visual Scales feature.
- *Go to present day* - Automatically go to the present day diary without the need to swipe multiple times neither insert it in *Select Date*.
- *Export* - Export the database for further analysis .
- *Help* - Alert dialog with help about the diary.

The user has three different typer of inputs to provide in this feature. Number selection, in all the fields where times should be presented, text input, for *complaints* and *other*, where the user should provide any information he might find useful. and item selection, where a list of pre-determined options is presented.

3.3.2 Psychomotor Vigilance Task - PVT

The PVT feature has the objective of measuring the user reaction time to a visual stimuli. It was implemented in a dialog that opens when the user presses the respective button on the diary screen.

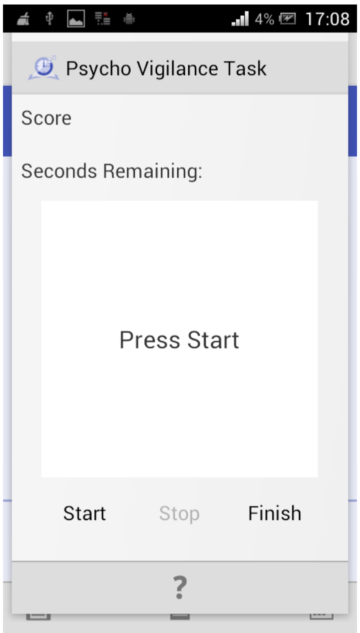


Figure 3.8: Screenshot of the PVT task feature.

[1]The user does not need to press this button to actually save the data. The application has all the necessary safeguards, so, in case the user forgets to save, the info is not lost.

As seen in Figure 3.8 the user is presented with the main information in the white square. Any additional info can be obtained with the help button.

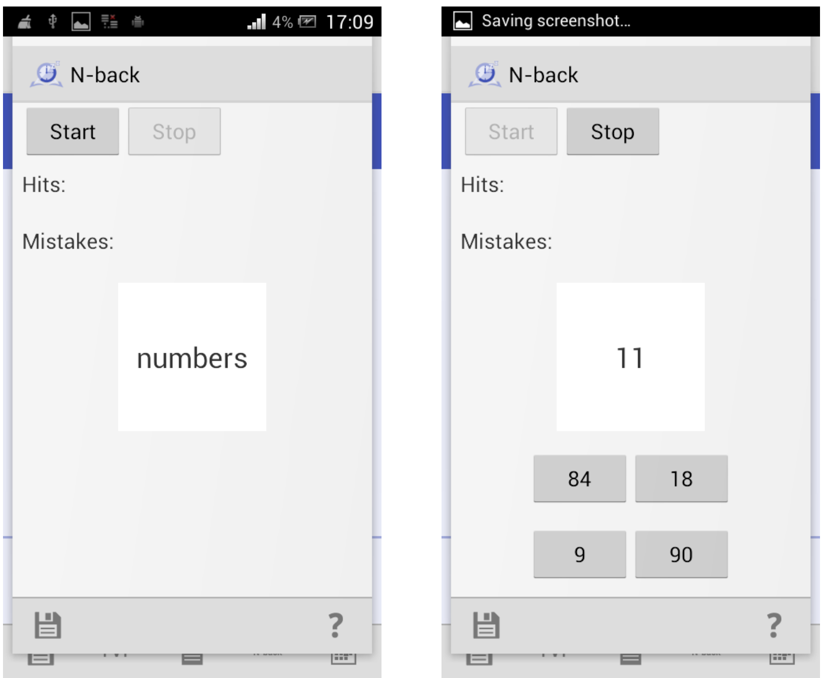
After the user presses *Start*, the countdown timer starts and the test begins. The duration for a full trial is 120 seconds. The application displays a message *get ready...* and as soon as the message *Touch Me* appears, it must, as quickly as possible, press the white square. The stimuli are generated with random delays so no habituation occurs. The system calculates the time between the message is displayed and the click on the square.

