Comparing the Sensor Glove and Questionnaire as Measures of Computer Anxiety

Department of Computer Science and Informatics

Faculty of Agricultural and Natural Sciences

University of the Free State, South Africa

Dissertation

By

Tlholohelo Stephania Nkalai (2006089599)

Submitted in fulfilment of the requirements for the degree

MAGISTER SCIENTIAE

(Computer Information Systems)

in the Faculty of Natural and Agricultural Sciences

Department of Computer Science and Informatics

January, 2014

Supervisor:

Dr. L. de Wet

Department of Computer Science and Informatics

ACKNOWLEDGEMENTS

My sincerest gratitude goes to my supervisor, Dr. de Wet. Thank you for your guidance, patience, support and encouragement. I would also like to thank Prof. Schall who dedicated his precious time assisting me with the statistical analyses despite his busy schedule.

Many thanks go to the staff of the Department of Computer Science and Informatics at the University of the Free State for their friendliness and support. You made me feel at home.

To my mother, mother-in-law and father-in-law, thank you from the bottom of my heart for the countless times you supported me throughout the challenging times I went through. I love you. To my precious daughter, Bokang, thank you for allowing me to take some time to pursue my studies. I will always love and appreciate you. To the rest of my family and friends, thank you for your encouragements and prayers.

Saving the best for last, I would like to thank my heavenly Father who gave me life, wisdom, loving people and all the resources I needed to complete this dissertation. I stepped out of the boat and walked on the water as you instructed. It was challenging but thank you for not letting me drown.

DECLARATION

I hereby declare that the work which is submitted here is the result of my own independent work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references. I further declare that the work is submitted for the first time at this university/faculty towards the Magister Scientiae degree in Computer Information Systems and that it has never been submitted to any other university/faculty for the purpose of obtaining a degree.

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T.S. Nkalai Date

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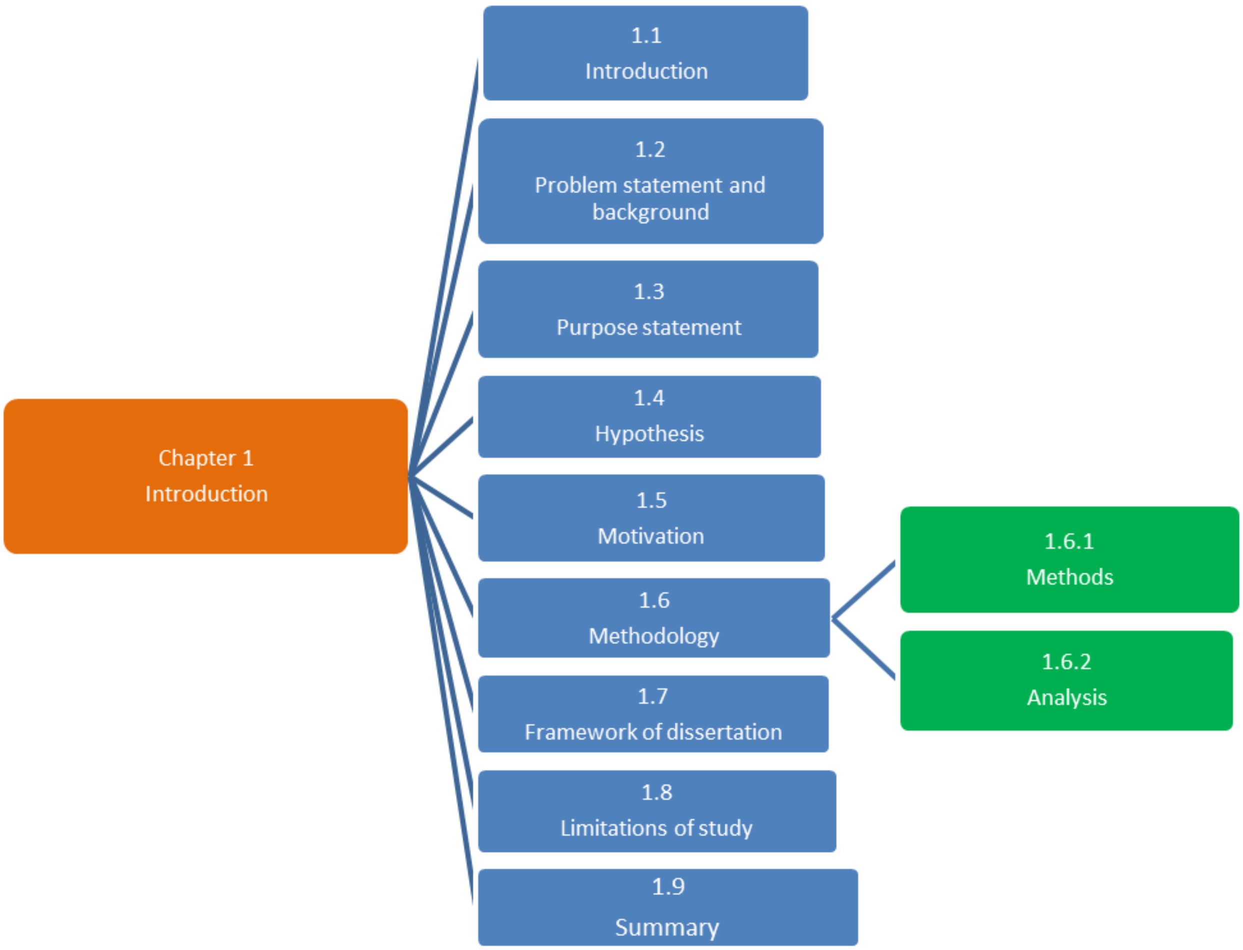


CHAPTER 1: INTRODUCTION

1.1 Background

Computers are used extensively these days as it is almost always a necessity in the workplace. However, some people avoid using computers because they experience computer anxiety (Ursavas & Teo, 2011). A similar finding was discovered concerning the teachers in the study conducted by Rosen and Weil (1995b). Literature consists of various computer anxiety definitions. Chua, Chen, and Wong (1999) define it as an emotional fear or phobia experienced by individuals when using computers or when thinking of using computers. Different findings about computer anxiety regarding age, gender, computer ownership, educational attainment and computer experience exist. Sarwat (2009) investigated computer anxiety of employees aged between 24-58 years. The findings showed that older and non-experienced employees reported having experienced computer anxiety more than the young adults. However, in the research study conducted by Hismanoğlu (2011), there was no age difference with respect to prospective teachers experiencing computer anxiety. In another study where computer anxiety was examined among university and college students who majored in physical and health education, findings showed that there was no significant age difference in experiencing computer anxiety (Ademola & Idou, 2013).

Findings about the relationship between computer anxiety and gender are inconclusive. Some studies found that females had lower levels of computer anxiety than males (Aziz & Hassan, 2012; Brosnan & Lee, 1998; Deniz & Erkan, 2012), and that females exhibited more positive attitudes towards computers than males (Kubiatko, Haláková, Nagyová, & Nagy, 2011; Siann, Macleod, Glissov, & Durnel, 1990). On the contrary, other findings indicate that females demonstrate computer anxiety more than males (Broos, 2005; Brosnan, 1998; Busch, 1995; Chou, 2003; Czaja et al., 2006; Gina, Kevin, & Walker, 2010; Karavidas, Lim, & Katsikas, 2005; Rosen & Weil, 1995a; Sarwat, 2009; Simsek, 2011). Some studies discovered no significant relationship between computer anxiety and gender (Ademola & Idou, 2013; Havelka, Beasley, & Broome, 2004; King, Bond, & Blandford, 2002; Olatoye, 2009; Shah, Hassan, & Embi, 2012).

Ownership of a personal computer is another correlate of computer anxiety whose research findings are contradictory. Some research studies found that individuals who own personal computers experience less computer anxiety than those without computers (Korobili, Togia, & Malliari, 2010; Tuncer, Dogan, & Tanas, 2013). In some findings, computer ownership and computer experience were found to reduce computer anxiety (Baloğlu & Çevik, 2008; Yushau, 2006). However, the findings of Hismanoğlu (2011) showed no significant relationship between computer anxiety and computer ownership.

Educational attainment is correlated inversely with computer anxiety (Tuncer et al., 2013). It is therefore expected that individuals with a higher education level will experience less computer anxiety than those with a lower level of education. This is in agreement with the research findings where employees with only certificate qualifications experienced higher computer anxiety scores than those with higher levels of education (Shah et al., 2012). Despite these findings, a study performed by Simsek (2011) revealed that elementary level students were less anxious than secondary level students.

Computer experience is an additional correlate of computer anxiety. Garland and Noyes (2004) state that literature is in disagreement regarding the precise definition of computer experience. It is sometimes defined by the number of years of using a computer and in other literature studies it is stated as the number of hours of computer use per week. When computer experience increases, computer anxiety decreases (Bradley & Russell, 1997; Broos, 2005; Chu & Spires, 1991; Korobili et al., 2010; Sarwat, 2009; Tekinarslan, 2008). Contrary to this finding, some researchers have discovered that when the participants' level of computer experience increases, their computer anxiety also increases (Burger & Blignaut, 2004; Gos, 1996; Rosen & Weil, 1995a).

A number of research studies on computer anxiety relied solely on the reports given by the participants; examples include research studies by Aziz and Hassan (2012); Doyle, Stamouli, and Huggard (2005); Hismanoğlu (2011); Karavidas, Lim, and Katsikas (2005); Korobili, et al. (2010); Longe and Uzoma (2007) and Wilfong (2006). These research studies were performed using computer anxiety questionnaires. Examples of these questionnaires include the following: Computer Attitude Scale (CAS), Beckers and Schmidt Computer Anxiety Scale (BSCAS), Computer Anxiety Index (CAIN), Beck Anxiety

Inventory (BAI) and Computer Anxiety Rating Scale (CARS).

Even though various studies utilised questionnaires solely to measure computer anxiety, Isen and Erez (2006) state that this method has various limitations. Firstly, the participants use introspection when attempting to report their emotional experiences. Nisbett and Wilson (1977) state that the problem with introspection is that the participants are oblivious of the processes that affect the way they behave although they may be aware of the content of their thoughts. Secondly, factors such as incentives or even rules can influence the participants to respond the way they think is appropriate or expected by the researcher (Bandura, 1971 as cited in Isen & Erez, 2006). Thirdly, the participants may experience ambiguous emotions which can be difficult to interpret accurately. The use of questionnaires exclusively is therefore insufficient for drawing conclusions about emotions (Isen & Erez, 2006).

Other measurements of computer anxiety exist. These are measurements of individuals' physiological signals such as skin conductance and heart rate. Signs of computer anxiety can be sweaty palms, dizziness, being short of breath, a pounding heart, and feelings of unreality (Appelbaum & Primer, 1990; Beckers & Schmidt, 2001; Mayo Clinic, 2012). Unlike other studies, this research project investigated computer anxiety using an existing computer anxiety questionnaire in conjunction with data collection methods of usability evaluation. Of particular interest was the measurement of participants' skin conductance in usability testing.

Usability testing is a process whereby a product is assessed to determine whether it is usable by the intended users in order to accomplish the tasks it was developed for (Dumas & Reddish, 1999). In usability testing, participants are given tasks to perform using the product, and their actions and responses are recorded as they interact with the product. It is these actions and responses of the participants that aid in establishing the level of usability of the product. According to Lee (1999), data collection methods used in usability testing include observation, interviews/verbal reports, thinking-aloud, questionnaires, video analysis, auto data-logging programs and software support. Lately, measurement of physiological signals has been performed as an additional data collection method (Lin & Hu, 2005; Mirza-Babaei, 2011).

Participants' behaviours which affect physiological signals, such as increased heart rate and slightly sweaty hands, are difficult to observe. In order to monitor them specialised equipment, which is also unobtrusive, is required. However, the devices that were available in the early research studies were obtrusive. When using these devices, a participant would have to be attached to electrodes that were connected to the data collecting device via cables. The participant was also required to be motionless while the data collection was carried out. Examples of such equipment include the early sensor systems that belonged to Thought Technologies' Prompt family and Mindmedia (Peter, Ebert, & Beikirch, 2005).

The equipment that was used in this research study was unobtrusive; it is called an Emotion RECognition system (EREC). According to Kaiser and Oertel (2006), this system consists of a sensor glove, a Polar heart rate chest belt and a data collection unit (refer to figure 10). The glove contains sensors measuring skin temperature and skin resistance while the chest belt measures heart rate (Peter, Schultz, Voskamp, Urban, Nowack, Janik, Kraft, & Göcke, 2007). The system is light in weight and operates wirelessly. It also allows natural movements of the participant (Peter et al., 2005).

This research study aimed at using the extant computer anxiety questionnaire (CARS) in combination with data collection methods of usability evaluation to investigate computer anxiety in computer illiterate individuals. Specifically, the research investigated whether the EREC system could be used reliably to measure computer anxiety and whether it added any value to the existing computer anxiety questionnaires. The data collection methods are mentioned in section 1.6.1.

1.2 Problem statement and research questions

A vast amount of research has been conducted pertaining to computer anxiety. However, as stated before, numerous contradictory findings exist concerning the correlates of computer anxiety. These correlates include but are not limited to gender, computer experience and age. For example, while some researchers found that the levels of computer anxiety are not affected by the gender of individuals, other research findings state differently, details about these correlates are given in section 2.3. As mentioned in section 1.1, most of the research studies that investigated computer anxiety utilised computer anxiety questionnaires solely. This poses various problems, including the possibility of inaccurate results because of having to depend on the subjective responses of the participants. It is impossible for the researcher to know with absolute certainty whether the responses were accurate or not. For example, individuals tend to forget about their experiences when asked about them after a certain time has elapsed. Moreover, some individuals could attempt to impress the researcher by responding in a certain way which is not a true reflection of what they experienced.

With regard to the given problems, it was deemed important to incorporate an objective measurement of computer anxiety in a mixed method study in order to obtain more concrete results about computer anxiety. This led to the research questions which state:

- *To what extent does a sensor glove add value in measuring computer anxiety during usability testing when compared to anxiety questionnaires and observations?*
- *To what extent is computer anxiety influenced by age, gender, computer experience, educational attainment, and ownership of a personal computer according to the anxiety questionnaire and the sensor glove?*

1.3 Purpose statement

The goals of this mixed methods study were to:

1.3.1 establish whether using a sensor glove provided complementary knowledge to an existing computer anxiety questionnaire when compared to anxiety questionnaires and observations;

1.3.2 compare the computer anxiety of participants using a sensor glove and an anxiety questionnaire with relation to performance;

1.3.3 compare the computer anxiety of participants using a sensor glove and an anxiety questionnaire with relation to the selected factors (age, gender, computer experience, educational attainment and ownership of a personal computer).

1.4 Hypotheses

The notation $H_{0,\,i}$ has been used to denote multiple null hypotheses where i denotes the i^{th} null hypothesis. The hypotheses which were tested are the following:

$H_{0,1}$: There is no correlation between CARS scores and conductance readings of the sensor glove before and after interaction with a computer.

$H_{0,2}$: There is no relationship between computer anxiety and performance as measured by a sensor glove and a computer anxiety questionnaire.

$H_{0,3}$: There is no difference in the anxiety information provided by a sensor glove and a computer anxiety questionnaire regarding selected factors (age, gender, computer experience, educational attainment and ownership of a personal computer).

Triangulation mixed methods design was particularly chosen to enable the collection of both quantitative and qualitative data concurrently, analysing the data separately and then merging it. The quantitative data was used to determine the participants' anxiety scores (using CARS) and skin conductance (using the EREC system). The qualitative data, such as observations and interviews, provided emotional experiences of the participants while they were performing tasks on the computer. The two types of data were collected in the usability lab. It was imperative to collect both quantitative and qualitative data to enable convergence of the results, hence gaining more insight than if only one data type was used.

1.5 Motivation

The various research findings regarding computer anxiety were mostly performed in regions other than third world countries. This research study was conducted in Bloemfontein in the Republic of South Africa (RSA), a third world country where the unemployment rate in the 3rd quarter of 2013 was about 24.7%, and about 14% of the population have Grade 12 as their highest level of education (Statistics South Africa, 2013). This situation could be improved by offering these individuals computer literacy training to increase their chances of securing employment. However, according to early research studies (Ellis & Allaire, 1999; Laguna & Babcock, 1997) individuals tend to experience higher levels of computer anxiety as they grow older. If computer anxiety is not mitigated the tendency is that the individuals experiencing it will avoid using computers (Deane, Henderson, Barrelle, Saliba, & Mahar, 1995; Parayitam, Desai, Desai, & Eason, 2010). This will decrease their chances of becoming part of a work-force in a technological society; with the consequence that their standard of living will not be improved. This research sought to acquire knowledge pertaining to computer anxiety with regard to individuals with the before-mentioned background. It was expected that gaining understanding about computer anxiety (e.g. the causes) would assist in providing computer literacy training customised for such a type of population.

As mentioned before in section 1.1, various research studies investigated computer anxiety using existing computer anxiety questionnaires solely. The drawback of this approach is that questionnaires are subjective; one cannot know with certainty the genuineness of the responses to the questionnaires. This research study aimed to investigate computer anxiety by utilising the extant computer anxiety questionnaires in addition to the mentioned methods of evaluation (see section 1.1). By using this approach, it was expected that more insight into the knowledge of computer anxiety would be acquired as the questionnaires would be complemented by an objective measurement which is measuring skin conductance. Furthermore, this approach of investigating computer anxiety which includes an objective measurement was expected to be the first in RSA because no research results on computer anxiety using this method could be found.

1.6 Methodology

1.6.1 Methods

This research utilised triangulation mixed methods design. According to Creswell, Plano Clark, Gutmann and Hanson (2003), triangulation mixed methods design is suitable for research studies where the researcher simultaneously gathers quantitative and qualitative data about a phenomenon so as to achieve a better understanding of the phenomenon. This enables the researcher to compare and contrast the different findings and as a result establish well-validated conclusions. The data collection methods used in the research were the EREC system, CARS questionnaire, two self-developed questionnaires (pre-test and post-test questionnaires), interviews and observations (using pen and paper). A detailed discussion of the research methods is given in chapter 3.

1.6.2 Analysis

Analysis was performed on data collected from the methods mentioned in section 1.6.1. Demographic data about the participants, including their computer experience, was extracted from the pre-test questionnaire (see Appendix B). Alternatively, the post-test questionnaire, as provided in Appendix C, consisted of data about the emotions that the participants experienced while performing different tasks (see Appendix F) on the computer. The data that was extracted from the CARS questionnaire (in Appendix A), is the sum of the scores that each participant obtained, which indicated the level of anxiety experienced by the participant before and after performing the tasks on the computer. Descriptions of the behaviours of the participants, as well as the time they spent to complete tasks, constitute the data from the pen and paper observations. Interviews were conducted to ensure that the researcher understood the responses written by the participants on the questionnaires. The data from the EREC system constituted of skin conductance measurements.

The main statistical tests performed on the data were the correlation and Multivariate Analysis of Variance (MANOVA). The correlation was performed to determine if there was a relationship between the skin conductance data provided by the sensor glove and the CARS scores provided by the anxiety questionnaire. The MANOVA was used to confirm the findings that were established from using the correlation test. Moreover, the MANOVA was utilised to determine whether there was a difference in the anxiety information provided by the sensor glove and a computer anxiety questionnaire regarding the selected factors (age, gender, computer experience, educational attainment, and ownership of a personal computer).

The outline for the chapters of the dissertation follows.

1.7 Framework of dissertation

In chapter 1, the background, problem statement and research questions were discussed. Included in this chapter also is the motivation that led to the research study. Chapter 2 consists of a literature study pertaining to computer anxiety, its correlates and the extant questionnaires utilised to measure it. Literature regarding physiological signals and the various instruments for their measurements are also discussed.

In chapter 3 the research design that was selected for this research is discussed. Moreover, the research methodology is described with specific reference to the data collection process, methods and the instruments that were used for the pilot study and the experimental study. Chapter 4 provides the results and the analysis thereof. In chapter 5, the results are interpreted and compared with previous research findings. Moreover, conclusions and recommendations are made.