The *Score:* shows the delay in the previous attempt. In the end of the trial, the information about the time the task was initiated, all reaction times, mean time for the entire trial and unwanted clicks, i.e., when the user presses the square before the stimuli appears, are stored in the database. However, in the diary log, only the mean reaction time and the start time are displayed.

3.3.3 N-back Task

The n-back feature has the objective of assessing the user working memory state. It was also implemented in a dialog that opens when the user presses the respective button on the diary screen.

When the dialog prompts, a white square, where the stimuli will be presented, and two buttons (start and stop) are visible. After pressing the start button, a number will appear in the white square for 1 second. After this, the number changes and four buttons with four different answers appear below the white square.



(a) Before start **(b)** After start

Figure 3.9: Screenshot of the n-back task feature.

The user must select the correct answer corresponding to the previous number. After the selection, the number changes again as well as the four answers. The user must always select the correct answer corresponding to the previous number presented in the white square. The process repeats itself for 50 trials. This n-back task was designed as 1-back, as seen by the need to choose the answer according to the previous number. If a 2-back task was implemented the user would see, for the first trial, two numbers with 1 second delay and after that repeat the selection process, always referring to the last but one number.

The application calculates the time the user takes to answer, the number of correct answers and the number of mistakes. The results are presented in the form of Adjusted Hit Rate (AHR).

AHR was calculated by the operations:

$$\mathbf{AHR} = \mathbf{HR} - \mathbf{ER} \tag{3.1}$$

,where

$$\mathbf{HR} = \frac{\textit{Number of Hits}}{\textit{Total numnber of Trials}} \tag{3.2}$$

$$\mathbf{ER} = \frac{\textit{Number of Errors}}{\textit{Total numnber of Trials}} \tag{3.3}$$

An AHR = 0 represents a response level of 50%; all correct responses with no errors means an AHR = 1; all incorrect responses represents an AHR = -1

The user can terminate the task at anytime without loss of data. It is also possible to use the help button for a specific explanation of this feature.

3.3.4 Visual Scales

For this application two visual scales,SFC and KSS, were implemented in a dialog that prompts after the user presses the *Visual Scales* button in the diary feature. The user must choose the correct options from the lists according to his subjective evaluation of sleepiness and drowsiness, respectively.

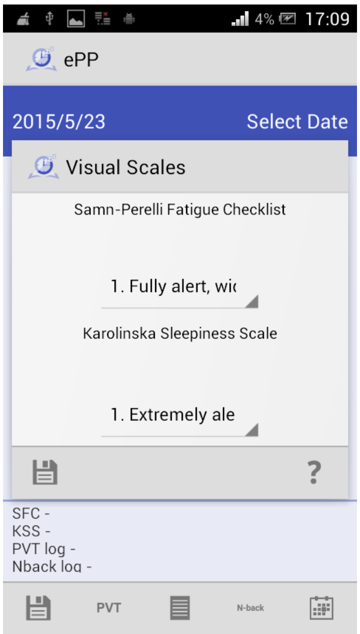


Figure 3.10: Screenshot of the Sleep Scales feature.

After providing the intended information, the user must save his answer with the save button. This is the only feature where automatic saving is not presented. This happens because in this feature the user do not need to start the task, so if the user mistakenly presses the *Visual Scales* button a record of its states would be added to the database. This way that problem is overcome.

3.3.5 Attention Monitor

This feature is an all new concept for, as it name suggests, monitoring attention, throughout long periods of time.

Starting from the PVT concept a new approach was designed. Just like the PVT, the system will measure the user sustained attention. The user will be presented with different stimuli over time, to which he should respond as quickly as possible. Three different stimuli and two ways of giving a response were implemented. The system is adaptive, working in closed chain.