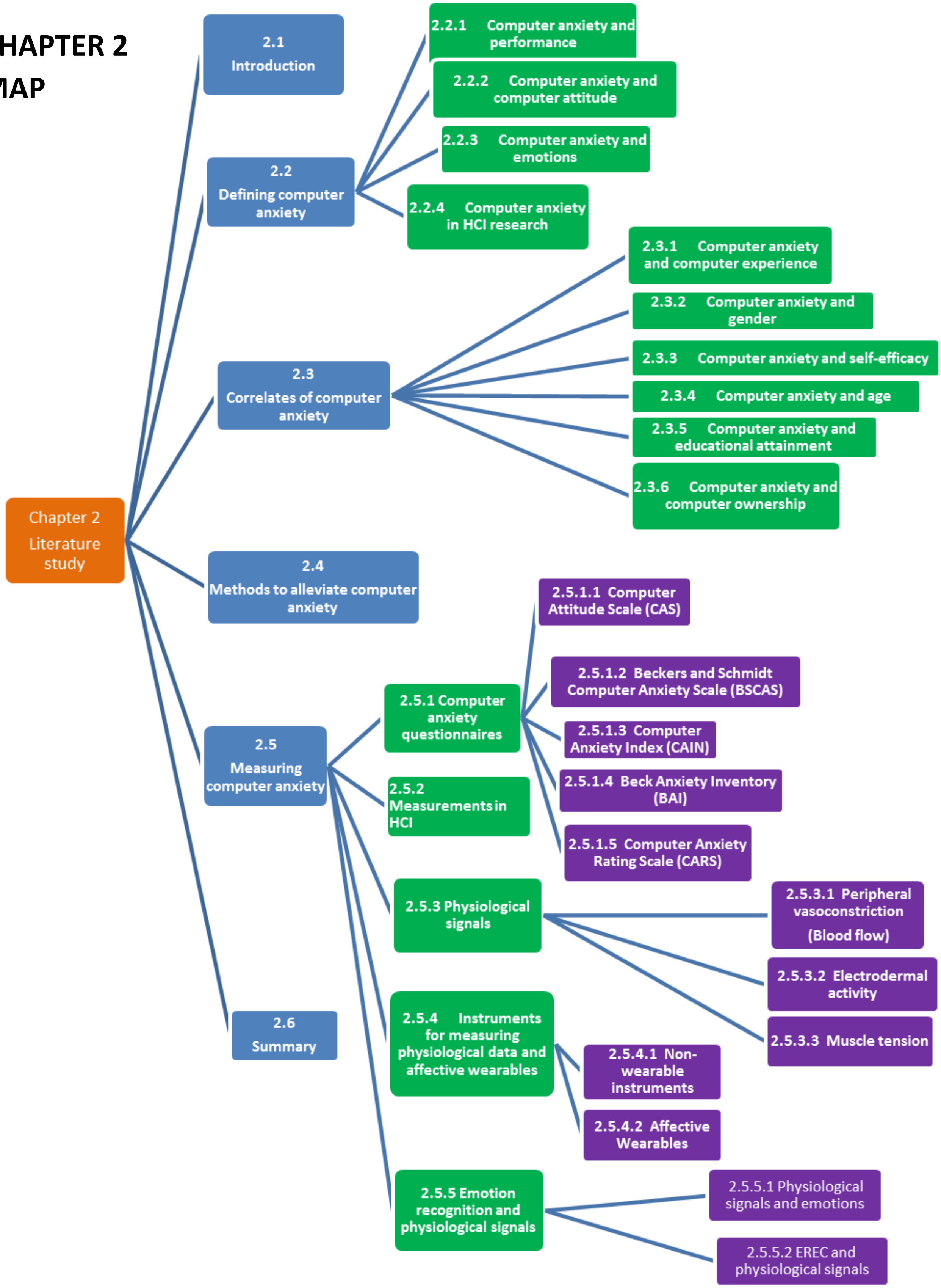
1.8 Limitations/scope of the study

Only skin resistance data was used despite the fact that the EREC system also measures skin temperature and heart rate. The researcher found it challenging to maintain a constant room temperature in the laboratory where the tests were conducted, hence the skin temperature data was not used in the analysis. The heart rate monitor, which was part of the EREC package malfunctioned, therefore the participants' heart rate could not be measured.

1.9 Summary

This chapter provided an overview of what the research entails. The chapter started by providing a brief background which included literature about computer anxiety and the contradictory findings in relation to its correlates. The problem statement, research questions and research goals were specified. Next, the motivation which led to the research study was discussed. Following the motivation was the brief discussion on the methodology and the outline of the chapters in the dissertation. The next chapter, chapter 2, provides further literature studies which are related to this research study.

CHAPTER 2 MAP



CHAPTER 2: LITERATURE STUDY

2.1 Introduction

In the preceding chapter an overview of the research study was provided. This included the problem statement, research questions and research goals. A literature preview was given to provide the background that lead to this research study. This chapter will take the literature that was consulted in the research study one step further. The details will incorporate definitions of the concepts relevant to the study.

2.2 Defining computer anxiety

Anxiety is referred to as “a diffuse, unpleasant, vague sense of apprehension, often accompanied by autonomic symptoms” (Kaplan & Sadock, 1998, p. 581). Specifically, computer anxiety is “a diffuse, unpleasant, and vague sense of discomfort and apprehension when confronted by computer technology or people who talk about computers” (Blignaut, Burger, McDonald, & Tolmie, 2005, p. 500). According to Chua et al. (1999), computer anxiety is an emotional fear or phobia experienced by individuals when using computers or, when thinking of using computers. Both these definitions of computer anxiety involve fear or apprehension caused by having to deal with computers. Various terminologies have been used in literature to refer to computer anxiety; the terms include technophobia (Brosnan, 1999), computerphobia (Rosen, Sears, & Weil, 1987), computer apprehension (Anderson, 1996) and computer resistance (Bohlin & Hunt, 1995).

Anxiety can be classified into two areas: trait anxiety and state anxiety (Biggs & Moore, 1993). Biggs and Moore (1993, p. 243) define trait anxiety as ‘‘a general readiness to react with anxiety in many situations’’ while state anxiety refers to ‘‘anxiety actually experienced in a particular situation’’. Several authors agree that computer anxiety is a state anxiety; it is connected entirely to the actual presence of a computer (for example, Bohlin & Hunt, 1995; Laguna & Babcock, 1997; Rosen & Maguire, 1990). It is regarded as a temporal emotional state as it is experienced during the period when the anxiety causing situation of factor is present (Baralt & Gurzynski-Weiss, 2011). Suggested strategies that can be implemented to minimise computer anxiety include: computer systems that can be used with ease (Appelbaum & Primmer, 1990); providing the users with pleasant learning experiences (Onifade & Keinde, 2013); use of manuals, consultant user groups and computer specialists, as a means of providing user support (Appelbaum & Primmer, 1990); implementing computer-supported collaborative learning for university students (Parayitam et al. 2010) and advanced training to ensure that users remain interested as they progress (Appelbaum & Primmer, 1990).

Although the various researchers assert that computer anxiety is a form of state anxiety, Beckers, Wicherts, and Schmidt (2007) disagree. They declare that computer anxiety has a base in trait anxiety. In their investigation, they performed two studies to determine whether computer anxiety is a mutable temporary state or a comparatively stable personality state. Their findings revealed that in both studies computer anxiety was strongly related to trait anxiety rather than state anxiety. Computer anxiety is mostly a consequence of novices feeling out of control when interacting with computers during their initial experiences. The initial feelings do not easily fade away and as a result they affect succeeding interactions with computers. It is therefore important that novices should be provided with a friendly and relaxed environment, as well as professional support during their initial interactions with computers (Beckers & Schmidt, 2003).

Researchers agree that individuals experiencing computer anxiety exhibit certain physiological reactions. These reactions include sweaty palms, dizziness or light headedness, breathing rapidly, a pounding heart, feelings of unreality, chest pain, shaking or trembling (Appelbaum & Primer, 1990; Beckers & Schmidt, 2001; Mayo Clinic, 2012; Gardner, Young & Ruth, 1989). Some of these physiological reactions are similar to those of individuals experiencing stress. According to MedlinePlus Medical Encyclopedia (2011), the symptoms of stress may include pain in the abdomen, headaches and muscle tightness or pain. For highly stressed individuals, the symptoms may include a faster heart rate, skipped heartbeats, rapid breathing, sweating, trembling and dizziness. It is apparent that based on these symptoms of anxiety and stress, it is easy to misinterpret anxiety for stress or vice versa. To distinguish between the two, Merrill (2013) states that stress is instigated by an existing stress-causing factor or "stressor" while anxiety is stress that remains after the "stressor" is gone. Despite this distinction, anxiety and stress are sometimes used interchangeably with the understanding that they have a similar meaning (Princeton University, 2013).

Individuals who experience computer anxiety have a tendency to avoid using computers. This finding was discovered in early research studies such as those conducted by Gardner et al. (1989) and Igbaria and Chakrabarli (1990). In their study, Gardner et al. (1989) classified managerial and professional workers into three groups according to their attitudes toward computers. The groups are normal, computer anxious and phobic. The phobic group reported that when they were faced with a computer, they experienced symptoms that include feelings of unreality, avoiding to use computers, panicking, fear of losing control, sweaty palms, pounding heart, chest pain, shaking or trembling, shortness of breath, and dizziness or light headedness. The computer anxious reported that they avoid computers whenever possible. There also existed a likelihood of experiencing discomfort when having to use computers. The computer anxious and the phobic groups encountered the same consequence namely, avoiding the use of computers. Igbaria and Chakrabarli (1990) agree with the findings of Gardner et al. (1989) and further suggest that some people avoid using computers completely because of experiencing computer anxiety and stress. In addition, Deane et al. (1995) state that avoidance of computer use is considered to be one of the behavioural indicators of computer anxiety.

2.2.1 Computer anxiety and performance

Individuals experiencing computer anxiety tend to score poorly in tests which require them to use computers (Glaister, 2007; Parayitam et al., 2010). In the study conducted by Glaister (2007), the student nurses who reported to have medium to high anxiety levels performed poorer than those with low levels of computer anxiety. According to Parayitam et al. (2010), students experiencing computer anxiety obtain low grades as a consequence of avoiding assignments or exercises which necessitate them to use computers. Despite these findings, a recent study conducted by Olufemi and Oluwatayo (2014) revealed a non-significant difference in the performance of students with high, moderate and low computer anxiety. The performance was based on the scores obtained by the students in a computer-based test.

2.2.2 Computer anxiety and computer attitude

Computer anxiety and negative computer attitudes are related to some degree. In the early research studies, computer anxiety and negative attitudes toward computers were used interchangeably, for example as discussed by Jawahar and Elango (2001). However, Kernan and Howard (1990), assert that the concepts are different, thus, they should be handled as separate constructs. In addition, Blignaut et al. (2005) state that negative attitudes toward computers are not caused by computer anxiety only. They further claim that an individual may have negative attitudes towards computers although his or her level of computer anxiety is very low. Perhaps these concepts have been misunderstood because of the way they have been defined or used by some researchers.

Clarke (2000, p.12) defines computer anxiety as "...evidence of one or more of the following: (a) anxiety about present or future interactions with computers or computer related technology, (b) negative global *attitudes* about computers; and/or (c) specific negative conditions or self-critical internal dialogues during present computer interactions or when contemplating future computer interaction." From this definition, it is clear that computer anxiety is related to computer attitude.

2.2.3 Computer anxiety and emotions

From the mentioned computer anxiety definition by Chua et al. (1999), which is in agreement with Cambre and Cook (1987), computer anxiety is specified as an emotional state. As a result, computer anxiety can be implied to be an emotion. There is not one definition which psychologists agree on concerning emotions. However, one of the definitions state that an emotion is a “relatively brief episode of synchronized response of all or most organismic subsystems in response to the evaluation of an external or internal event as being of major significance” (Borod, 2000 as cited in Broek, 2011, p. 9).

Research concerned with emotions involves various disciplines of computer science, namely Human-Computer Interaction (HCI), Artificial Intelligence (AI) and Health Informatics (Broek, 2011, p. 18). This research involving emotions is called affective computing. It is defined as “computing which relates to, arises from, or deliberately influences emotion” (Picard, 1999, p. 1). The goal behind affective computing is to provide computers with emotional intelligence and make them understand emotions in a similar way as a human being would do (Picard, 1997). A vast amount of research findings in affective computing has been established and the research is still ongoing. It is especially performed by the Media Laboratory team at the Massachusetts Institute of Technology (MIT). Further details about these research studies are presented in sections 2.5.3 and 2.5.4.

2.2.4 Computer anxiety in HCI research

In section 2.2.3 it was concluded that computer anxiety is an emotion. It was also stated that research in emotions involves a number of disciplines; however, the field of HCI is of particular interest in this dissertation as the research study was performed in this discipline. According to Picard (1999), enabling computers to recognise and be able to respond appropriately according to the emotional state of their users can improve human-computer interaction.

2.3 Correlates of computer anxiety

Computer anxiety has various correlates that include age (Czaja et al., 2006), computer experience (Wilfong, 2006), academic major, ethnicity (Baloğlu & Çevik, 2009), gender (Deniz & Erkan, 2012), educational attainment (Tuncer et al., 2013), general anxiety (Harrison & Rainer, 1992), ownership of a personal computer (Korobili et al., 2010), corporate pressure (Blignaut et al., 2005) and culture (Blignaut, McDonald, & Tolmie, 2002; Tekinarslan, 2008). Beckers and Schmidt (2001) state computer anxiety to be a multidimensional construct instead of a unitary one. They suggest that at least 6 dimensions exist in the build-up of computer anxiety. These are computer illiteracy (in terms of attained computer skills), lack of self-efficacy (lacking confidence in one’s ability to learn to use computers), heightened physical awareness caused by being in the presence of computers (for example, sweaty hands or palms and shortness of breath), affective feelings, negative beliefs about computers, and positive beliefs about computers.

When they tested the model of the 6 dimensions of computer anxiety, Beckers and Schmidt (2001) discovered several relationships between the factors of computer anxiety. Firstly, they found that computer literacy greatly influences aversive physical awareness in a negative directive manner. Secondly, computer literacy influences affective feelings in a positive manner. Thirdly, they discovered that there is a relation between computer literacy and self-efficacy. The relationship between these two could be that self-efficacy influences computer literacy; however, this relationship could not be tested in the particular research study. Lastly, they found that there is no direct relationship between self-efficacy and physical awareness, or between self-efficacy and affective feelings (Beckers & Schmidt, 2001).

Although literature shows that there are numerous correlates of computer anxiety, the discussion in the subsequent sections will focus on the research findings related to computer experience, gender, self-efficacy, age, educational attainment and computer ownership as these have been found to be common in research studies.

2.3.1 Computer anxiety and computer experience

A vast amount of literature states that computer experience is negatively correlated to computer anxiety; the more experience individuals acquire, the less their anxiety (Beckers & Schmidt, 2003; Bovée, Voogt, & Meeelissen, 2007; Broos, 2005; Talebi, Zare, Sarmadi, & Saeedipour, 2012). Beckers and Schmidt (2003) found that as one gains more computer experience, it leads to a higher liking of computers and a decrease in physical awareness. Additionally, more computer experience lets one perceive oneself as being more computer literate and as a result, it leads to less physical awareness. They also assert that during their first experiences with computers, individuals that are given an atmosphere that allows them to feel in control, relaxed, and having fun, end up attaining more experience and liking of computers. Lastly, they state that computer anxiety develops mainly as a consequence of novices feeling out of control during their first experiences with computers.

Rosen et al. (1987) also agree that the nature of the experience that individuals are exposed to during their first encounter with a computer, determines the computer anxiety that they experience. In their study, Rosen et al. (1987) discovered that a number of people that had negative first experiences with computers remained anxious or even became more anxious while acquiring more computer experience. However, findings from a more recent study showed that individuals who were exposed to early bad experiences with computers may have the chance to recover from the initially high computer anxiety they experienced when they are followed by high impact good experiences (Todman & Drysdale, 2004).

From these findings it is evident that computer experience plays an important role in determining computer anxiety of individuals. One would want to investigate whether experienced computer users ever experience computer anxiety that is worth giving attention to. Beckers, Rikers and Schmidt (2006) conducted a study where they investigated whether computer anxiety would hinder experienced computer users while performing complex computer tasks. Their findings revealed that experienced computer users developed a certain amount of anxiety, a “threshold”. This is “a level below which anxiety would only be a dormant factor, waiting to be elicited by a stressful stimulus of a sufficient magnitude” (p. 464). This anxiety only hinders the users’ performance in cases when it is sufficiently high or in the context where the users are required to perform ambiguous computer tasks.

2.3.2 Computer anxiety and gender

Findings regarding the relationship between computer anxiety and gender are inconclusive. Some studies discovered no significant relationship between computer anxiety and gender (Anthony, Clarke, & Anderson, 2000; Başarmak & Güyer, 2009; Havelka, Beasley, & Broome, 2004; Hismanoğlu, 2011; King, Bond, & Blandford, 2002; Popovich, Gullekson, Morris, & Morse, 2008; Rosen & Maguire 1990; Sam, Othman, & Nordin, 2005, Tuncer et al., 2013). In a meta-analysis of studies on computer anxiety, Rosen and Maguire (1990) found women to elicit computer anxiety levels that are slightly higher than those of men. However, the difference was insignificant. King et al. (2002) suggested that gender should be regarded as an insignificant variable when considering differences in computer anxiety. In their study, they discovered a slight difference of computer anxiety between males and females. The findings of Rosen et al. (1987) revealed that gender had no relationship with computer anxiety, however, sex-role identity did. From their data, they discovered that feminine-identity students experienced more computer anxiety than male-identity students, irrespective of their gender. Tuncer et al. (2013) found gender to have no effect on computer anxiety in their study. The study aimed at investigating computer anxiety of high school students in different departments of the Tunceli Vocational School at the Tunceli University.

Despite the fact that certain research findings discovered no significant relationship between computer anxiety and gender, a number of other research findings established relationships. In some studies females were found to have lower levels of computer anxiety than males (Aziz & Hassan, 2012; Brosnan & Lee, 1998; Deniz & Erkan, 2012). In their study, which examined computer anxiety of 286 Hong Kong nationals in comparison with 206 United Kingdom nationals, Brosnan and Lee (1998) discovered that although the United Kingdom sample showed no gender differences in relation to computer anxiety, the Hong Kong males reported having greater computer anxiety than the females. The anxiety actually occurred when the males anticipated using the computers rather than when using them. Aziz and Hassan (2012) investigated computer anxiety of higher secondary students in Punjab, a state located in India. A total number of 1062 students studying computer science were issued a scale for measuring computer anxiety. Apart from the computer anxiety score, the scale also incorporated the students' demographic data, such as gender. The total number of students consisted of 643 males and 425 females. The findings revealed that there was a significant difference between the computer anxiety scores of males as opposed to that of the females. The mean scores of males were higher than those of females indicating that males reported more computer anxiety than females.

A number of findings indicate that females demonstrate computer anxiety more than males (Beckers & Schmidt, 2003; Broos, 2005; Brosnan, 1998; Busch, 1995; Chou, 2003; Czaja et al., 2006; Karavidas, Lim, & Katsikas, 2005; McIlroy et al., 2001; Rosen & Weil, 1995a; Simsek, 2011). The study conducted by Karavidas et al. (2005) constituted of 86 females and 131 males residing in South Florida. The mean age of the sample was 72 with the minimum and maximum ages being 53 and 88 respectively. The participants were administered questionnaires with scales for measuring life satisfaction, self-efficacy, computer knowledge, and computer anxiety. When the data was analysed, it was discovered that regarding computer anxiety, females experienced higher levels than males. The study performed by Simsek (2011) investigated the relationship between computer anxiety and self-efficacy among 845 participants. The participants comprised students and teachers in elementary and secondary schools in Turkey. In this study, computer anxiety was measured using Oetting's (1983) Computer Anxiety Scale (COMPAS). The results of the study with regard to computer anxiety revealed females' anxiety scores to be higher than the males'.