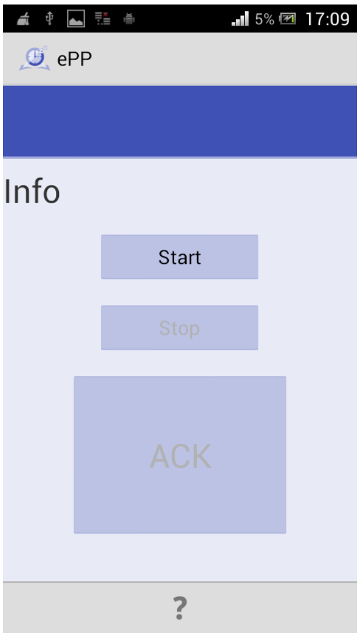


Figure 3.11: Screenshot of the Attention Monitor feature.

In Figure 3.11, its possible to observe the *Attention Monitor* feature of the application.

When the user presses start the application will search the device for the presence of three different hardware that will produce different stimuli. First the speaker for auditory stimuli, next the presence of a camera flash for visual stimuli, and finally, a vibrator for tactile stimuli.

After gathering the information about the available hardware for stimuli production, the system randomly chooses one of them, which will be used for the first five trials.

During these five trials the delay between stimuli and their intensity is constant, the values used are the default (values for the different stimuli parameters are shown in table 3.3).

After the first five trials the system calculates the mean response time of the user, and then, recalculates the values for the parameters of the next stimulus. From now on, all stimulus are produced randomly between the hardware options, with parameters according to the mean response time of the last five trials.

Table 3.3: Values for the different stimuli parameters

Mean Response Time (ms)	Intensity (%)	Delay (min)
Default	50	4
$<$400	25	10
$>$400 and $<$600	25	8
$>$600 and $<$800	50	4
$>$800 and $<$1000	75	2
$>$1000	1000	2

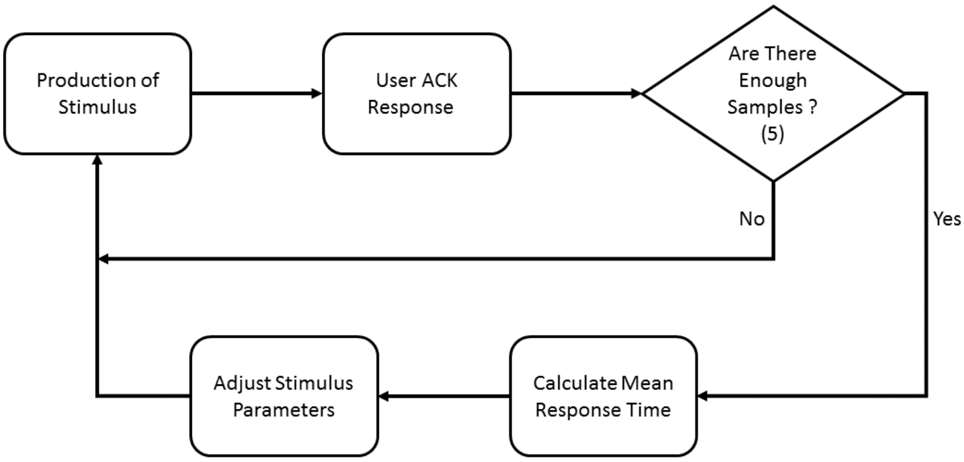


Figure 3.12: Flowchart for the closed chain feedback in the Attention Monitor feature.

The user must give a signal of Acknowledge (ACK) to the system. It can be done either by pressing the ACK button on the screen or by pressing the button on the headset[2].

If the user takes more than 30 seconds to give an ACK signal, the system activates an alarm.

The main objective of this system is to monitor attention during work-hours, e.g., monitor the attention of the driver in a bus trip, or monitor a pilots attention in a long-haul flight.

[2]Currently the headset must be connected by the audio jack, as bluetooth headsets are not yet supported. Any common headset with a button to answer calls can be used.

3.3.5.A Graphics

Figure 3.13: Flowchart for the closed chain feedback in the Attention Monitor feature.

The Graphics feature is only related to the Attention Monitor results. In this feature the user can select and view their performance results during a specific task. In the dropdown button on the top of the screen all the performed tasks identified with date and time are presented. After selection, the graphic corresponding to that task will appear. This graphical representation shows the reaction times (y-axis) over for the duration of the entire task (x-axis).The user can pan and zoom as intended. With this visual interaction the user can analyze their performance ratings and relate them with specific events during the task, for example, an increase in reaction times corresponding to the morning hours where the subject reported more sleepiness.

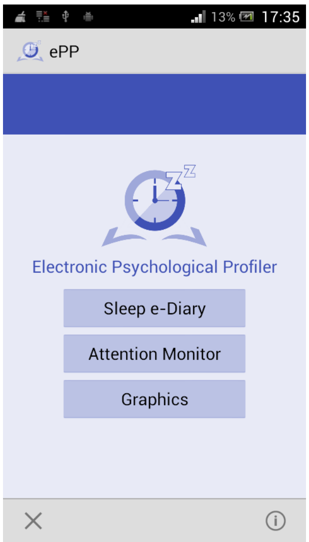
4

Application Outputs

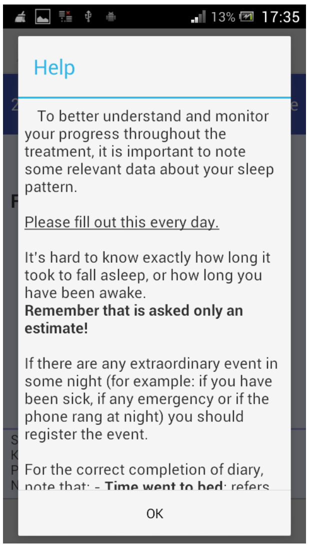
In the present Chapter the Outputs from the application are presented, both for the user and the physician.

The main goal for this thesis was the elaboration of an Android application for psychological assessment, hereby presented as Electronic Psychological Profiler (ePP). In order to create a suitable User Experience (UX) for the patient several rules were followed according to previous studies.[42],[43],[45].

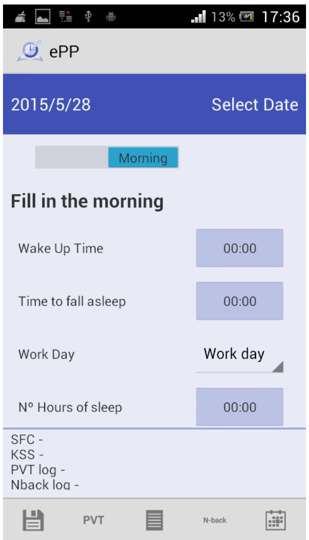
First lets address how the user interacts with the ePP.



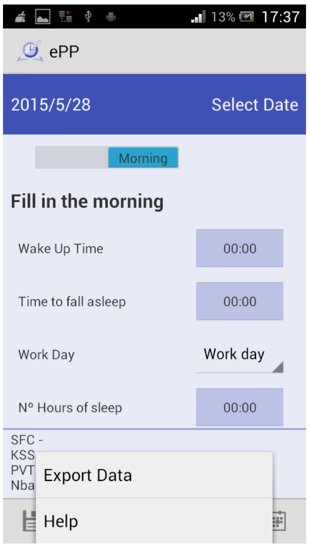
(a) Main screen



(b) Help screen



(c) Diary screen



(d) Overflow button

Figure 4.1: Screenshots of the Electronic Psychological Profiler (ePP).

In Figure 4.1 its possible to see the main feature of the ePP, namely, the sleep diary. The user is presented with a set of fields that describe his sleep routine, like wake up time, time to fall asleep, number of awakenings, etc.. The diary is devided in two parts, night and morning, which can be accessed by pressing the swith button on the top of the screen.

There are also several buttons on the action bar[1], specifically, save, PVT, n-back, visual scales, go to today, and an overflow button (characterized by three vertical dots). If the device possesses a menu button, the overflow button will disappear and its functions can be accessed from there. The overflow button contains the help and export database functions.