Possibly an overlap exists between gender and computer experience where computer anxiety is concerned. In a number of the studies where females were found to experience more computer anxiety than males, the males had more computer experience than the females. For example, Busch (1995) stated that the males in their study reported to have gained more computer experience by playing games and programming than the females did. Moreover, the results from the studies conducted by Beckers and Schmidt (2003) indicated that females experienced higher levels of anxiety than males possibly because they had less experience with computers than males. Lastly, Karavidas et al. (2005) found that even though the female adults (aged between 53 and 88 years) in their study reported to have more computer anxiety than the males, their ratings of computer experience was found to be significantly lower than the rating of the males.

2.3.3 Computer anxiety and self-efficacy

Self-efficacy was mentioned in section 2.3 as confidence in one's ability to learn to use computers (Beckers & Schmidt, 2001). It can also be defined as the judgment which individuals possess concerning their capability to use a computer (Compeau & Higgins, 1995). Computer anxiety is negatively correlated to self-efficacy (Simsek, 2011). This finding is expected because when individuals gain confidence about their ability to perform tasks, they perceive that their chances of success are higher, therefore their anxiety decreases (Johnson, 2005; Roslan & Mun, 2005). Doyle, Stamouli and Huggard (2005) investigated the relationship between computer anxiety and self-efficacy amid four groups of students studying in the first, second, third and fourth years of their computer science degree. When analysing the data of the first year students, no significant relationship between computer anxiety and self-efficacy was established. However, with the other three groups it was found that a negative relationship between computer anxiety and self-efficacy existed. This relationship was observed to intensify in strength as the year of study increased. According to Harrison and Rainer (1992), the more individuals perform computer-related tasks, the more their self-efficacy increases. Incorporating this finding into the study conducted by Doyle et al. (2005), it can be assumed that as the computer science students progressed in their studies (performing more computer-related tasks) from second year to fourth year, their self-efficacy increased, thereby reducing their computer anxiety. Perhaps this presumption could be verified if the study had been performed with the students when they commenced their studies, as first years and continued until they completed the fourth year of study.

2.3.4 Computer anxiety and age

There is a discrepancy in the findings relating computer anxiety and age. The findings from the study performed by Hismanoğlu (2011) showed no significant age difference with regard to prospective English language teachers experiencing computer anxiety. The CARS questionnaire was among the instruments used in this study and the mean age of the sample was 22.4 years of age, with the Standard Deviation (SD) being 3.05. In a similar manner, Ademola and Idou (2013) found no significant age difference in computer anxiety. Krendl and Boihier (1992) reported that students from fourth grade up to tenth grade had more or less the same perception about the difficulty of using computers. They suggested that age may not be considered a factor in predicting computer anxiety. According to them, “age is an additional factor that consistently shapes individuals’ perceptions of and attributions about computers’’ (p. 225).

Contrary to the mentioned findings on computer anxiety and age, Rosen et al. (1987) discovered that older adults experienced more computer anxiety even though they did not possess more negative attitudes than younger students. This finding is in agreement with Ellis and Allaire (1999) whose study involved older adults (aged between 60 and 97 years). It was found that the older an individual becomes, the more anxious he/she tends to be. A similar finding was discovered from the study conducted by Czaja et al. (2006). In their study, they involved 1,204 participants whose ages ranged from 19 to 81 years. The results of the study showed that older adults experienced more computer anxiety than middle-aged adults. The middle-aged adults in contrast, indicated higher levels of computer anxiety than the younger adults. The results also indicated that the older adults were less likely to use computers than the younger adults. Lastly, the findings of Laguna and Babcock (1997) revealed that older adults (55 – 82 years) experienced more computer anxiety than young adults (18 – 27 years). However, the anxiety experienced by the older adults was with regard to performance in terms of decision time rather than performance in terms of accuracy (Laguna & Babcock, 1997).

It is worth mentioning that with older adults, the level of computer anxiety is affected by other factors such as educational attainment and computer knowledge. For example, in the mentioned study by Ellis and Allaire (1999) computer anxiety was investigated in relation to age, computer anxiety, educational attainment and computer knowledge. As already mentioned, the findings revealed that age was positively related to computer anxiety. However, educational attainment was found to be positively related to both computer knowledge and computer interest, but negatively related to computer anxiety. The more educated individuals had more computer knowledge and computer interest, and they exhibited less computer anxiety than those with lower levels of education (Ellis & Allaire, 1999). Moreover, in another study concerning older adults, Rogers, Cabrera, Walker, Gilbert, and Fisk (1996) reported that the older frequent users of automatic-teller technology were more educated than the older users who did not use the technology.

2.3.5 Computer anxiety and educational attainment

Educational attainment can be considered by various measures such as grade of study/highest grade achieved, type of education or a combination of the measures. In the study conducted by Tuncer et al. (2013), the participants' grades and their type of education were considered separately when evaluating the effect on computer anxiety. The grade of study was considered by comparing the first-year students with the second-year students. Regarding the type of education, the groups considered were those students who attended school in the daytime (normal education), and the students who attended school in the evening (evening education). The evening education students had obtained relatively lower exam marks. The findings of the study showed that educational attainment (grade of study and type of education) and computer anxiety were negatively related. The second-year students experienced less computer anxiety than the first-year students. Higher levels of computer anxiety were found among the evening education students than among the normal education students. Despite these findings, a study performed by Simsek (2011) revealed that elementary students were less anxious than secondary students. This finding is contradictory to the finding of Tuncer et al. (2013).

2.3.6 Computer anxiety and computer ownership

The terms 'computer ownership' and 'ownership of a personal computer' are used interchangeably in this study. Literature findings show that individuals who own computers experience less computer anxiety than those without computers (Korobili et al., 2010; Tuncer et al., 2013). In some findings, computer ownership and computer experience are said to reduce computer anxiety (Baloğlu & Çevik, 2008; Yushau, 2006). However, the findings of Hismanoğlu (2011) showed no significant relationship between computer anxiety and computer ownership. In the study, Hismanoğlu (2011) utilised the CARS questionnaire (Heinssen, Glass & Knight, 1987) and CAS questionnaire (Loyd & Gressard, 1984). The aims of the study were to examine the relationship between computer anxiety and computer attitude, and to investigate the effects of background characteristics on prospective teachers' computer anxiety and computer attitude.

Numerous contradictory findings were found regarding the correlates of computer anxiety. The correlates where the differing findings were established are gender, age and educational attainment. Despite this, research findings are in agreement to some extent regarding computer experience and self-efficacy.

Computer anxiety is undesirable and should be minimised whenever learners are trained in computer-related courses. Suggested methods to alleviate computer anxiety are discussed in the following section.

2.4 Methods to alleviate computer anxiety

Various methods are suggested in an attempt to alleviate computer anxiety; some were mentioned briefly in section 2.3. Dupin-Bryant (2002) proposes several methods that should be applied. The first technique is to incorporate humour in the lessons because laughter helps to establish a relationship between instructors and learners. Secondly, while in the introductory phase of the lessons, the instructor should provide basic concepts about computers without assuming that all the learners know these facts. Thirdly, the use of computer language should be avoided unless absolutely necessary. In cases where it is educationally essential to mention computer jargon, the instructor is advised to provide an explanation of the terminology before using it. Lastly, the instructor should allow the learners to have hands-on experiences with the computer. In an effort to assist the learners with tasks which they cannot accomplish on their own, the instructor should verbally guide the learners or utilise demonstration machines.

Wilfong (2006) suggested that while the individuals are experiencing anxiety, computer-based therapy should be used to minimise those feelings of anxiety. It is also recommended that when learners are introduced to new software, the instructor should use the application-based mode of teaching and be attentive to learners exhibiting the highest level of anxiety (Parayitam et al., 2010).

2.5 Measuring computer anxiety

As indicated in section 1.1, a number of research studies were conducted to measure computer anxiety using subjective measures exclusively. These measures rely on the responses given by the participants in completing the questionnaires. There are, however, objective measures that can be used to determine computer anxiety. These are measurements of the participants' physiological data such as skin temperature, skin conductivity, heart rate and pupil size variation. In the subsequent section, the questionnaires for measuring computer anxiety will be discussed. Following that discussion will be a section about the measurement of physiological signals. Lastly, various instruments that are used to measure physiological signals will be mentioned.

2.5.1 Computer anxiety questionnaires

Since the research goals of the study involved comparing an anxiety questionnaire with a sensor glove, it was considered vital to discuss some of the existing computer anxiety questionnaires. This would give insight into the choice of the questionnaire used for this study. Subsequently, in this section, further details are provided about the following computer anxiety questionnaires: Computer Attitude Scale (CAS), Beckers and Schmidt Computer Anxiety Scale (BSCAS), Computer Anxiety Index (CAIN, Beck Anxiety Inventory (BAI) and Computer Anxiety Rating Scale (CARS).

2.5.1.1 Computer Attitude Scale (CAS)

CAS was developed by Loyd and Gressard (1984). It is a Lickert-type scale consisting of 30 items. Responses to the statements in this scale can be chosen from four options, which are *Strongly Disagree*, *Disagree, Agree*, and *Strongly Agree*. The items are based on three subscales, namely computer liking, computer confidence and computer anxiety (Loyd & Gressard 1984). Bandalos and Benson (1990) revised it to consist of 23 items with the subscales: computer liking, computer confidence and computer achievement. They suggested that computer anxiety scores obtained using CAS should be compared among groups in order for CAS to exhibit construct validity. Taking this suggestion into consideration, CAS was found to be inappropriate for this study because no comparison of groups was done in the current study.

2.5.1.2 Beckers and Schmidt Computer Anxiety Scale (BSCAS)

BSCAS measures 6 fundamental factors causing computer anxiety, namely computer literacy, self-efficacy, physical awareness in the presence of computers (for example, sweaty palms, shortness of breath), affective feelings towards computers, positive beliefs about the benefits for society of using computers, and negative beliefs about the dehumanizing impact of computers. BSCAS comprises 32 Lickert-type statements on computers, with the option of scoring from 1 (entirely disagree) to 5 (entirely agree). The statements are designed to address the 6 factors underlying computer anxiety (Beckers et al., 2007).

2.5.1.3 Computer Anxiety Index (CAIN)

The CAIN scale consists of 26 Lickert-type items and allows participants to respond on a 6-point scale (1 = strongly agree, 2 = agree, 3 = slightly agree, 4 = slightly disagree, 5 =disagree, 6 = strongly disagree). The highest possible score of 156 indicates highest anxiety while the lowest anxiety is reflected by the score of 26 (Montag, Simonson, and Maurer, as cited in Laguna & Babcock, 1997, p. 321). In a comparative study of CAIN and other instruments, results indicated that CAIN is an appropriate test for Grade 11 and higher students, but not for students in lower grades (Gardner, Discenza, & Dukes, 1993).

2.5.1.4 Beck Anxiety Inventory (BAI)

BAI is a 21 item self-report measure designed to evaluate the anxiety symptoms of adults and adolescents. The items in BAI are descriptions of emotional, physiological and cognitive symptoms of anxiety. Respondents are required to indicate the degree to which they have experienced these symptoms on a scale of 0 to 3. Zero indicates "not at all", 1 = "mildly but it didn't bother me much", 2 = "moderately – it wasn't pleasant at times", 3 = "severely – it bothered me a lot". The scores are added to determine the total score. The highest possible total score is 63 (Grant, n.d.). According to Black (2009), BAI is one of the top 3 frequently used research measures of anxiety.

The researcher could not use BAI because its use required the presence of a practising psychologist throughout the entire process of data gathering to conduct interpretation of the scale. A psychologist who would be willing and available was too high a price.

2.5.1.5 Computer Anxiety Rating Scale (CARS)

CARS was developed by Heinssen, Glass, and Knight (1987) and was validated by Chu and Spires (1991). When tested on a sample of 270 introductory psychology students, CARS showed a good internal consistency ($\propto$ = .87). The test-retest reliability of (r = .70, p < .01) over a 4 week interval was obtained (Heinssen, et al., 1987). CARS has been used in a number of research studies (Bhoola-Patel & Laher, 2011; Hismanoğlu, 2011; Korobili, et al., 2010; Murthy, 2004; Tekinarslan, 2008) and proved to be reliable. For example, the study conducted by Barbeite and Weiss (2004) revealed a high Cronbach's $\propto$ of .92 for the CARS instrument. In another study conducted by Bhoola-Patel and Laher (2011), the reliability results of the CARS instrument revealed a Cronbach's $\propto$ of .85 while Korobili, et al. (2010) discovered a value that ranged between .71 and .79.

CARS consists of 19 items with a five-point Lickert type scale rated from 1 = "strongly disagree" to 5 = "strongly agree". The CARS scores range from 19 to 95 where the higher scores reflect higher levels of computer anxiety. Among the items are statements such as "I feel apprehensive about using computers; I have avoided computers because they are unfamiliar and somewhat intimidating; I am afraid that if I begin to use computers I will become dependent upon them and lose some of my reasoning skills". Nine items are reverse-scored. These include statements such as "The challenge of learning about computers is exciting; I feel that I will be able to keep up with the advances happening in the computer field; I feel computers are necessary tools in both educational and work settings" (Heinssen et al., 1987).

Among the computer anxiety questionnaires that have been discussed, CARS was deemed to be the most appropriate. Though it was designed a long time ago (1987), it has been employed in several studies including recent studies such as those conducted by Hismanoğlu (2011) and Korobili et al. (2010). CARS is reliable as it has been stated in section 2.5.1.6. Moreover, CARS was easily available on the Internet and it could be utilised free of charge when used for academic purposes.

It has already been mentioned that computer anxiety is an emotional state (refer to section 2.2.3), it is apparent that measurements that have been utilised to measure emotions can be used to measure computer anxiety as well. Having looked at the anxiety questionnaires, other possible measurements in the field of HCI (the field in which this study is conducted) are discussed.

2.5.2 Measurements in HCI

The term Interaction Design (ID), which is a subset of HCI, is defined as "designing interactive products to support the way people communicate and interact in their everyday and working lives" (Preece, Rogers, & Sharp, 2007, p. 8). The focus of ID is on designing positive user experiences. ID is concerned with designing and implementing interactive systems or products that are efficient, effective, easy to learn, safe and providing user satisfaction. To achieve this, effective evaluations of the systems have to be undertaken (Preece et al., 2007).

The three main approaches of evaluation in HCI are usability testing, field studies and analytical evaluation. Usability testing, which is the approach that has been selected for the purpose of this research study, is performed in a controlled test environment called a usability laboratory. When usability testing is conducted, participants are measured on their performance as they carry out typical tasks with the product or system under evaluation. The participants are observed and sometimes recorded using a video camera. Their interactions are commonly recorded by means of data loggings of the inputs to the system and outputs from the system. Other recordings performed include the time taken to complete the given tasks, task success rate and the number of errors made by the participants. The opinions of the participants are also investigated through questionnaires and interviews (Preece et al., 2007).

It was mentioned (in section 1.2) that participants' responses are subjective. Objective measurements are therefore introduced in the subsequent section. These are measurements of physiological signals.

2.5.3 Physiological signals

In the following section, an introduction to physiological signals and how they affect emotions will first be made. Secondly, instruments that have been used to measure physiological data will be introduced. Lastly, literature will be provided about instances where physiological data of participants (for example, skin conductivity and heart rate) was measured to determine the different emotions experienced by the participants. Examples of the emotions are anxiety, happiness and anger.

Physiological changes can indicate the emotions that an individual is experiencing. Examples of where such changes may occur are in the pupil size (Partala & Surakka, 2003), voice, facial expressions, gestures, heart rate, blood pressure and electro-dermal activity. Physiological changes are controlled by the autonomic nervous system (ANS) (Peter et al., 2009). This system is comprised of sympathetic and parasympathetic divisions. The sympathetic system prepares the body for quick action in response to stimuli (Barreto, 2008). When the sympathetic drive increases, it results in increases in blood pressure, sweating and heart rate. In addition, the blood is transported from the gut to the limb muscles, resulting in an arousal which is autonomic. Examples of behaviours associated with autonomic arousal are fight and flight responses (Vissing, Scherrer, & Victor, 1991). The parasympathetic system, on the contrary, promotes the body to be in a state of “rest and repose”, promoting activities such as digestion which require a small amount of energy (Martini, Ober, Garrison, Welch, & Hutchings, 2001).

The sympathetic and parasympathetic activations occur alternately, producing physiological changes that may be measurable (Barreto, 2008). Physiological changes are ascribed to three physiological processes, namely peripheral vasoconstriction, electro-dermal activity and muscle tension (Cacioppo, Tassinary, & Berntson, 2000). These terms are explained further in the subsequent sections.

2.5.3.1 Peripheral vasoconstriction (Blood flow)

The process whereby the diameter of blood vessels decreases is called peripheral vasoconstriction. Non-invasive measurements of the diameter of blood vessels have not yet been established, therefore other measurements, which include measuring peripheral skin temperature, are used. Changes in the diameter of the blood vessels correlate with changes in the peripheral skin temperature. Variations in the diameter of blood vessels cause a decrease or increase in the volume of blood flowing into a particular body part. This causes the temperature of the surrounding tissue to increase or decrease depending on the actual diameter of the contained blood vessels (Peter et al., 2009). It is expected that when the body responds to stimuli by activating the sympathetic autonomous nervous system, vasoconstriction occurs. This reduction of the blood vessels in turn reduces the blood flowing to the hairless areas of the hand, for example, the fingers (Krogstad, Elam, Karlsson, & Wallin, 1995). In such a situation, the temperature of the finger is expected to drop (Barreto, 2008). Skin temperature changes have often been measured in psychological studies and biofeedback applications to infer peripheral vasoconstriction (Peter et al., 2009). Consequently, skin temperature variations can be measured in order to observe the manifestation of affective changes of individuals. They are easily measurable using simple and easily available temperature sensors (Barreto, 2008). Skin temperature readings can however be affected by room temperature, as well as airflow around the body part where the temperature is being measured (Peter et al., 2009).

2.5.3.2 Electrodermal activity

According to Peter et al. (2009), electrodermal activity (EDA) is known by several terms, namely Galvanic Skin Response (GSR), Skin Conductance Level (SCL), Skin Conductance Response (SCR), Skin Resistance Level (SRL) and Skin Resistance Response (SRR). GSR is defined as a change in the electrical properties of the skin when responding to stress or anxiety (Princeton University, 2013). In an event when an individual experiences increased sympathetic activation, for example, in cases of stress and nervous tension, the individual’s palms become damp. This is because increased sympathetic activity causes the sweat ducts and the surface of the skin to be hydrated.

This hydration (sweating) causes the skin resistance to decrease but the conductance to increase (Barreto, 2008). The term used to describe changes in electrical conductance of the skin is EDA. It is reflective of the changes in the autonomic sympathetic arousal associated with emotional and cognitive states (Critchley, 2002). In humans, as well as in various animals, autonomic responses in the skin such as sweating and vasomotor changes, operate as emotional expressions and social signals. These assist the individual to be able to interact accordingly (Darwin, 1998). To measure EDA, a pair of electrodes is attached to the surface of the skin and a small current is passed between the electrodes while the conductivity level is measured (Barreto, 2008). Alternatively, no current is applied externally but the electrical activity is measured from the skin itself (Bio-medical.com, 2002). GSR is among the signals that are used in polygraph ('lie-detector') tests and in studies that involve stress and cognitive workload (Picard & Scheirer, 2001). It is considered to be very sensitive to physiological changes (Barreto, 2008).

It is frequently difficult to determine the cause of a certain skin conductance response because it can be triggered by various stimuli. Nonetheless, it is generally the case that the skin conductance level swiftly elevates in events which are major or of intense nature (for example when experiencing stress and anxiety). When executing tasks that involve mental workload, the level is inclined to increase suddenly and then decrease slowly. Normally this is the response at the beginning of new and engaging experiences (Picard & Scheirer, 2001).

2.5.3.3 Muscle tension

Muscle tension can indicate the emotional arousal experienced by an individual. This can be easily viewed by observing the postural changes and gestures that the individual exhibits. However, valence (the extent at which an event is perceived as pleasant) can be indicated by subtle affect-related muscle activity that can be viewed on the face of the individual. It is not easy to measure muscle tension with adequate resolution and accuracy; therefore electromyography (EMG) and visual observation are used. These are the most frequently used measurements to infer muscle tension. Regarding EMG, surface electrodes are attached to the skin above the muscle and then the changes in the electrical potentials, which activate the muscle fibres, are measured. Visual observation entails utilising video cameras to record the individual and then using sophisticated algorithms to identify particular body movements (gestures) or changes in the individual's facial expressions (Peter et al., 2009). Video-based systems, which are used for identifying emotions, are much less intrusive than EMG sensors; however, the former are challenging to use. This is because the facial expressions and appearances of individuals differ greatly therefore they become difficult to analyse computationally (Tullis & Albert, 2008).

Pupil diameter is another physiological signal which is affected by muscles. The diameter of the pupil can range between 1.5mm to more than 9mm (Barretto, 2008). It is controlled by two contrasting sets of muscles of the iris named the sphincter and dilator pupillae. The activity in the ANS influences the dilations and contractions of these muscles (Barretto, 2008). According to Steinhauer, Siegle, Condray, and Pless (2004), when the sympathetic activity increases, it results in an increase in the dilator muscle causing dilation to occur. Since the parasympathetic activity works in contrary to the sympathetic activity, increase in the sympathetic activity is a decrease in the parasympathetic activity. This means that the constriction of the sphincter, which is performed by the parasympathetic activity, is reduced, hence the sphincter muscle is relaxed and dilation is promoted. It is therefore evident that either sympathetic or parasympathetic activity can cause pupil dilation (Bradley, Miccoli, Escrig, & Lang, 2008).

Although the amount of light and accommodation reflexes primarily affect pupil diameter (Beatty & Lucero-Wagoner, 2000), various other influences exist. According to research, pupil diameter can be controlled by a number of states that an individual can experience, for example, when an individual performs activities that require physical or mental effort, when levels of interest in executing tasks change or when an individual responses emotionally to a certain situation (Tullis & Albert, 2008). Barretto (2008) states that in situations when an individual expects to solve difficult problems or even thinks of performing muscular action, the pupil diameter somewhat increases. This finding was not new because early research studies such as those performed by Hess and Polt

(1964) made a similar discovery. In their study, Hess and Polt (1964) investigated whether a correlation existed between pupil size and problem difficulty. The findings revealed that the more complex a problem became, the further the pupil size increased as a result of increased mental effort.

In the subsequent section, examples of instruments used to measure physiological signals are mentioned.

2.5.4 Instruments for measuring physiological data and affective wearables

Various instruments exist for measuring different types of physiological signals; however, some of them are obtrusive. With the obtrusive instruments, a participant is attached to electrodes that are connected to wires and the participant is required to be motionless during data capturing. However, other instruments which are less obtrusive have been manufactured. Examples of these instruments are introduced in two categories in the following section, namely non-wearable instruments and affective wearables.

2.5.4.1 Non-wearable instruments

Examples of non-wearable devices that will be discussed in this section are the emotion mouse, electromechanical film chair and eye-tracker.

Emotion Mouse

The mouse was developed by a company called International Business Machines (IBM). This is a device that looks similar to an ordinary mouse (see figure 1), except that it has buttons coated with copper and an infrared port on its side. The Emotion Mouse is able to measure the physiological signals of the individual using it. The signals it measures are skin temperature, heart rate and skin conductivity. It is able to detect even minute movements that the user might make with it. The measured signals are transmitted from the mouse via wires into the computer that analyses the data to establish the emotional state of the user (Austen, 2000).

Figure 1: Emotion Mouse

(Adapted from Austen, 2000)

Electromechanical film (EMFi) chair

The EMFi chair (see figure 2) was developed at the Technical Research Centre in Finland, and it is used for measuring heart rate.

Figure 2: EMFi chair

(Anttonen & Surakka, 2005)

The EMFi chair has sensors of electromechanical film (EMFi) embedded in its seat, backrest and armrests. Ballistocardiography (BCG) is the foundation upon which the EMFi chair is able to measure heart rate. When a heart beats, it creates a recoil which spreads through the body and is measured by BCG. It is suggested that the EMFi chair can be used as an unobtrusive measurement of the participant's emotional reaction (Anttonen & Surakka, 2005).

Eye-tracker

An eye-tracker is a device that locates and records the movements of a participant's eyes on screen. When eye-trackers were introduced, they were large devices that were mounted on the head. However, nowadays an eye-tracker is in a form that resembles a flat panel computer monitor (see figure 3). Containing special diodes which reflect light from the pupil, an eye-tracker is able to monitor fixations, gaze paths and the pupil diameter of an individual interacting with the computer (O'Brien, 2007).

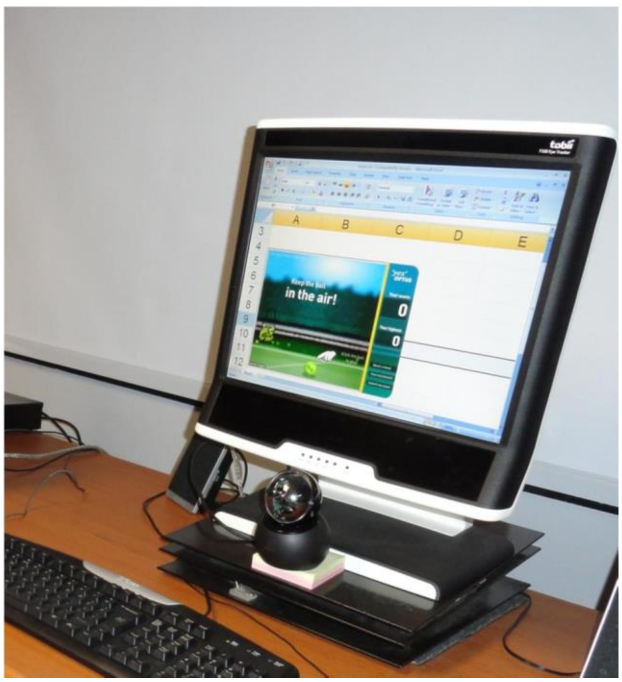


Figure 3: Tobii's Eye-tracker

(Picture taken in the usability lab at the University of the Free State)

Various research and usability studies in HCI have used eye-trackers (Namahn, 2001). It has been used to investigate, for example, emotional stimulation using audio stimuli (Partala & Surakka 2003); emotional arousal and autonomic activation (Bradley et al., 2008), and diverse means of increasing the usability of a word processor for use by users of different expertise levels, ages and abilities (Beelders, 2011, p. 1).

Although an eye-tracker has been used in a number of research studies, there are disadvantages associated with it. Firstly, it is not constantly 100% accurate because data is lost when a participant's eyes move away from the object of study. However, modern eye-trackers have devices where the participant's head is mounted to avoid head movements. Secondly, eye-tracking equipment is expensive. Thirdly, the room where eye-tracking is performed is required to have constant light or light that can be controlled. This is especially true for studies which involve measurement of pupil dilation. Fourthly, the use of an eye-tracker is limited; only one participant can be tested at a given time (O'Brien, 2007).

Having examined a few examples of instruments that can be used for measuring physiological signals, the discussion now diverts to the instruments which are specifically worn, which are called affective wearables.

2.5.4.2 Affective Wearables

Affective computing and its goal of providing computers with emotional intelligence were introduced in section 2.2.3. In the endeavor to accomplish this goal, various "affective wearables" have been designed. Picard and Healey (1997, p. 1) define an affective wearable as "a wearable system equipped with sensors and tools which enables recognition of its wearer's affective patterns". According to these researchers, the affective wearable should be able to detect patterns such as changes in the ANS activity (e.g. increasing skin conductivity or heart rate) and expressions elicited as a result of the emotions experienced (e.g. an angry gesture, a joyful smile). Some affective wearables do not only recognise the wearer's patterns, but also react in certain pre-programmed ways in response to those patterns (Healey & Picard, 1998). Examples of affective wearables are given below.

BodyMedia SenseWear Armband

The armband (see figure 4) was designed by BodyMedia, Inc. It consists of a skin temperature sensor, a galvanic skin response sensor, two-axis accelerometer, a heat-flux sensor, an ambient temperature sensor, and a polar chest strap. It is considered to be non-invasive as it is worn on the upper arm. The armband is responsible for measuring physiological signals including GSR, heart rate, temperature, movement, and heat flow. The signals are collected in the armband which is later connected to the Innerwear Research Software (with a dock station) in order to transfer the data (Lisetti & Nasoz, 2004).

Figure 4: BodyMedia SenseWear System

(SwordMedical, 2010)

Emotiv EPOC

An EPOC headset was developed by a company named Emotiv Systems. It can be tuned to read an individual's thoughts and then interpret what the individual wants to do. The headset is a light-weight and wire-less device with 14 extensions of electrodes, allowing free movement by the individual wearing it (see figure 5). It is worn on the head similarly to headphones (McGrath, 2008). The headset is used, for example, by game players to control the way they play the game by merely using their thoughts, expressions and emotions. The Emotiv EPOC is able to detect more than 30 different expressions, actions and emotions. Detectable facial expressions include wink, smile, laugh, anger (displayed by furrowed eyebrows), shock (displayed by raised eyebrows), crossed eyes, smirk, grimace and horizontal eye movement. Push, pull, drop, lift and rotate are among the cognitive actions that Emotiv detects. The emotional detections incorporate tension, frustration, meditation, immersion, boredom and excitement (Emotiv Systems News Desk, 2008).

The technology utilised in Emotiv EPOC is called electroencephalogram (EEG). This is a measurement of brain waves represented in a graph (McGrath, 2008). In order to clarify the phenomenon of brain waves, the activity in the brain is first explained.

Figure 5: Emotiv EPOC

Emotiv EPOC neuroheadset (n.d.)

Inside the brain are billions of nerve cells called neurons. The neurons continuously interact by sending messages among themselves, even during sleep. Sending these messages require neurons to utilise electrical impulses which in turn produce electrical current. The pattern made by the electrical current emitted from one neuron to another is called brain waves. The brain emits various types of waves concurrently; however, a certain brain wave can dominate in a specific state of an individual. For example, the brain can fire delta waves in deep sleep, theta waves in light sleep, beta waves in a state of excitement or stress and alpha waves when an individual is in a relaxed, conscious state. Even though certain brain waves are correlated to specific emotions and thoughts, slight differences in the wave patterns exist from person to person. It is due to this reason that the Emotiv EPOC requires that an individual should practice performing some actions before playing the game. These actions include lifting, dropping and pushing an object (McGrath, 2008).

Galvactivator

This is a device worn similarly to a glove in order to detect skin conductivity of the wearer (see figure 6). An LED display is attached to the glove for the purpose of illuminating in accordance with the wearer's skin conductivity values which are sensed by the glove.

Figure 6: Galvactivator

(Picard & Scheirer, 2001)

When the display glows, the light is made visible to everyone including the wearer. Increase in the skin conductivity causes the display to glow brighter and it fades when the conductivity decreases. When skin conductivity increases, it is a good indication that emotional arousal has ensued. Arousal signifies emotional activation and predicts the levels of attention and memory (Reeves & Nass, 1996). For example, highly arousing events are likely to be given more attention and remembered for a longer period of time than low-arousing events. The galvactivator is one of the devices designed in affective computing to assist individuals to communicate their emotional information (Picard, 1997).

StartleCam

A StartleCam is a system that consists of a wearable digital video camera, computer and sensing system (Healey & Picard, 1998). It is depicted in figure 7.

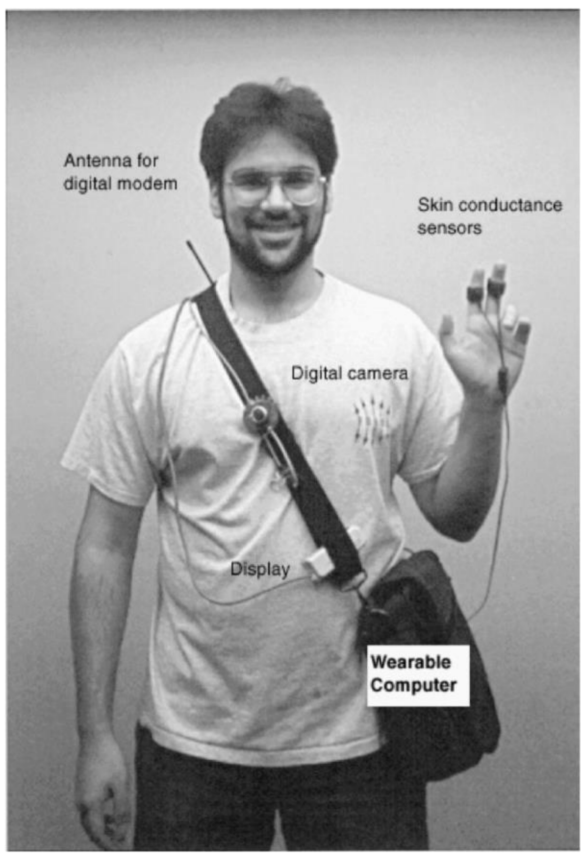


Figure 7: StartleCam

(Healey & Picard, 1998)

The StartleCam is controlled by the events that the wearer encounters whether they happen consciously or pre-consciously. As opposed to the traditional ways of recording, for example, where the user of the camera would consciously press record on the camera, the system provides an additional functionality. It saves pictures during events which it detects to be apparently of interest to the wearer (Healey & Picard, 1998).

The aim of the system is to capture events that were of interest to or drew the attention of the wearer. The system is able to detect such events of interest by measuring the skin conductivity of the wearer. The system records digital images in a buffer as the skin conductivity is measured. When patterns in the skin conductivity signal reflect a “startle response”, the recently captured images in the buffer are downloaded and may be transported to a webserver wirelessly (Healey & Picard, 1998).

eSense Skin Response

The eSense Skin Response is a product of Mindfield Biosystems. It is a small sensor that measures skin conductance using two electrodes and the microphone input of a tablet (Android or Apple iOS.) or smartphone (Mindfield Biosystems, 2013). eSense is shown in figure 8.

Figure 8: eSense Skin Response

(Mindfield Biosystems, 2013)

The electrodes in Velcro straps are attached to two adjacent fingers and the skin conductance is measured between them. An individual is able to measure his/her stress levels because skin conductance is directly depended on the individual's state of stress or relaxation. Feedback about the momentary stress levels is provided by means of measurement curves, video display and audio feedback features (Mindfield Biosystems, 2013).

<u>iCalm sensor</u>

iCalm is an interactive continuous autonomic logging and monitoring device which measures physiological changes of an individual. Infants, children and adults can wear it comfortably for days on end (Fletcher et al., 2010). Figure 9 illustrates various forms in which it can be worn.

Figure 9: Several form factors used for iCalm:

(upper left) baby sock with sewn electrodes, (upper right) wrist worn band, and (bottom) foot/ankle sensor band. (Fletcher et al., 2010)

According to Fletcher et al. (2010) iCalm comprises various sensors which enable measurement of EDA, heart rate variability (HRV), environmental temperature and motor activity. Customarily sensors for measuring EDA are placed on the palms or the fingers since sweat glands at these locations tend to be densely dispersed. However, with iCalm these sensors are located at the wrist or the ankle. This permits wearing of the sensor for a long time (up to weeks) with comfort. The drawback of the placement of these sensors however, is that the iCalm takes a long time (a minimum of 15 minutes) to react because of the slow moisture build up between the skin and the electrodes (Fletcher et al., 2010).

iCalm has been designed to be affordable, reliable and utilise low power. The need to purchase several batteries for each study has been avoided by using rechargeable batteries. Because the batteries are rechargeable, they have been totally embedded into the wearable fabric thus protected from unwanted weather conditions. The fabric is electrically conductive and it is washable. However, the electronics in a pouch should be removed before washing the fabric. The physiological data on iCalm can be received and displayed on a mobile phone directly. This has been made possible by developing a Bluetooth gateway device that bridges an IEEE 802.15.2 network and Bluetooth network. Furthermore, a website, iCalm.org, was implemented for sharing, storing and analysing collected data (Fletcher et al., 2010).

iCalm has the potential to be used in several health applications and medical interventions such as drug abuse, congestive heart failure, obesity, behavioral therapy and autism (Eydgahi, Williams, Fletcher, & Picard, 2010). For instance, patients with autism could be provided treatment according to their individual affective states (Fletcher et al., 2010).

Emotion Recognition Sensor System (EREC)

According to Kaiser and Oertel (2006), the EREC system was developed in Germany at the Fraunhofer Institute for Computer Graphics Rostock (IGD-R). The two main parts of the EREC system are the sensor unit and the base unit. The sensor unit, in the form of a glove, stores the skin resistance and skin temperature sensing elements. Moreover, the sensor unit collects data of the heart rate from a Polar heart rate chest belt. Additionally, it measures the environmental air temperature. Although the sensing elements are integrated in the glove, the sensor circuitry is placed in a small wrist pocket (Peter et al., 2007). The components of the EREC II (excluding the Polar heart rate chest belt) are shown in figure 10.

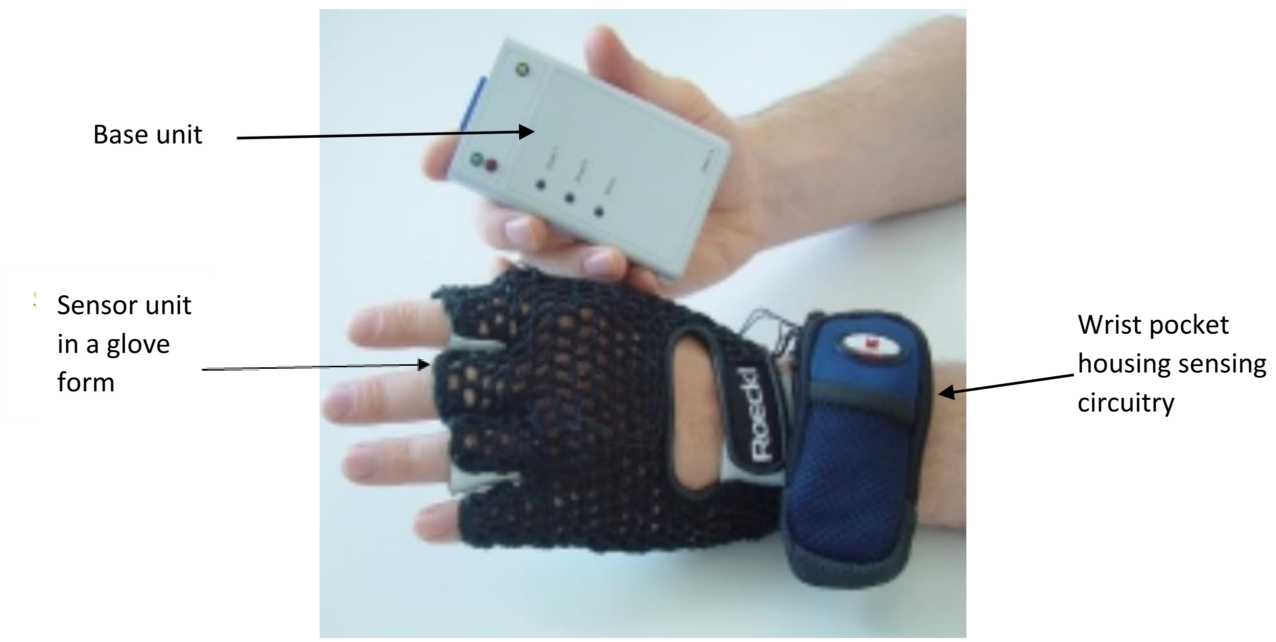


Figure 10: EREC II components

(Kaiser & Oertel, 2006)

The sensing elements and the circuitry are connected by a thin cable and a PS/2 shaped socket. The base unit's responsibilities are to receive the pre-validated sensor data, evaluate it, as well as store it on local memory, or send it to a processing host. The base unit is wirelessly connected to the sensor unit (Peter et al., 2007). The skin temperature is measured in degree Celsius with a resolution of 0.01 ˚C. The skin resistance uses the kilo ohms scale with a resolution of 300 kilo ohms. The heart rate's units are beats per minute with a resolution of 1 beat per minute.