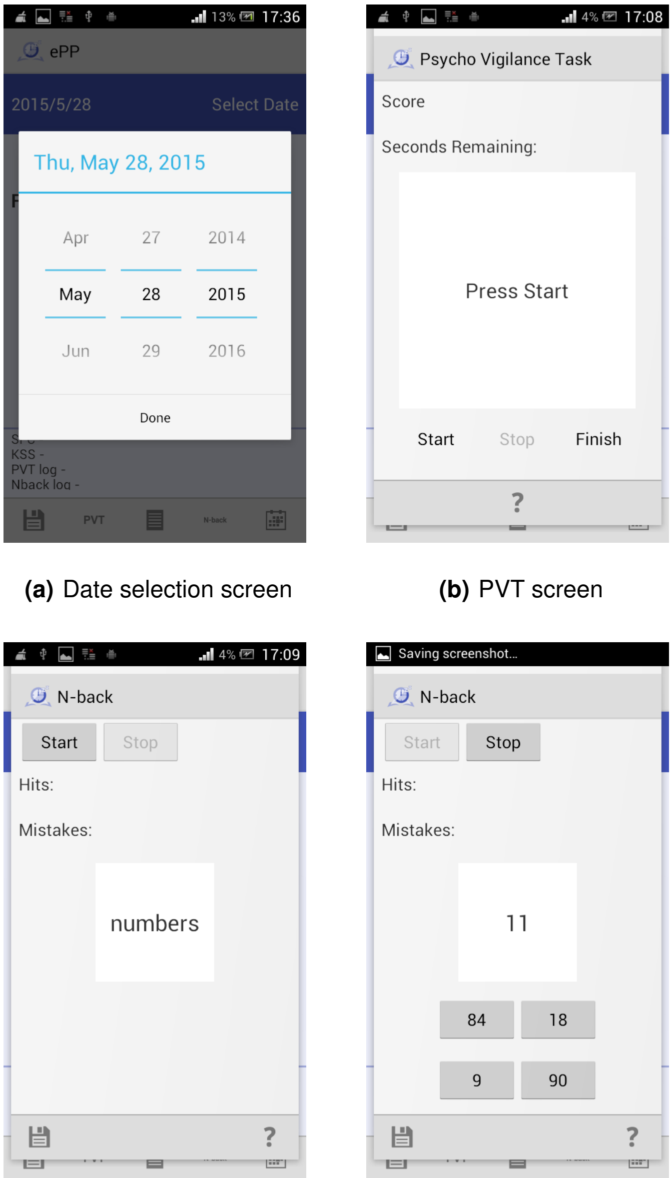
When the patient starts the application for the first time the help screen will automatically appear, as it contains valuable information for the correct completion of the diary.

In this feature the user can fill its personal sleep diary using three simple types of input. By clicking on the ”time” buttons and selecting the specific time that the event occurred. By typing text, just for fields *Complaints* and *Other*, or by selecting one of the several options presented in dropdown buttons, for example in *Type of day*.

The user can navigate through the dairy by swiping left and right, going to the next or previous day, respectively. Or simple by selecting the desired date in the *Select Date* button.

If for some reason the user forget to save the diary before closing the application no data is lost. The ePP automatically saves the diary in order to prevent data losses.

[1] The action bar can be devided, as shown in Figure 4.1(c) depending on the screen resolution of the device. Nowadays, in the majority of the devices the action bar will only appear on the top of the screen.



(a) Date selection screen

(b) PVT screen

(c) N-back screen - Before start

(d) N-back screen - After start

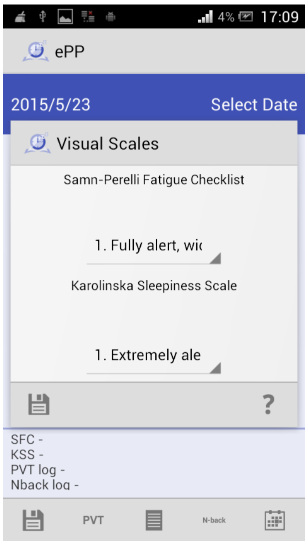
Figure 4.2: Screenshots of the Electronic Psychological Profiler (ePP).

Figure 4.2, shows the PVT and n-back features. The user can access these them from the diary screen. Every performance result obtained is saved in the current day date.

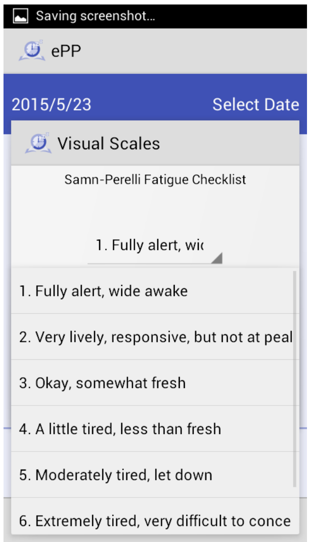
If the user simply enters and leaves one of these features by mistake, no data is saved into the database, on the contrary, if the user starts one of them, even if he forgets to save the results the collected data is stored for further analysis.

In the previous Chapter was already mentioned how PVT and n-back work, the length of the tasks is 5 minutes and 50 trials, respectively.

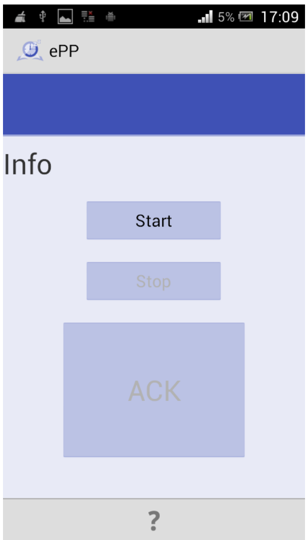
The user can access specific help for the different tasks by pressing the help button, distinguished by the interrogation mark.



(a) Visual scales screen



(b) SFC options



(c) Before start

(d) After start

Figure 4.3: Screenshots of the Electronic Psychological Profiler (ePP).

Figure 4.3 presents the last two features of the ePP. The Visual Scales contains two sleep associated scales, the Samn-Perelli Fatigue Checklist (SFC) and the Karolinska Sleepiness Scale (KSS). The user must select the level of sleepiness and drowsiness corresponding to his self-reported subjective assessment.

When pressing the dropdown button for each scale, all the corresponding levels of sleepiness and drowsiness are presented. After selection a checkmark highlights in front of it, this way the user gets a visual clue of their action.

Finally, The attention Monitor feature is divided in two sections. The attention monitor itself, and the graphical view of the results. When using the Attention Monitor, the user gets a simple screen with three buttons and a information label.

After pressing the start button, the user must respond to a random stimulus, which can be auditory, visual or tactile, as quick as possible. To answer to the stimulus the user can press the ACK button on the screen or a button on an headset. The first five stimuli will be of the same type (the type is randomly selected in the beginning of the process). The existence of different stimuli depends on the user's Android device hardware.

After the first five stimuli, the ePP calculates the mean response time of the user, and recalculates the intensity and delay for the next stimulus. Depending on the response time, the stimuli can be apart from each other up to 10 minutes, and with differences in intensity up to 75%. From now on, every stimuli will depend on the user's mean response time for the past five trials.

The info label will provide the last five response times, so the user can keep track of its performance during the task.

If the user takes more than 30 seconds to give the ACK signal, the system will automatically start a sound alarm.

This feature is intended to be used during the day-to-day activities of the user, specially in work-related ones. This way is possible to assess the user sustained attention throughout the day.