The EREC system performs data validation. This is done in the sensor unit (housed in the glove) and in the base unit. The sensor unit detects measurement errors or sensor failures; in the event that an error occurs, appropriate measures are applied (Peter et al., 2005). For example, if data is not received from a sensing element, then a "best estimate" is sent. In this case a flag in the transmission protocol is set signifying that the data are only estimates. The data validation in the sensor unit is regarded as low-level, while the validation in the base unit is considered to be high-level (Peter et al., 2009).

The high level validation is founded on the Self Validation (SEVA) standard (Henry, 2001). According to Henry (2001), SEVA data consists of: validated measurement value (VMV), validated uncertainty (VU), measurement value status (MVS), device status (DS) and detailed diagnostics (DD). The base unit stores the SEVA data and it communicates it to processing applications together with the data (Peter et al., 2009). The EREC system has undergone evaluations concerning acquisition of emotion- related physiological parameters. Two sets of independent studies were conducted in Germany and Australia. The studies focused on four different application fields, namely medical, human performance in sports, driver assistance, and multimodal affect sensing. Results from the studies revealed that the hardware for sensing and processing the data is acceptable for use in different research domains. However, the requirements on the user interface are diverse for the different research domains (Peter et al., 2007). The results also proved that the EREC system is robust, reliable and easy to use (Peter et al., 2009).

As it was mentioned in section 2.2.2 that computer anxiety is an emotion, research studies involving emotions and physiological signals are explored in the following section. The discussion is vital because it provides an outline of research studies where emotions were investigated based on individuals' physiological signals.

2.5.5 Emotion recognition and physiological signals

The discussion will commence with the studies where various emotions were investigated using different instruments. At the end, literature will be provided about the studies where the EREC system was used since it is the instrument under investigation in this research study.

2.5.5.1 Physiological signals and emotions

Lisetti and Nasoz (2004) performed a research study where they elicited different emotions from participants while measuring their physiological signals (GSR, heart rate and skin temperature). The BodyMedia SenseWear Armband was the instrument used for measuring the physiological signals. The elicited emotions were sadness, anger, fear, surprise, frustration, and amusement. In their investigation to map physiological signals to different emotions, these researchers discovered that frustration was demonstrated largely by GSR differences rather than heart rate and temperature differences. The higher the frustration levels of the individuals, the more their GSR increased. Alternatively, fear and anger were found to relate more with heart rate. When participants experienced fear, their heart rate values increased, however, when they experienced anger their heart rate decreased.

In a study conducted by Vrana (1993), 50 participants used their imagination to elicit feelings of disgust, anger, pleasure and joy. As they were imagining these emotions, their heart rate, skin conductance and facial EMG were measured. They were also requested to report the emotions they experienced after the imagination trials. The results of the study showed that the heart rate accelerated more during disgust, anger and joy imagery than during pleasant imagery. Facial EMG became useful in that it discriminated disgust from anger imagery.

Anttonen and Surakka (2005) conducted a study to determine changes in the heart rate of participants when they are subjected to emotionally provocative stimulation. The participants were exposed to visual, auditory and audiovisual stimuli. The EMFi chair and the Tunturi earlobe photoplethysmography (PPG) were used for measuring heart rate and the results compared. A significant correlation (r=0.99) existed between the two heart rate measurements. The results from the study showed that emotional stimulation causes the heart rate to slow down. The heart rate decelerated greatly when participants were exposed to negative stimuli rather than positive or neutral stimuli (Anttonen & Surakka, 2005).

In a study where physiology was explored as a metric for evaluating usability, the relationships among three types of data were investigated. The three types of data were task performance, subjective assessment and physiological measures. The findings of the study revealed that physiological data, specifically GSR, correlated with task performance data. A decrease of the task performance resulted in an increase of the normalised GSR. Moreover, GSR was reflected in the subjective reports which assessed stress levels. The instrument used for gathering the subjective responses of the participants relating to stress was the Rating Scale Mental Effort (Zijlstra, 1993). The physiological data measured apart from GSR was blood volume pulse (BVP) and heart rate. Neither of the two physiological data correlated with task performance (Lin &Hu, 2005).

Although the method of determining emotions by analyzing facial expressions is seldom practiced, Essa and Pentland (1997) successfully developed a video-based system that could determine six static facial expressions, namely anger, disgust, happiness, surprise, eyebrow raise and neutral. Another system, called FaceReader, was found to correctly classify 89 percent of facial expressions according to their emotions. FaceReader was tested by Den Uyl and Van Kuilenburg (2005) using 980 images of facial expressions from a database. The emotions that were identified were happy, angry, sad, surprised, scared, disgusted and neutral.

Levenson, Ekman, and Friesen (1990) performed a study where participants were guided to generate facial configurations for anger, disgust, fear, happiness, sadness and surprise. The participants followed instructions given by a coach to perform these different facial structures. The participants were then asked to mention the feelings, memories or sensations that occurred during each of the facial patterns. As the participants executed the tasks, heart rate, skin conductance, finger temperature, and somatic activity were examined. The findings of the research regarding the negative and positive emotions were as follows: heart rate acceleration was greater for anger and fear than for happiness; skin conductance increased more for fear than for happiness, and skin conductance increase was higher for disgust than for happiness. Among the pairs of the negative emotions the findings were as follows: heart rate acceleration was greater for anger than for disgust; heart rate acceleration was greater for fear than for disgust; heart rate acceleration was greater for sadness than for disgust; finger temperature increased more with anger than with fear.

A number of studies were also performed where variation in pupillary size were investigated when participants emotionally responded to various stimuli. The pupil size diameter was measured using the eye-tracker. Partala and Surakka (2003) recruited 30 participants in a study where they investigated pupil size variation during and after exposing the participants to auditory emotional stimulation. The stimuli were the positive, negative and neutral sounds which the participants were asked to listen to. The participants were also required to describe their subjective experiences about the stimuli they were exposed to. Findings of the study revealed that both emotionally positive and negative stimuli caused a significantly larger pupil size than the neutral stimuli. The ratings of the subjective experiences mentioned by the participants verified that the stimuli affected their emotional experience. Furthermore, there were no pupil dilation differences between males and females when exposed to emotionally positive and negative stimuli.

Bradley et al. (2008) investigated the pupillary reaction when viewing emotionally arousing pictures. A total number of 96 pictures from three categories: pleasant, neutral and unpleasant, were used. The data from the research revealed that the pupil dilated more when viewing both pleasant and unpleasant pictures than when neutral pictures were viewed. This led to the finding that emotional arousal causes increase in pupil size. This discovery agrees with the findings of Partala and Surakka (2003). Moreover, it is in agreement with the poster abstract by Steinhauer, Boller, Zubin and Pearlman (1983), who stated that the pupil dilated when viewing both pleasant and unpleasant pictures. However, these findings by various researchers are contrary to earlier discoveries by

Hess and Bolt (1960). According to Hess and Bolt (1960), the pupil dilated when participants viewed pleasant pictures and constricted when viewing unpleasant pictures. In their study however, they used only five participants and they were required to view five pictures as opposed to 27 participants and 96 pictures in the study conducted by Bradley et al. (2008).

Having presented the studies where various emotions were investigated using different instruments, the discussion diverts to the research studies where EREC was utilised to determine physiological signals.

2.5.5.2 EREC and physiological signals

Tischler, Peter, Wimmer, and Voskamp (2007) conducted a pilot study in which emotion recognition technologies were employed in two test cars to determine the driving pleasure of the participants. One car was new compared to the other which was a 25 year old model. Both cars were fitted with the same technologies in order to compare the participants' behaviour in each of them. The technologies used were intended to capture data from speech, facial features and physiological signals. Interviews and questionnaires were also incorporated to determine the subjective responses of the participants. Regarding data from the EREC system, the findings provided proof that skin resistance and temperature were reliable data sources. However, the confidence in the heart rate data from the chest belt was low. The physiological data in this study was therefore omitted when considering the final results. The overall findings of the study showed that affect sensors can be used for measuring positive emotions in real-world settings and that analysis of all modalities should be performed to obtain meaningful results.

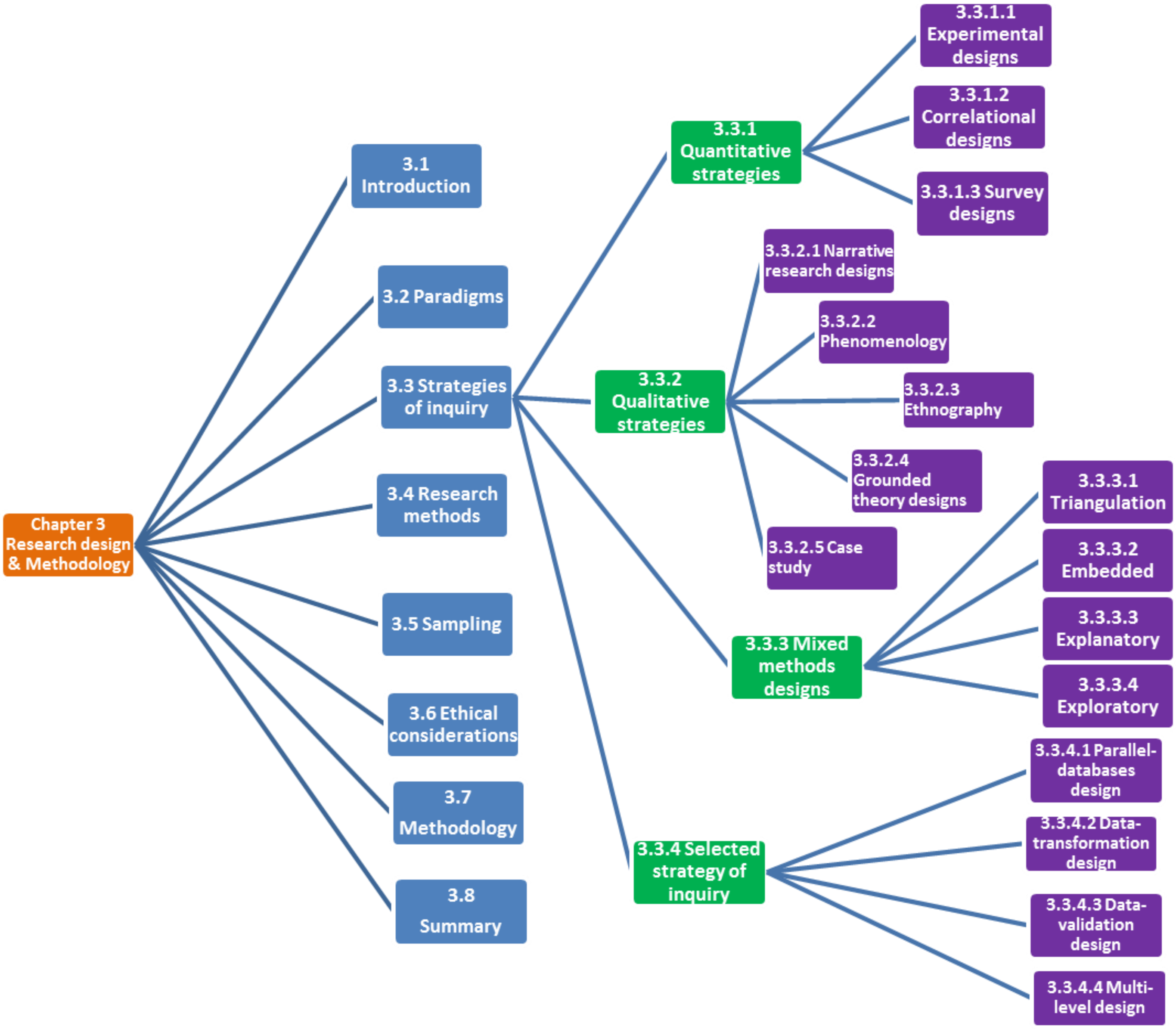
In another study, the EREC system was utilised to investigate emotional states of users in order to provide them with personalised services and products in accordance with their current emotional states. The model that was implemented was fed input consisting of physical activity and emotion-related bio-data of the user. The physical components of the model consisted of: a device for sensing emotional data (EREC system); a mobile phone to gather the emotional data; a server for storing data, a training module and an emotion recognition module (Hussain, Peter, & Bieber, 2005).

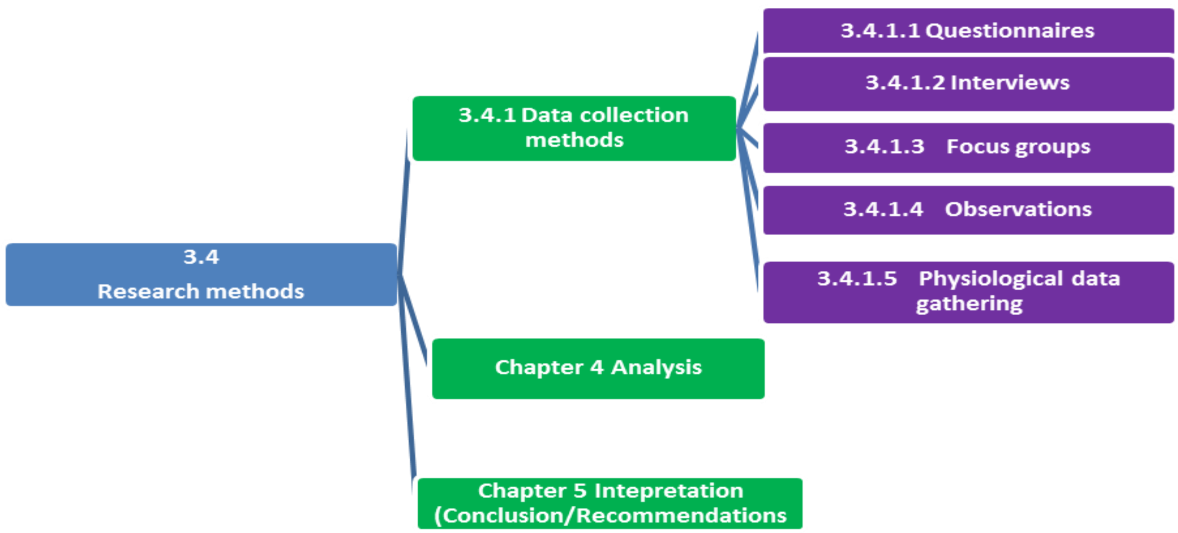
The version of EREC used in the study was ERECblue. This device sends out physiological readings (skin temperature, skin resistance and pulse) including hand movement data via Bluetooth to a receiving device (e.g. the mobile phone). The physical components interact with each other wirelessly through technologies such as Bluetooth. The model computes the probable emotional state of the user and then selects an appropriate personalised service. The chosen service in this study was in the form of a ring tone from the mobile phone; the tone depended on the current emotional state of the user. The model was evaluated by implementing a prototype and then testing it. The outcomes of the evaluation revealed that personalised products and services can be provided by determining emotional states of users and using mobile technology. The model also provides prospects of the development of emotionally intelligent systems (Hussain, Peter, & Bieber, 2005).

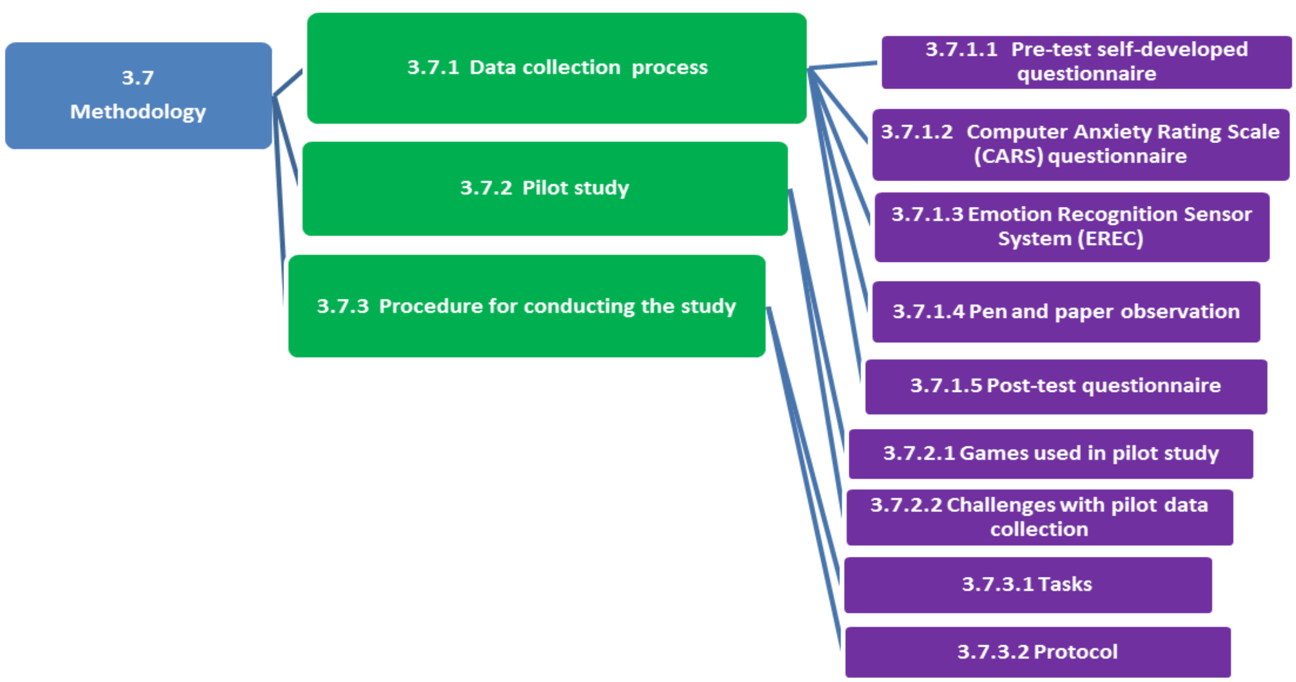
2.6 Summary

Computer anxiety was defined and its connection to emotions explained. Literature pertaining to the computer anxiety correlates was discussed. Possible measurements of computer anxiety were discussed such as computer anxiety questionnaires and measurements of physiological signals. Lastly, studies where physiological signals were measured to determine emotions were conferred including the study where the EREC sensor glove (which is the instrument under study) was utilised. The subsequent chapter discusses the research design and methodology which were adopted in order to execute the research study.

CHAPTER 3 MAP




3.4
Research methods
3.4.1 Data collection methods
3.4.1.1 Questionnaires
3.4.1.2 Interviews
3.4.1.3 Focus groups
3.4.1.4 Observations
3.4.1.5 Physiological data gathering
Chapter 4 Analysis
Chapter 5 Intepretation (Conclusion/Recommendations


3.7
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3.7.2 Pilot study
3.7.3 Procedure for conducting the study
3.7.1.1 Pre-test self-developed questionnaire
3.7.1.2 Computer Anxiety Rating Scale (CARS) questionnaire
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CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

In order to understand how the research will be executed, it is vital for the researcher to understand the problem to be solved so as to be able to choose the appropriate steps or methods to solve it. Terminology concerned in executing a research project will be explained and the actual procedure that was performed will be detailed in this chapter.

According to Creswell (2009), a research design is a plan for conducting research that entails an interconnection of philosophy, strategies of enquiry and specific methods. This means that when planning for research, these three components have to be taken into consideration in combination. The strategies of enquiry that are chosen should relate to the philosophical worldview (paradigms) assumptions decided upon. Furthermore, the specific methods selected should translate the approach into practice. A framework showing the interconnection of the three considerations is depicted in figure 11.

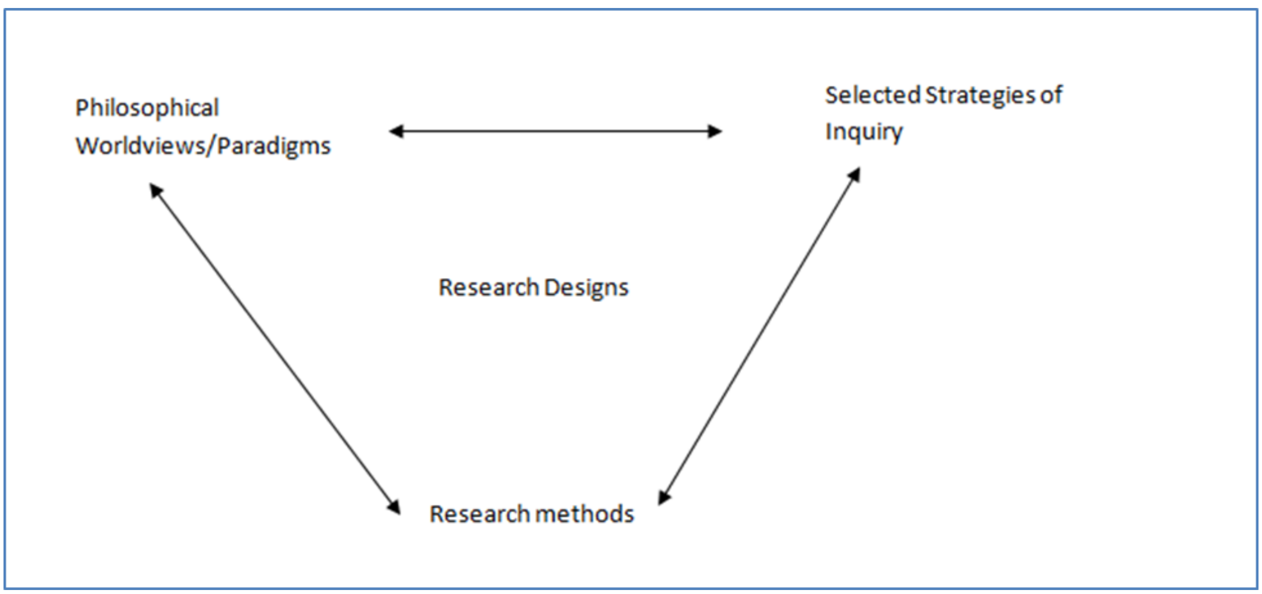


Figure 11: A framework for design – The interconnection of worldviews, strategies of inquiry, and research methods

Adapted from Creswell (2009)

3.2 Paradigms

A paradigm is the "basic belief system or world view that guides the investigation" (Guba & Lincoln, 1994, p. 105). According to Terre Blanche and Durrheim (2006, p. 6) paradigms are "all-encompassing systems of interrelated practice and thinking that define for researchers the nature of their inquiry along three dimensions: ontology, epistemology and methodology". Ontology refers to the nature of the reality to be studied. Epistemology stipulates the nature of the relationship between the researcher and that which is being researched. Methodology specifies the process that will be followed by the researcher to perform the study (Terre Blanche & Durrheim, 2006). The dimensions are also known as philosophical assumptions. Table 1 gives a summary of three common paradigms.

Table 1: Positivist, interpretive, and constructionist paradigms

Terre Blanche and Durrheim (2006)

Paradigms	Philosophical Assumptions		
	Ontology	Epistemology	Methodology
Positivist	• Stable external reality • Law-like	• Objective • Detached observer	• Experimental • Quantitative • Hypothesis testing
Interpretive	• Internal reality of subjective experience	• Empathetic • Observer subjectivity	• Interactional • Interpretation • Qualitative
Constructionist	• Socially constructed reality • Discourse • Power	• Suspicious • Political • Observer constructing versions	• Deconstruction • Textual analysis • Discourse analysis

The fourth paradigm, which was applied in this research study, has components of both positivism and constructivism paradigms. It is called by several names, namely neopostpositivism (Manicas & Secord, 1982), postpositivism (Denzin & Lincoln, 1994; Guba & Lincoln, 1994), critical realism (Hunt, 1991), or realism (Healy & Perry, 2000). In positivism there is one concrete reality while in interpretism there are numerous realities. However, with realism there exists numerous perceptions about one mind-independent reality (Healy & Perry, 2000). While positive research is value-free and interpretive research is value-laden (Creswell, 1994), realism is aware of the values of the researchers and the human systems, thus it is value-cognizant (Krauss, 2005). With realism, there is an awareness that reality and people's perceptions of reality differ (Bisman, 2002). It is therefore vital to develop numeric measures of observation and study individuals' behaviour in this paradigm (Creswell, 2009). In order to determine the source that drive actions and events, qualitative and quantitative methodologies are both acceptable in the realism framework (Healy & Perry, 2000). Statistical analyses, case studies and structured or semi-structured in-depth interviews are examples of methods that are acceptable in the realism paradigm (Bisman, 2002).

With realism discussed as the paradigm that was employed in the research study, it is also important to classify this research study according to the strategies of inquiry that were employed.

3.3 Strategies of inquiry

Strategies of inquiry are also known as approaches to inquiry (Creswell, 2007) or research methodologies (Mertens, 1998). They are defined as "types of qualitative, quantitative, and mixed methods designs or models that provide specific direction for procedures in a research design" (Creswell, 2009, p. 11). As can be seen from the definition, the strategies are divided into quantitative, qualitative and mixed methods categories. Table 2 depicts an overview of the strategies of inquiry.

Table 2: Strategies of inquiry

(Creswell 2008, 2009)

Quantitative	Qualitative	Mixed Methods
• Experimental designs • Correlational design • Survey design	• Narrative research • Phenomenology • Ethnographies • Grounded theory designs • Case study	• Triangulation design • Embedded design • Explanatory design • Exploratory design

3.3.1 Quantitative strategies

Quantitative strategies are performed in accordance with what quantitative research is. Quantitative research is a type of research whereby the researcher makes decisions about what to study, what specific narrow questions to address, collects numeric data from participants, and uses statistics to analyse the numeric data. The researcher performs the investigation in an objective and unbiased manner (Creswell, 2008; Crossman, 2014). The basic quantitative strategies are discussed in the following sections.

3.3.1.1 Experimental designs

In a true experimental design, the researcher is able “to fully control or manipulate the experimental conditions so that a direct comparison can be made between two or more conditions while other factors are, ideally, kept the same” (Lazar, Feng, & Hochheiser, 2010, p. 27). One feature concerning the full control aspect is the existence of complete randomisation; the researcher can randomly allocate participants to various conditions. Because of complete randomisation, experimental designs uncover causal relationships. A study that consists of multiple measures or groups of participants yet the participants are not randomly assigned to the various conditions, is said to be a quasi-experiment. A study in which one observation group or measure exists is called a non-experiment (Lazar et al., 2010).

3.3.1.2 Correlational designs

In correlational designs, the degree of association (or relation) between two or more variables is measured using a statistical procedure called correlational analysis. The degree of association, which is a number, points out whether the variables being compared are related or whether one predicts the other. In correlation designs, one group of individuals is studied as opposed to two or more groups which are studied in an experimental design (Creswell, 2008).

3.3.1.3 Survey designs

Survey designs are used when the researcher wants to establish trends, attitudes or opinions in a large group of individuals (population). Usually questionnaires or surveys are administered to a randomly selected sample of participants or even an entire population where possible (Fowler, 2009). Generalisation is the goal of the findings; therefore, random selection is an important factor (Edmonds & Kennedy, 2013).

3.3.2 Qualitative strategies

Qualitative strategies are based on the definition of qualitative research. Qualitative research is defined as a type of research in which the researcher depends on the opinions of the participants. The researcher "asks broad, general questions; collects data consisting largely of words (or text) from participants; describes and analyzes these words for themes; and conducts the inquiry in a subjective, biased manner" (Creswell, 2008, p. 46). Five qualitative strategies of inquiry are discussed in the subsequent sections.

3.3.2.1 Narrative research designs

Narrative research designs are procedures in which the researcher learns the lives of individuals and one or more individuals are requested to provide stories about their lives (Clandinin & Connelly, 2000). The researcher then tells and describes the stories of the individuals' lives by writing narratives about their experiences (Creswell, 2008). The final narratives written by the researcher encapsulate the views from the individuals together with those of the researcher's life (Clandinin & Connelly, 2000).

3.3.2.2 Phenomenology

Phenomenological research is a strategy of inquiry whereby the researcher is concerned with understanding social and psychological phenomena from the perspectives of the participants (Welman & Kruger 1999). The researcher is interested in the lived experiences of the participants - what they thought, perceived, and even remembered (Maypole & Davies, 2001). To enable the researcher to develop patterns and relationships of meaning, it is necessary to study a small number of individuals through extensive and prolonged engagement (Moustakas, 1994). The researcher's own experiences about the phenomenon are not considered because the aim is to understand the experiences of the participants in the study (Nieswiadomy, 1993).

3.3.2.3 Ethnography

Ethnography is a strategy of inquiry in which an intact cultural group of individuals is examined in a natural setting, for example, in the environments they live and work in, so as to develop a portrait of how they interact. In ethnography, the researcher aims to describe, analyse and interpret a cultural group's shared patterns of behaviour, beliefs, and language which developed over time. The data in ethnographic designs is collected from various sources (Creswell, 2008), however, the primary sources are observations and interviews which are conducted over a prolonged period of time (Creswell, 2007).

3.3.2.4 Grounded theory designs

Grounded theory designs are procedures performed systematically to derive a general explanation, or grounded theory, which explains an action, process or interaction among people. This theory is grounded in the data gathered from the participants. The primary data source is from interviews (Creswell, 2008). Two main features that define a grounded theory design are that data is constantly compared with emerging categories, and that theoretical sampling of various groups is performed with the intention of maximising the differences and similarities of information (Creswell, 2009).

3.3.2.5 Case study

A case study is an approach to research that enables a phenomenon to be explored within its context using a number of data collection procedures. The aim is to reveal and understand multiple facets of a phenomenon (Baxter & Jack, 2008) by performing an in-depth exploration of a program, event, process, activity or individuals. The major characteristic of a case study approach as viewed by Denscombe (2003, p. 30) is “its focus on just one instance of the thing that is to be investigated”. Even though some researchers use two or more instances, the principle in case study research is to focus on individual instances and not a wide spectrum. This approach enables the researcher to gain more insights by looking into an individual case which may have wider implications (Denscombe, 2003).

3.3.3 Mixed methods designs

A mixed methods research design is a procedure whereby both quantitative and qualitative research methods for collecting and analysing data are mixed in a single research study in order to understand a research problem (Creswell & Plano Clark, 2007). There are a number of reasons for using mixed methods design in a research study. Firstly, it is primarily employed when the quantitative and qualitative data together provide a better understanding of the research problem than when either type is used on its own. In this case, the researcher is able to build on the strengths of the quantitative and qualitative data. Secondly, it is used when one type of research, for example quantitative, is insufficient to answer the research problem or research questions. In such a case more data, for example qualitative data, would be collected as a follow-up on the quantitative data in order to acquire more elaborate and specific information that could not be obtained from the statistical test results obtained from the quantitative study. Lastly, a mixed methods design can be used when a researcher desires to include a qualitative component into a study that is basically quantitative. For example, a researcher conducting an experimental study could discover useful findings from the quantitative data about an intervention. However, when qualitative data is collected additionally, more understanding of how the intervention worked could be acquired (Creswell, 2008).

Mixed methods designs have different types that are categorised according to the following: priority or weight given to the collection of quantitative and qualitative data; the sequence followed when the data collection is performed regarding the quantitative and qualitative data; the manner in which the data is analysed (whether the researcher analyses the data separately or in one analysis), and the stage in the research study when the data was mixed (Creswell, 2008). The main types of mixed methods designs are depicted in figure 12.

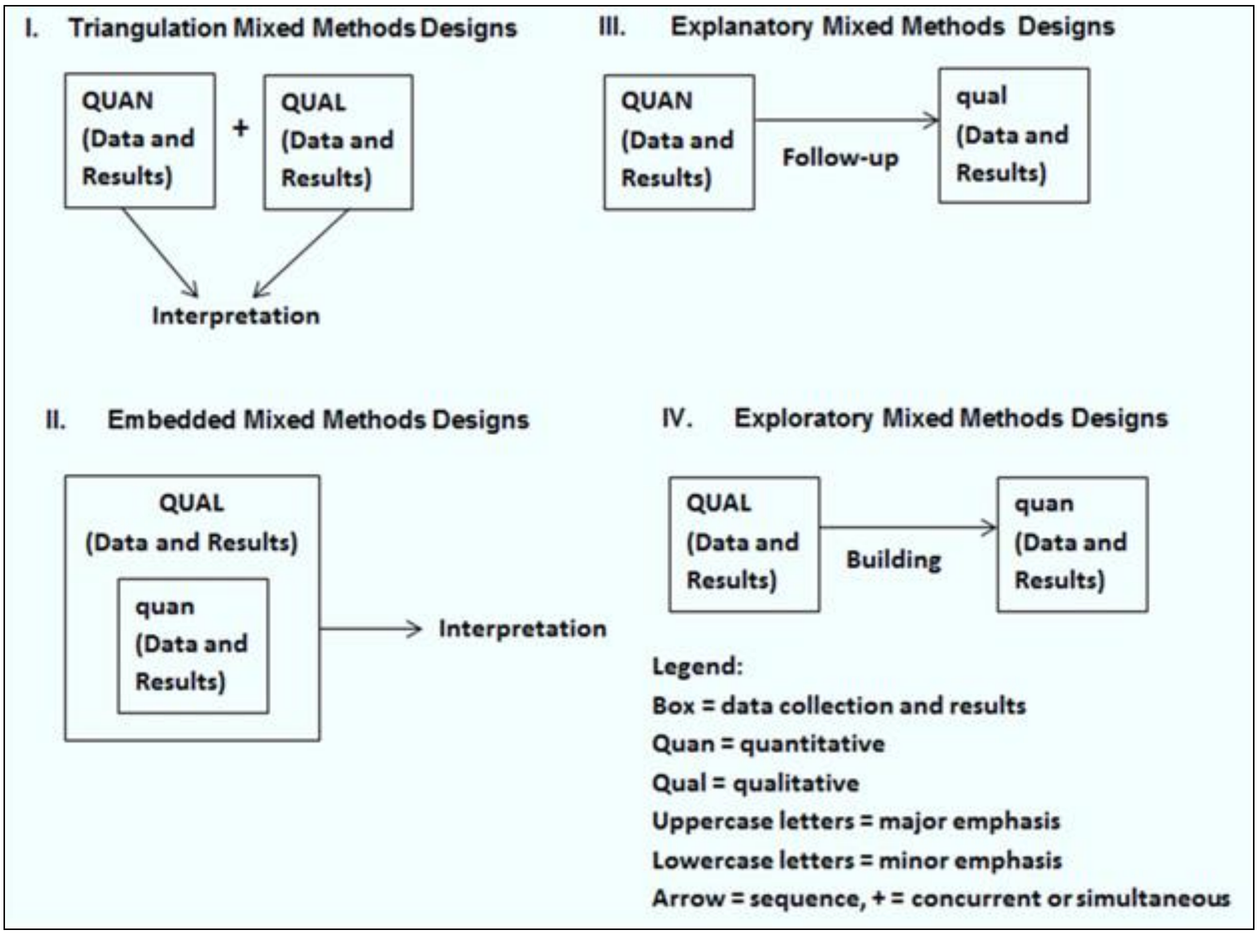


Figure 12: Types of Mixed Methods Designs

(Creswell & Plano Clark, 2007)

3.3.3.1 The triangulation mixed methods design

The triangulation mixed methods design is known by various names such as simultaneous triangulation (Morse, 1991), concurrent triangulation design (Creswell, 2009) and convergent-parallel approach (Edmonds & Kennedy, 2013). In triangulation mixed methods design, the researcher gathers data using both quantitative and qualitative methods concurrently (Creswell, 2008). The quantitative and qualitative methods are conducted during one phase of the research study (Plano Clark & Creswell, 2008) and the results from the two methods are combined, usually in the interpretation phase. The reason for using the different types of data collection is to offset the weaknesses of one form of data collection with the strengths of the other form. Although in ideal situations the quantitative and qualitative approaches are given equivalent priority (as shown in figure 12), practically either approach may be given the priority (Creswell, 2009).

The procedure followed by a researcher using triangulation mixed methods design involves collecting quantitative and qualitative data concurrently into databases, analysing both databases separately, comparing the analysis results from the databases and performing interpretation with the intention of determining whether the results are in support or contradiction of each other. When the two data sets are directly compared, the process is termed *triangulation* (Creswell, 2008).

Several advantages for using the triangulation mixed methods design exist. These include the fact that it combines the strengths of both qualitative and quantitative data collection. Firstly, while qualitative data provides information about context or setting, information from quantitative data allows for generalisability (Creswell, 2008). Secondly, Plano Clark and Creswell (2008) state that this design is familiar to most researchers therefore it can result in substantiated and well-validated findings. Thirdly, since the data collection is performed concurrently, time spent collecting data is shorter than in other designs which are performed sequentially (Creswell, 2009), such as explanatory and exploratory designs (see arrows in figure 12).

The triangulation design also has disadvantages. It necessitates great effort and expertise from the researcher to perform the research effectively because of the different data collection forms used. Moreover, because the results of the analyses are of different forms, it can be problematic to compare them (Creswell, 2009). Additionally, in some variations of this design where the integration is done in the analysis phase, there is some difficulty when transforming one form of data into the other for integration and comparison purposes (Plano Clark & Creswell, 2008). Lastly, when the integration has been performed, discrepancies in the results can still occur, requiring the researcher to collect more data or revisit the databases to reconcile the differences (Creswell, 2008).

3.3.3.2 The embedded mixed methods design

In the embedded mixed methods design, the researcher gathers quantitative and qualitative data simultaneously, similar to the triangulation design. However, the purpose is to have one form of data (secondary) support the other form of data, which is primary. The secondary form of data also provides supplementary information not provided by the primary source of data. It follows then that the embedded mixed method researcher treats the primary form of data collection with priority rather than the secondary form (Creswell, 2008). The procedure followed by the researcher includes gathering and analysis of both quantitative and qualitative data within a customary quantitative or qualitative research design (Greene, 2007). The data sets are collected with the purpose of answering different research questions and the data sets are analysed separately. Although the two forms of data are usually collected simultaneously in the embedded design, there are instances when the secondary data is gathered either before, during or after the study is completed (Creswell, 2008; Creswell & Plano Clark, 2011).

The advantage of this design is that it provides the benefits of both quantitative and qualitative data in a single study. Additionally, it can allow the researcher to gather qualitative data despite the overall design being predominantly a quantitative approach. This addition of the qualitative data aids in legitimising the use of such forms of data in some fields that are new to qualitative research (Creswell, 2008). The drawback of this design is that it can be challenging to combine the results since the data is meant to answer different research questions (Creswell, 2008; Creswell & Plano Clark, 2011). Moreover, adding the qualitative data collection during a correlational or experimental study can interfere with the outcomes. It is therefore necessary to introduce measures which will reduce this, for example, gathering the qualitative data after the experiment. Another disadvantage, which is also applicable to the triangulation design, is that gathering quantitative and qualitative data concurrently may be hard work for a single researcher (Creswell, 2008).

3.3.3.3 The explanatory mixed methods design

The explanatory mixed methods design is also called the sequential explanatory strategy. In this design, the researcher collects and analyses quantitative data in the first phase. This phase is then followed by another phase, which is gathering and analysing qualitative data (Creswell, 2009). The second phase is meant to elaborate on the results of the initial quantitative data. Quantitative data collection and analysis is given more priority (Creswell, 2008) and the data is mixed when the "initial quantitative results informs the secondary qualitative data collection" (Creswell, 2009, p. 211).

One advantage of the explanatory design is that it can be used to provide more insight in a situation where unexpected quantitative results occur. A follow-up qualitative data collection in such cases would enable the researcher to perform in-depth exploration of these unexpected results. Another advantage of using the explanatory design is that by nature it is simple. The steps to follow are in separate stages, therefore this design is easy to implement. The nature also simplifies the process of describing and reporting. The drawback of this design is the long duration to collect data with the two separate phases (Creswell, 2009; Creswell & Plano Clark, 2011). Another disadvantage is that it may be challenging for the researcher to choose the aspect of the quantitative results to use for the follow-up quantitative data collection. Lastly, collecting both quantitative and qualitative data can be labour intensive for one researcher (Creswell, 2008).