The user can visualize its performance results for the attention monitor, in the graphics feature. In the dropdown button on the top of the screen all the performed tasks, identified with date and time, are presented. After selection, the graphic corresponding to that task will appear. This graphical representation shows the reaction times (y-axis) over for the duration of the entire task (x-axis).The user can pan and zoom as intended. This way, the user can relate their results with specific events that occurred during the task.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Joao_Ribeiro_E-Diary															
2	DATE	WAKE_UP	BED_TIME	TIME_TO_	NUMBER_	NUMBER_HOURS_SLEEP	TOTAL_TIME_AWAKE	NUMBER_	NAP_TIME	EXERCISE_	EXERCISE_	NUMBER_	NUMBER_	LUNCH_TI	DINNER_T	COMPLAIN
3	04/06/2015	07:10	23:30	00:20	1	07:00	00:15	0	00:00	00:00	0	5	0	12:30	19:30	
4	03/06/2015	09:00	23:30	00:30	2	08:00	00:20	0	00:00	00:00	0	4	0	12:30	19:30	
5	02/06/2015	07:10	23:30	00:15	5	07:00	02:00	0	00:00	00:00	0	5	5	12:30	19:30	
6	22/05/2015	07:10	23:30	00:20	1	07:00	00:20	0	00:00	00:00	0	4	0	12:30	19:30	
7	21/05/2015	09:00	23:30	00:25	1	07:00	00:20	0	00:00	00:00	0	5	0	12:30	19:30	
8	20/05/2015	07:10	23:30	00:15	3	07:00	01:00	0	00:00	00:00	0	5	3	12:30	19:30	
9	19/05/2015	09:00	23:30	00:20	2	08:00	00:00	0	00:00	00:00	0	5	0	12:30	19:30	
10	18/05/2015	07:10	23:30	00:15	1	07:00	00:15	0	00:00	00:00	0	4	0	12:30	19:30	
11	17/05/2015	07:10	23:30	00:30	0	07:00	00:00	0	00:00	00:00	0	4	0	12:30	19:30	
12	16/05/2015	09:00	23:30	00:30	0	08:00	00:00	0	00:00	00:00	0	4	4	12:30	19:30	
13																

Figure 4.4: Database screenshot in an Microsoft Excel Spreadsheet

For the analysis of the dairy components, performance tasks results, visual scales data, and even, attention monitor performances, by the psychologist or physician, this information must be available in an user friendly manner.

The database of the ePP was built using SQLite language, thus being organized in tables. In this case, there are two tables, one for the Diary and related tasks, and another for the Attention Monitor. It is possible to export the database to a simple Comma-Separated Values (.CSV) file for further analysis. To do so, the user must select the export function present in the overflow button in the diary feature, to export the corresponding database, or, select the export button in the Graphics feature to export the Attention Monitor database.

When the user does so, a dialog appears asking for the introduction of their first and last names according to the example shown. After pressing OK, the database will be exported to the downloads folder of the device. This folder was selected as the standard destination for the files because every Android device must have one, contrary to other folders that depend on another factors for existence.

After exporting the database it can be sent via Internet, e.g., e-mail, or uploaded directly to a computer. .CSV files can be open with a wide range of programs, with Microsoft Excel being on of them. Figure 4.4 presents an example of a database.

5

Conclusions and Future Work

During this work an Android application was developed aimed at overcoming the current flaws present in psychological assessment tools.

Starting with a bibliographical review, the underlaying concepts linked to sleep and its associated disorders, assessment tools, memory and attention, was possible to design a useful application for psychological assessment, able to exceed the flaws presented in the tools commonly used by physicians.

After contextualization, the problem was defined and the subsequent design and implementation of the application described. The ePP was implemented using Java language in the IDE Eclipse. All the decisions from the design of the logo to the underlying mechanisms for each one of the features the comprise the ePP were presented.

Followed by an explanation from the user point of view with all the relevant visual aids for better understanding of the process.

It is possible to say that the main objectives purposed in the begining of this thesis were achieved with success. One can not fail to mention the importance of CENC in validating the usefulness of this application, as already one study using the ePP for data collection was presented.

The Electronic Psychological Profiler turned out to be a very versatile application in their midst, with several features that help the physician in the assessment of psychological disorders. It is a very easy to use and as an Android app can be used by a large portion of the population.

For future developments the most important aspect relies in the creation of a back-end solution that uses the capabilities of cloud storage. With such application the physician could monitor patients in real time, therefore being capable of adapting treatments and introducing new ones. A more visual appealing software for data analysis would be of highly importance, but with the ability to also use the big data capacities of spreadsheet calculations.

With the available mobile data plans, almost everyone is connected to the Internet, this way the use of cloud services would withdraw the need for patient concerns related to database exports and the need to send them for the physician for analysis.

Using the feedback from patients the UI can also be improved, finding better ways for the user to cycle between features inside the application. One possible way to overcome this issue may rely in using the fragments behavior in UI.[15] One possible disadvantage for this method may be in the fact that only newer devices support that feature, nevertheless, with the current growing rate of the smartphone market that may not be a problem.

Transition to other platforms should also be in the horizon, because this way, more people can be covered. The main OS to address are IOS and Windows Phone, as combined with Android, account for over 98% of the smartphone market.

In mobile application development, for the current OS, possibilities are endless and many additions to this platform can be made. From adding more performance tasks to inclusion of more sleep scales. Also, using the sensors embedded in the smartphone its possible to build actigraphs, oximeters and much more. Nowadays, several new technologies that can be paired with android devices are appearing in the market, such as Myo Armband from Thalmic Labs Inc. These devices can help building extensive platforms for physiological and psychological assessment.

Another very important aspect for future work is the validation of the purposed Attention Monitor feature. Without relevant clinical findings that may correlate the veracity of the results, it wont be possible to spread the technology to other studies.

In conclusion, the Electronic Psychological Profiler, is a powerful application that integrates various systems that otherwise would be separated, requiring more concerns for the patient.

It wont be possible to overcome the knowledge acquired by a physician over years of practice, nevertheless, applications such as the ePP accelerate a process that must be as quickly as possible, for better and accurate disorder assessment.

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A

Appendix A

A.1 Karolinska Sleepiness Scale

The Karolinska Sleepiness Scale is a 9 point scale based on a self-reported subjective assessment of drowsiness. The user must select which statement best describes is current drowsiness level.

1. Extremely alert
2. Very alert
3. Alert
4. Rather alert
5. Neither alert nor sleepy
6. Some sighs of sleepiness
7. Sleepy, but no difficulty remaining awake
8. Sleepy, some effort to keep alert
9. Extremely sleepy, fighting sleep

Adapted from [23]

A.2 Samn-Perelli Fatigue Checklist

The Samn-Perelli Fatigue Checklist is a 7 point scale based on a self-reported subjective assessment of sleepiness. The user must select which statement best describes is current sleepiness level.

1. Fully alert, wide awake
2. Very lively, responsive, but not at peak
3. Okay, somewhat fresh
4. A little tired, less than fresh
5. Moderately tired, let down
6. Extremely tired, very difficult to concentrate
7. Completely exhausted, unable to function effectively

Adaptad from [37]

A.3 Epworth Sleepiness Scale

The user must rate eight different situations in a scale from 0 to 3, where:

- 0 = would never doze
- 1 = slight chance of dozing
- 2 = moderate chance of dozing
- 3 = high chance of dozing

Dozing refers to the loss of muscle tone accompanied by drowsiness. The eye lids slowly close while the head drops forward.

The situations are:

- Sitting and reading
- Watching TV
- Sitting, inactive in a public place (e.g. a theatre or a meeting)
- As a passenger in a car for an hour without a break
- Lying down to rest in the afternoon when circumstances permit
- Sitting and talking to someone
- Sitting quietly after a lunch without alcohol
- In a car, while stopped for a few minutes in the traffic

Adapted from [23]

A.4 Stanford Sleepiness Scale

The patient must select the number that best describes his level of alertness at the time of the test. There are 7 different levels:

1. Feeling active, vital, alert, wide awake.
2. Functioning at a high level but not at peak, able to concentrate.
3. Relaxed, awake but not fully alert, responsive
4. A little foggy, let down.
5. Foggy, beginning to lose track, difficulty staying awake.
6. Sleepy, prefer to lie down, woozy.
7. Almost in reverie, cannot stay awake, sleep onset appears imminent.

Adapted from [23]