3.3.3.4 The exploratory mixed methods design

The exploratory mixed methods design is similar to the explanatory design with the exception that the researcher begins with collecting and analysing qualitative data in the first phase and then gathers and analyses quantitative data in the second phase (Creswell, 2008). The purpose of the exploratory design is to initially explore a phenomenon by collecting the qualitative data and then use the quantitative data and results to interpret the qualitative findings (Creswell, 2009). The researcher puts more emphasis on the qualitative data than on the quantitative data (Creswell, 2008). The mixing of data occurs by connecting the qualitative data analysis and the quantitative data collection (Creswell, 2009).

Similar to the explanatory design, the exploratory design has the advantage of being straightforward to describe and report. It is also easy to implement. Secondly, the exploratory design is appropriate for a researcher who wants to build a new instrument as it allows for exploration of a new phenomenon as well as expansion of the qualitative findings (Creswell, 2009). The drawback of the exploratory design is the extensive length of time required to complete the two phases of data collection. Additionally, it can be problematic for a researcher to select the most appropriate themes to be measured in the follow-up quantitative phase of the study (Creswell, 2008).

3.3.4 Selected strategy of inquiry for the research

After an intensive study of the strategies of inquiry presented above, the strategy which was found to be applicable in this research study was the triangulation mixed methods design with more priority given to the quantitative data.

This design was considered to be appropriate for this study because of two reasons. Firstly, the researcher found it necessary to collect both quantitative and qualitative data in order to achieve the purpose of the study and understand the research problems (stated in section 1.2 and 1.3). The qualitative data from observations and open-ended questions from self- developed questionnaires provided more clarity on the results of the two instruments (CARS and EREC) whose data was mainly quantitative. Secondly, the data collection of both quantitative and qualitative data had to be performed concurrently, in one visit to the usability lab. This was due to the fact that the targeted individuals could be invited only once to participate because of their busy schedules. The majority of these participants were unemployed hence they spent their days seeking job opportunities, which they regarded as more important than participating in a research study.

Triangulation mixed methods design, which is referred to as a convergent-parallel approach by Edmonds and Kennedy (2013), has four categories, namely parallel-databases, data-transformation, data-validation and multi-level designs. The four categories are further discussed in the following sections.

3.3.4.1 Parallel-databases design

The structure of parallel-databases (see figure13) allows quantitative and qualitative data to be collected and analysed simultaneously, but separately. The two data types are then combined by means of comparing and contrasting the data to form an overall interpretive framework. In this design the researcher is able to validate data by merging the quantitative with the qualitative findings (Edmonds & Kennedy, 2013).

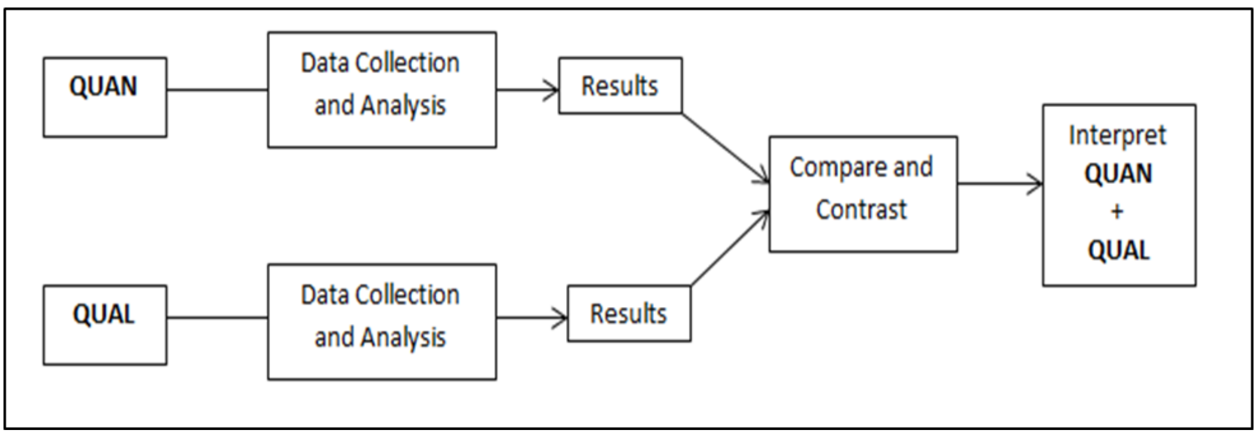


Figure 13: Parallel-Databases Design

(Edmonds & Kennedy, 2013)

3.3.4.2 Data-transformation design

The data-transformation design (see figure 14) is structured such that the researcher is able to gather quantitative and qualitative data concurrently, but independently. The two data types are analysed separately after which data transformation is performed. Any of the data types can be transformed; consequently quantitative data could be transformed into qualitative data or vice versa. However, only one data type is permitted to be transformed into another data type. This is followed by merging of the data and subsequent analyses (Edmonds & Kennedy, 2013).

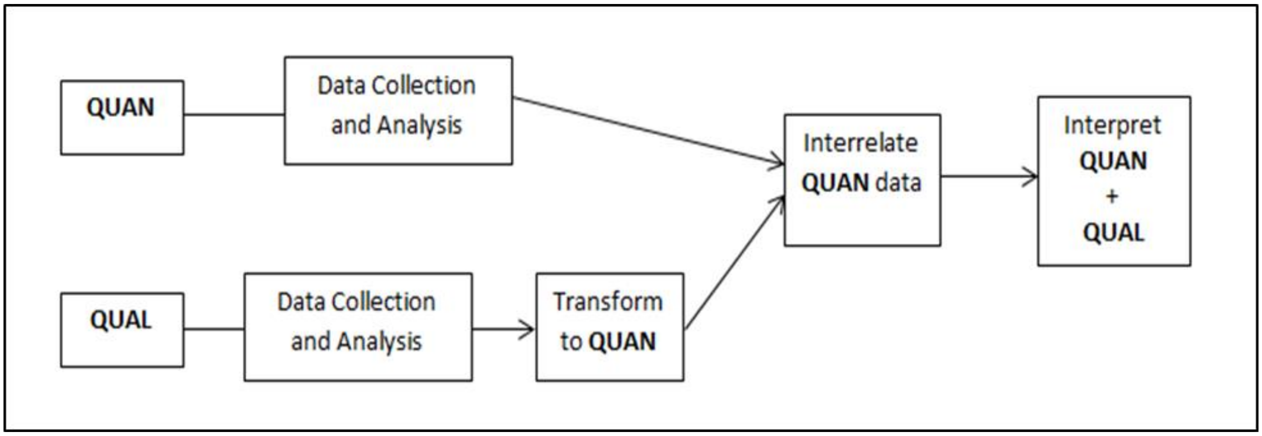


Figure 14: Data-Transformation Design

(Edmonds & Kennedy, 2013)

3.3.4.3 Data-validation design

Unlike the previous two designs where quantitative and qualitative data are collected separately, the data-validation design (see figure 15) allows for quantitative and qualitative data to be gathered together within the same measure. The objective with the data-validation design is to validate the quantitative data using the qualitative findings. The quantitative data is therefore more emphasised than the qualitative data in this design. Consequently, the qualitative findings do not undergo demanding data reduction and analysis (Edmonds & Kennedy, 2013).

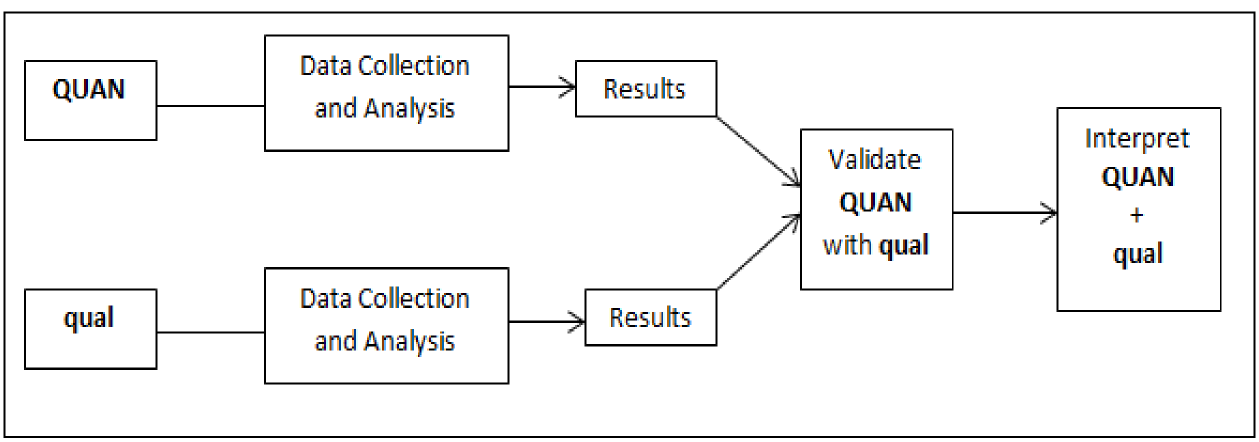


Figure 15: Data-Validation Design

(Edmonds & Kennedy, 2013)

3.3.4.4 Multi-level design

With regard to the multi-level design (see figure 16), the researcher is able to employ various methodological techniques (quantitative and qualitative) to address different levels within the system. An overall interpretation is established by merging the quantitative results and the qualitative findings from each level (Edmonds & Kennedy, 2013).

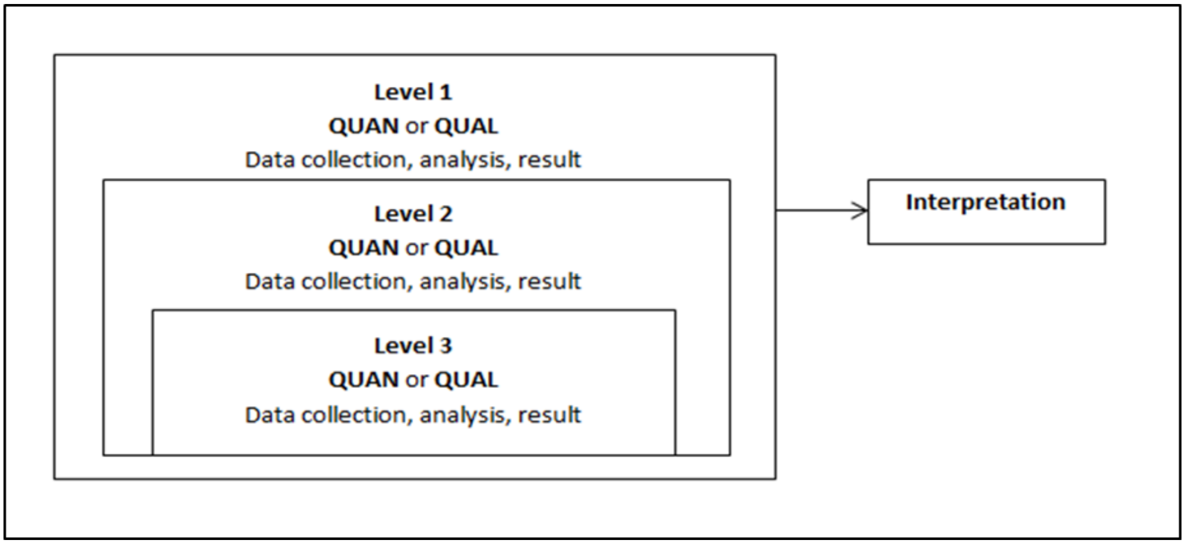


Figure 16: Multi-level Design

(Edmonds & Kennedy, 2013)

Among the four variants of convergent-parallel approach, the parallel-databases design was utilised as it was found to be the most applicable in order to answer the research questions in this research study. The nature of the research questions, especially the first question, required quantitative and qualitative data to be collected simultaneously. The quantitative data involved the sensor glove (skin conductance readings) and the CARS scores while the qualitative data was obtained from observations. The two strands of data had to be analysed separately and merged in the conclusion part of the study.

At this juncture an overview of the strategies of inquiry is provided. Strategies of inquiry were classified as quantitative, qualitative and mixed methods as stipulated in table 2. Mixed methods strategy was the one chosen for the research study. This strategy is categorised into four types, namely triangulation mixed methods, embedded mixed methods, explanatory mixed methods and exploratory mixed methods. Among the four types, triangulation mixed methods was selected for this research study. Triangulation mixed methods was further classified into parallel-databases, data-transformation, data-validation and multi-level designs. Among these four, parallel-databases design was chosen for the research study.

Having looked at the strategies of enquiry, various research methods including the ones applicable to this research study will be discussed in the subsequent section.

3.4 Research methods

Research methods are discussed as the third component to be considered in a research design, according to Creswell (2009). These methods include the forms of data collection, analysis and interpretation. In this section, various data collection methods are discussed while analysis and interpretation will be discussed in the following two chapters.

3.4.1 Data collection methods

Various types of data collection exist. However, this section will introduce the data collection methods which are generally employed.

3.4.1.1 Questionnaires

These are used for gathering demographic data and participants' opinions. Questionnaires may have open-ended questions, closed-ended questions or a combination of the two (Preece et al., 2007). Open-ended questions are essential to determine issues that the researcher has not discovered or to acquire suggestions about problems that the researcher might not expect. They are also used when an unlimited number of possible answers to a question exist. Although open-ended questions are necessary in a number of situations, their use should be limited because they can cause the respondent to be exhausted (Badre, 2002) and they are challenging to analyse (Lazar et al., 2010).

A questionnaire with well formulated and easy to answer questions is an efficient way of gathering data. Questions that can be easily answered include those that require the participant to tick answers from a list of options that reflect one's opinion (Hannan, 2007). These types of questions, where answers are already provided, are called closed-ended questions. Closed-ended questions that have a limited number of answers enable evaluation to be done with ease. However, care must be taken to ensure that the list of answers exhausts all the possible answers to the question and that the answers do not overlap.

Closed-ended questions can be presented in various formats, including ranking scales, checklists rating scales and multiple-choice questions. With regard to a ranking scale, some criteria are provided by which the respondent is required to order a list of items. The sorting may be done by physically ordering the items or by allocating numbers. Checklists provide less information than ranking scales. However, they offer more information than multiple-choice questions. A rating scale is useful for establishing the direction and extent of the respondent's opinion. Examples of rating scales are the Lickert scale and the Thurstone scale (Badre, 2002).

3.4.1.2 Interviews

An interview is a planned conversation between people where one person (researcher/interviewer) is interested in obtaining information from another person or persons (Oates, 2006). Interviews can be structured, unstructured or semi-structured (Saunders, Lewis, & Thornhill, 2007). In structured interviews, the questions asked by the interviewer are the same as in questionnaires – they require the interviewee to choose an answer from a predetermined set of choices. The questions are therefore said to be closed. On the contrary, questions in unstructured interviews are open; there is no specific format of answering the questions. Semi-structured interviews merge aspects of both structured and unstructured interviews as both open and closed sets of questions are asked (Preece et al., 2007). Johnson and Christensen (2012) classify interviews into 2 categories, namely quantitative and qualitative interviews. The outcome of quantitative interviews is ordinarily quantitative data which is then analysed by means of quantitative statistical procedures. This is because the quantitative interviews normally have a small number of open-ended questions with the majority of the questions being closed-ended (Johnson & Christensen, 2012).

To conduct the quantitative interviews, an interview protocol is used for collecting data. It incorporates the items, the response types and the instructions. The interviewer is required to read the words in the interview protocol exactly in the same way and in the same order to each interviewee. The interviewer records the responses provided by the interviewee on the interview protocol which is frequently in paper-format for in-person interviews. In the case of telephone interviews, the interview protocol is displayed on a computer screen. The reason for ensuring that the interview protocol is read the same way to all the interviewees is to standardise the stimulus exposed to each interviewee to ensure that the results will be comparable (Johnson & Christensen, 2012). Since quantitative interviews are standardised, they are said to be structured (Saunders et al., 2007).

Unstructured interviews are intended to discover in-depth information about a general idea that a researcher is interested in. Although the researcher is required to know the aspects to explore, in unstructured interviews no list of questions is prepared (Saunders et al., 2007). The interviewer follows the leads that arise when discussing the topics of interest with the interviewee. It is therefore imperative that the interviewer carefully listens to the interviewee so as to make a repository of the information and be able to prompt the interviewee with more questions wherever clarification or in-depth information is required (Johnson & Christensen, 2012).

Semi-structured and unstructured (in-depth) interviews are classified as qualitative interviews (King, 2004). Because of their unstandardised nature, it is advisable that audio-recording or note-taking be utilised to collect the interview data. In semi-structured interviews the researcher's intention is to cover the themes and questions already prepared. Nonetheless, these, together with the order of asking questions, may change from interview to interview. For example, additional questions may be introduced if there is a need to explore the research question and objectives in relation to the nature of events at particular organisations (Saunders et al., 2007).

3.4.1.3 Focus groups

A focus group is an interview conducted by a moderator or researcher with a small group of individuals to discuss, in-depth, the feelings and opinions of the individuals about a certain topic. The moderator facilitates the discussion, ensuring that the group members focus on the specific topic being researched. The group discussion is conducted by using open-ended questions which result in the gathering of qualitative data. The data consists of the words which are spoken by the participants in the group (Johnson & Christensen, 2012). There are various opinions about the optimal size for focus groups. Robson (2002) suggests 8 to 12 participants, while Johnson and Christensen (2012) suggest 6 to 12 participants. Regardless of these different views, a focus group generally consists of a small number of participants (Lazar et al., 2010). The participants consist of similar types of people whom are deliberately selected in this manner to enable discussions of the type of information which is of interest to the researcher (Johnson & Christensen, 2012).

Although interviews are powerful data collection techniques, focus groups are less labour-intensive. For example, instead of conducting interviews with 20 participants for an hour each, focus groups can be conducted where the participants are divided into groups and interviewed over a few hours. Because of the conversations that can arise in a focus group, many disadvantages found in interviews can be mitigated. In an interview where the interviewee is not talkative, the interview may fail. However, in a focus group interactivity is supported because the discussions are performed in a group; therefore the participants balance each other. Moreover, the participants can stimulate one another to voice their opinions in support of or opposition to certain views mentioned by other participants. Certain issues which could not have been raised in one-to-one interviews can arise in focus groups (Lazar et al., 2010).

3.4.1.4 Observations

The term observation in research refers to the process of collecting open-ended data by directly visualising the participants' experience as they perform the allocated research tasks at a research site. Observations are advantageous in that the researcher is able to collect firsthand information by directly observing the actual behaviour of the individuals. This is especially helpful in situations where participants are not able to express themselves verbally (Creswell, 2008). Observations can be classified into systematic and participant observations (Oates, 2006).

In systematic observations, the researcher decides beforehand what will be observed, and prepares a pre-designed schedule for recording the frequencies or durations of those observations. The researcher may find an existing schedule from literature which is applicable for his/her study. However, if the researcher designs the schedule from the beginning, it is advisable that he/she studies, in advance, the situation of interest in order to establish the types of events and activities which may occur and those that should be focused on (Oates, 2006). The data collected in systematic observations is usually quantitative as it commonly constitutes numbers such as time-on-task and task success. Time-on-task is the time which has elapsed between the start of a task and the end of a task. Task success is the accomplishment of the task by the participant regardless of the extent in which it was accomplished (Tullis & Albert, 2008).

An advantage of using systematic observations is that the researcher does not have to be present at all times to do the recording of the observations. The researcher can issue the schedule to assistants and train them on the different types of events to be recorded, as well as how to record them. The researcher may run a pilot test where the assistants are given a chance to practice the recording of the observations to ensure inter-observer reliability (Oates, 2006).

With regard to participant observation, the researcher can observe the participants and take notes while also participating in the activities under observation. This gives the researcher the opportunity to have the same experience as the participants in that setting. The observation can be termed overt or covert. Concerning the overt observation, the participants are made aware that a specific person is conducting a research study in relation to what they do. However, in covert observation the participants are not made aware of the researcher. Four types of roles exist which the researcher can assume with regard to participation, namely complete observer, complete participant, participant-observer and practitioner-researcher (Oats, 2006).

In the complete observer role, the researcher observes the participants without being involved in the activities at the research site (Oats, 2006). Researchers normally adopt this role when they are not familiar enough with the individuals and the site where the research is taking place (Creswell, 2008). The advantage of the complete observer role is that the researcher is able to completely focus on the tasks and the participants at the research site. However, the drawback of this role is that the researcher is deprived of the emotional experience undergone by the participants who actually perform the tasks at the research site (Saunders et al., 2007).

The researcher assuming the role of the complete participant attempts to be part of the group being investigated so as to undergo the same experiences that the group experiences. The researcher is necessitated to have the essential credentials as a true participant in order to fit in with the group being investigated. These credentials can be the appropriate age, gender or even qualifications. Even though the role of complete participant gives the researcher the advantage of experiencing emotionally what the participants go through as they perform activities at the research site, the downside to this approach is that it may be problematic for the researcher to note the observations while also participating at the research site. The researcher might have a chance to note the observations after leaving the research site (Creswell, 2008). If this happens, then the researcher might forget some of the observations made.

Unlike the complete participant where necessary credentials are required, the participant-observer does not require the credentials to perform the observations. The researcher who is a participant-observer follows and observes the participants as they perform their duties or daily activities, nonetheless, the researcher takes part only in the tasks which are appropriate for him/her. The researcher may have an opportunity to learn about how the activities are done and the experiences of the participants if the participants can trust the researcher and even forget about his/her presence at the research site (Oats, 2006).

The practitioner-researcher is different from the other three roles in that the researcher investigates his/her own work organisation and at the same time performs his/her duties at the same workplace. The benefit of this role is that the researcher does not spend a lot of time with familiarisation of the work environment. Furthermore, since the researcher already works at the research site, negotiating access into the work environment is unnecessary. Nevertheless, the researcher is still expected to ask for permission to do the research from his/her managers and colleagues because the researcher can risk losing the job if the managers and colleagues discover by accident that the research is being performed without their consent. The drawback of this role is that it is time-consuming because the researcher has to allocate time to perform both the research and the duties at work (Oats, 2006).

According to Creswell (2008), the researcher is not restricted to choosing one role from the beginning to the end of the data collection. The role can be changed depending on the role the researcher deems appropriate at that time to provide the necessary data.

Two environments where observational data can be collected are in the laboratory and in the real world where the behaviour happens naturally. When the observation occurs in the laboratory, it is termed laboratory observation, where-as in the real world, it is called naturalistic observation. With the laboratory observation, the researcher creates a controlled environment which is suitable for the tests. Conversely, with the naturalistic observation the researcher actually visits the place where the behaviour takes place naturally (Johnson & Christensen, 2012).

3.4.1.5 Physiological data gathering

This method of collecting data is applicable where the researcher wants to record participants' behaviours which cannot be easily detected – they require certain equipment to be captured. Examples of physiological data are skin resistance, heart rate and skin temperature. Various instruments for measuring physiological data exist. Physiological data and the instruments which measure them were discussed in section 2.5.3 and 2.5.4 respectively.

In this research study, the data collection methods which were deemed applicable and thus employed were questionnaires, interviews, observations and physiological data gathering. Specifically, the employed questionnaires were the pre-test and post-test questionnaires, as well as the CARS questionnaire. The pre-test questionnaire provided demographic information of participants while the emotional experiences of the participants were presented in the post-test questionnaire. CARS is a questionnaire that was used to measure the anxiety of the participants before and after working on a computer. The interviews with each participant were employed where the researcher wanted clarification on the participant's responses written in the post-test questionnaire. Observations were employed to observe the behaviours of each participant while performing tasks on the computer. Physiological data, specifically skin resistance, was measured to investigate whether the participant experienced anxiety in the process of doing the tasks or not.

3.5 Sampling

Sampling is another consideration that has to be addressed when planning a research study. Sampling addresses issues such as the selection of participants for the research study as well as the sites where the data collection will be performed. Sampling techniques are grouped into probability sampling and non-probability sampling. Probability sampling entails random selection while non-probability sampling does not (Trochim, 2006).

A sample obtained from random selection has the same probability of being selected from the population as any other sample of equal size from the same population (Dowdy & Weardon, 1983). The selected individuals from the population are said to be representative of the population they have been selected from. It is consequently the case that findings made using this sampling strategy can be generalised to the population which the sample represents (Creswell, 2008). Common types of probability sampling are simple random sampling, systematic sampling, stratified sampling and cluster sampling (Oates, 2006). Types of non-probability sampling are quota sampling, purposive sampling, snowball sampling, self-selection sampling and convenience sampling (Saunders et al., 2007).

Convenience and purposive sampling techniques were employed in the different stages of this study. Convenience sampling was employed in the pilot study. According to Castillo (2009), convenience sampling is utilised in situations where the researcher is interested in recruiting participants who are readily available despite the fact that they may be unrepresentative of the entire population. The participants who were recruited for the pilot study were students who had passed and completed a computer literacy course offered by the Department of Computer Science and Informatics at the University of the Free State, where the research study was conducted. It was therefore easy to recruit these participants because they were readily available. Furthermore, since the participants were intermediate computer users, it was assumed that the signs of anxiety that they exhibited were caused by the games they performed on the computer and not by a ‘fear of using computers’. This was imperative as it enabled the researcher to check whether the research instruments were functioning properly.

The sampling technique that was employed in the actual study was purposive sampling. According to Saunders et al. (2007), purposive sampling enables the researcher to choose cases that will best answer the research questions and address the research objectives. In this sampling technique, the researcher purposely selects individuals who are regarded as the most representative (Barbie, 2007) and the sites which are particularly informative in order to provide understanding about the phenomenon under study (Creswell, 2008). With reference to the mentioned reasons, the purposive sampling technique was found to be appropriate for this research.

The population which was considered to be most appropriate for this study comprised of individuals who were computer illiterate and therefore expected to exhibit computer anxiety. Accordingly the sample selected consisted of individuals who were computer illiterate and had basic education (with Matric or Grade 12 as the highest qualification). They had been enrolled in a programme called Mangaung University of the Free State Community Partnership Programme (MUCPP). In this programme, the participants received free computer literacy training for a short period of one week. The participants were recruited for this study after completing the programme. The data collection was conducted in the usability lab belonging to the Department of Computer Science, at the University of the Free State in Bloemfontein. The usability lab offered the appropriate environment for the testing instruments to be used with one participant at a time performing tasks on a computer.

Since this study was a triangulation mixed methods study, according to Creswell (2011) it was necessary to consider and decide on the following factors in relation to sampling: whether to use the same individuals as the sample for the quantitative and qualitative data collection, and whether the sample size for the quantitative data would be the same as for the qualitative data. In this study, the sample consisted of the same individuals in the quantitative and qualitative data collection procedures. The sample size was also equal for the two types of data collection. The purpose for these choices was to substantiate the quantitative results with the qualitative results.

Research involving human participants necessitates ethical considerations to be implemented in order to properly handle and care for participants. The following section discusses ethical considerations of relevance to this study.

3.6 Ethical considerations

According to Blandford et al. (2008), the three most important components to consider in relation to ethics are:

- vulnerable participants,
- informed consent,
- privacy, confidentiality and maintaining trust.

Vulnerable participants include the old, young or sick. Another group of vulnerable participants consists of those who are compelled to participate because of their relationship with the researcher, for example, a student participating in a research study conducted by the lecturer. Other participants are those who may feel threatened by certain aspects of the study. In this study the situation of having vulnerable participants was avoided by explaining to the participants that it was the EREC glove that was being tested and not them particularly. Additionally, they were recruited after completing the computer literacy training which meant that their non-participation in the study did not affect the outcome of their training. As a result, none of the participants was compelled by circumstances to participate. Moreover, the recruited participants were able adults who did not have the above-mentioned characteristics of the vulnerable groups.

An informed consent form was issued to each participant before the data collection commenced. The consent form (see appendix D) explained the purpose of the research study, and the tasks the participant was required to perform. Additionally, the consent form stipulated that the participant was partaking in the study voluntarily and had the freedom to withdraw at any time without being penalized. Moreover, the consent form stated that the information collected from the study would be kept confidential as none of the participant's names would be disclosed at any time. The contact details of the researcher were also provided in the consent form in case the participant required information about the study. The participant was required to sign the form, providing proof that he/she agreed to participate in the study knowing what to expect.

The participants had to be transported in the researcher's vehicle to the usability lab, located at the University of the Free State, where the research study was conducted. Due to this factor, a transportation consent form (see appendix E) was also issued to each of the participants before travelling in the researcher's vehicle. Before embarking on the journey to the usability lab, the researcher explained to the participants the purpose of the study, what was expected of the participants and why the participants had to travel about 20 km to the university. The researcher also presented the participants with her valid driver's license in order to assure the participants that the vehicle would be driven by a qualified driver.

Having discussed the numerous considerations made in the design of this research study, the following section discusses the methodology that was followed to conduct the research.

3.7 Methodology

In section 3.4.1 data gathering methods which are usually employed in research studies were discussed. The applicable methods selected for *this* research study are discussed in this section together with the implementation procedure.

The research study employed triangulation mixed methods design. This design encapsulates both quantitative and qualitative data collection methods which are conducted in parallel to each other. The quantitative phase involved measuring skin conductivity of participants using the EREC system. Additional quantitative data was obtained from the scores of the CARS questionnaire (see Appendix A) which was administered to the participants to determine their anxiety scores before and after interacting with the computer. Although the participants' responses on CARS were based on their subjective views (qualitative data), the researcher was interested in the overall score (quantitative data) obtained by each participant. The other sources of quantitative data were closed-ended questions found in two self-developed questionnaires (pre-test and post-test questionnaires; see appendix B and C respectively). Further quantitative data was also obtained from observations where measurements such as the duration for each task and the task success were established.

The qualitative phase engaged open-ended questions in the two self-developed questionnaires (pre-test and post-test questionnaires) and behaviours established in observations. The participants were observed as they performed the tasks (see Appendix F) on the computer and the observations were noted by writing them down. Informal interviews were conducted with the participants to ensure that the researcher understood their responses stated in CARS and the self-developed questionnaires. The data collection methods and the procedure which was followed are discussed in the subsequent sections.

3.7.1 Data collection methods employed in the study

The above-mentioned data gathering methods were executed in a sequence which is depicted in figure 17. The methods are explained further in the following sections.

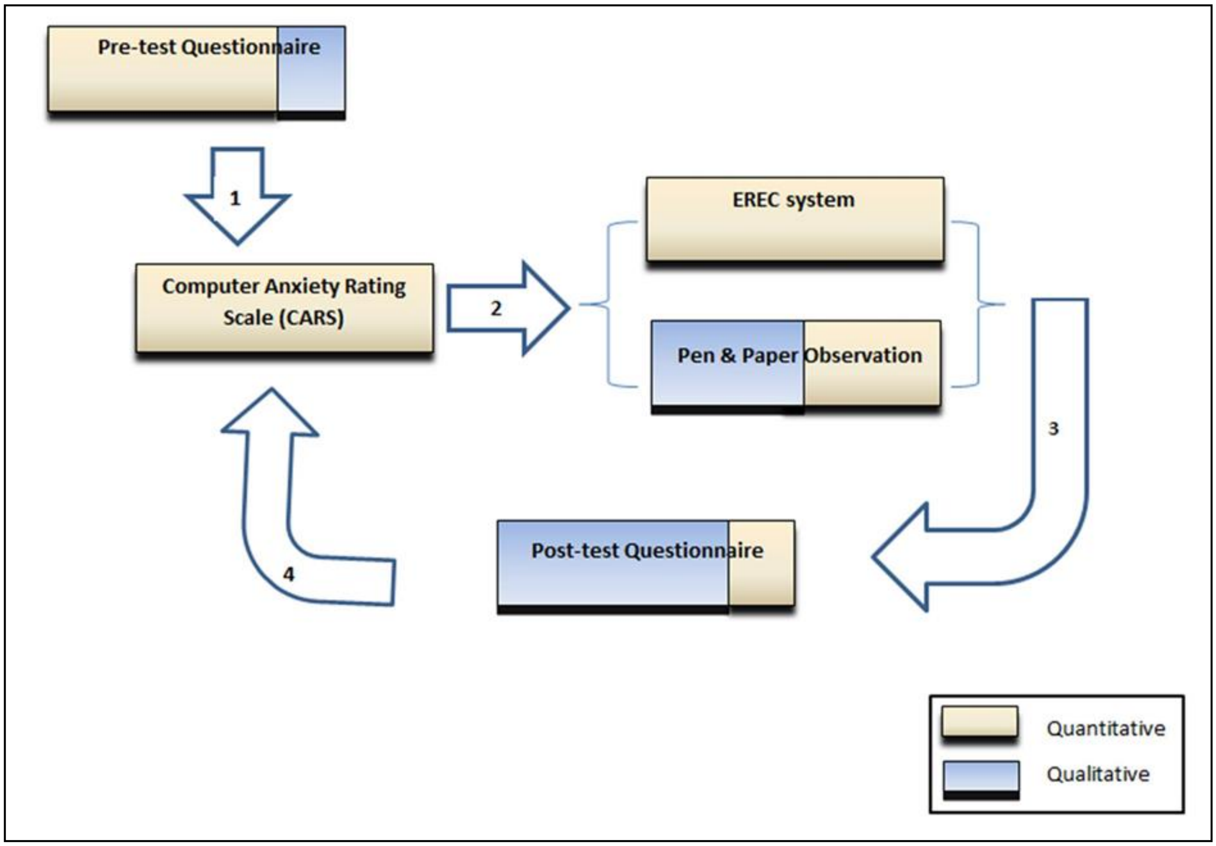


Figure 17: Data collection process

3.7.1.1 Pre-test self-developed questionnaire

The pre-test questionnaire (see appendix B) was utilised for capturing demographic data, for example, participants' personal details (e.g. age and gender), educational background (e.g. highest qualification), computer experience (e.g. the number of hours in a week spent using a computer and duration, in years, of using the computer), and ownership of a computer. This data was obtained to assist in determining whether factors such as age, gender, educational background and computer experience correlated with anxiety experienced by the participants. It is also in this questionnaire that participants were asked briefly about the emotions they experienced when they first utilised computers, and their emotions at the time when they were going to use a computer for research purposes. The participants were also asked to provide a reason for the change in the emotions, where applicable, between the time of their first encounter with the computer and on that specific day of the research.

3.7.1.2 Computer Anxiety Rating Scale (CARS) questionnaire

CARS was introduced in section 2.5.1.6. As mentioned before, the 19 items which comprise this scale can be responded to on a five-point Lickert scale. The highest total possible score is 95 while the lowest is 19. The higher scores indicate higher computer anxiety levels and vice versa. The CARS questionnaire was completed by each participant before and after executing tasks on the computer. The aim was to measure and compare the levels of computer anxiety of the participants at these two instances. An example of the CARS questionnaire is presented in Appendix A.

3.7.1.3 Emotion Recognition Sensor System (EREC)

EREC was introduced in the previous chapter in section 2.5.4.2 and it is depicted in figure 10. It was used to measure skin conductivity. The EREC system actually measured skin resistance in Kilo-ohms (kΩ) which was converted into conductance in milli-Siemens (mS). Conductivity is the reciprocal of resistivity therefore the conversion was performed easily. Ten skin resistance readings were captured within one second and the recording was performed until all the tasks were executed. The data was recorded in a Microsoft (MS) Excel application.

The researcher did not find the application software that was packaged with EREC to be user-friendly, therefore a software application, which allowed easy data capture, was implemented by an Honours student in the Department of Computer Science and Informatics. The software application that was implemented, also served as a project in partial fulfilment of an Honours degree, and the student scored a distinction.

3.7.1.4 Pen and paper observation

The researcher performed systematic observation where each participant performed tasks on the computer in a usability lab. The recordings were performed on a pre-designed schedule using pen and paper. Recordings of time-on-task and task success were noted. Time-on-task allowed the researcher to make an assessment of the various task durations. The task success rate (percentage of the tasks successfully completed) enabled the researcher to evaluate the performance of the participants by task. The tasks that were not completed in the given amount of time were also noted. Also of importance were the overt behaviours of the participants, such as body language, words uttered, and facial expressions. The data gathered from the observation therefore consisted of both quantitative and qualitative data types.

3.7.1.5 Post-test questionnaire

The post-test questionnaire (see Appendix C) was used to record the subjective emotions experienced by the participants in the different stages of the data gathering. The questionnaire provided data on the tasks which caused the participants to elicit anxiety and/or stress. The participants indicated the specific tasks among the allocated nine that caused them to experience the two emotions. The participants were also required to provide explanations for experiencing those emotions. The questionnaire required the participants to additionally rate their experiences with the glove in terms of comfort and time taken to set them up.

The data collection was conducted in the usability lab belonging to the Department of Computer Science and Informatics at the University of the Free State, Bloemfontein. The usability lab offered the appropriate environment for the testing instruments to be used with one participant at a time performing tasks on a computer. A pilot study was conducted at first, followed by the experimental study.

3.7.2 Pilot study

The pilot study was performed in order to verify that the EREC system measured anxiety levels of participants and that the statements in the questionnaires were understandable. The pilot study was conducted in the usability lab where 10 intermediate computer users were recruited as participants. These participants were students who had completed their computer literacy course. The course content included learning how to use a mouse and keyboard and how to use a word processor and spreadsheet applications. In the pilot study, the researcher used several computer games which were intended to elicit different levels of anxiety beginning with the least to the most fearful. Computer games were used in the pilot study as they were deemed to be more appropriate than a word application – the pilot participants (intermediate users) were already familiar with the MS Word application which probably would not have caused them anxiety.

3.7.2.1 Games used in the pilot study

The computer games that the participants played are described briefly in the order in which they were presented to the participants:

- The colour test (Flamegames, 2005): The game has eight screens and each screen has a word and two buttons to choose from. The word is the name of a colour and it is written in a different colour to the one displayed by the word. The player is required to click on the button which represents the color of the word and not the name of the colour itself. The player is given four seconds to choose; otherwise the next screen is displayed. At the end of the game, the player is scored according to the number of correct matches made.
- The Optus tennis challenge (Optus, n.d.): In this game the player is required to hit the tennis ball and keep it in the air. This is done by meticulously clicking the tennis ball continuously. It requires the player to concentrate as points are issued to the player when the ball is hit several times without landing on the playground.
- Circuit powerpoint presentation (Circuit, n.d.): The game requires the player to locate and click on a red dot 'hidden' in the picture with the aim of following a circuit around the office. Different pictures are displayed one at a time with the red dot changing locations on the pictures. After a few times of finding and clicking on the red dot, a terrifying picture (circuit) suddenly appears and a screaming sound is voiced out. After that shock, the game ends with a Halloween greeting.

The games had varying durations. The colour test and the circuit powerpoint presentation lasted approximately a minute while the optus tennis challenge was allocated five minutes. With the optus tennis challenge, the researcher stopped the participant from playing when the five minutes had elapsed.

3.7.2.2 Challenges with pilot data collection

When the pilot study was conducted, a number of challenges were encountered. These challenges are presented here as well as the solutions implemented to mitigate those challenges. Firstly, the software that was packaged with the EREC system was not suitable for capturing the data required in this study. A separate software application had to be implemented. Secondly, the glove did not fit every participant precisely because of its small size. For some participants it was a perfect fit while for others it was either too small or too big. The size issue posed some challenges. For the smaller hands, Velcro straps were used to tighten the sensors to the skin so that the sensors would remain in contact with the skin. However, this was a solution that worked with some participants, but not all. The challenge which was posed by participants with bigger hands was that the EREC copper wires which connect the glove sensors were cut loose from the sensors several times during the experiment. In such cases, if the skin conductivity readings constituted more than 30 percent non-zeroes, all the data regarding that participant was discarded. Because the participants could not fit the glove before they were recruited, an arrangement was made to have experts from the Electronics Department at the University of the Free State, repair the wires whenever they disconnected.

The experimental study was then performed taking into consideration the challenges that were encountered in the pilot study.

3.7.3 Procedure for conducting the study

The procedure for executing the pilot and the actual studies was similar. The only exception between the two studies was found in the tasks displayed on the computer screen for manipulation. While the participants in the pilot study utilised games, word processor tasks (see Appendix F) were used by the participants in the actual study.

3.7.3.1 Tasks used in the study

There were nine MS Word-related tasks which the participants were asked to perform using the MS Word application (see Appendix F). The tasks were presented in a small moveable application window which was designed in such a way that only one task was displayed at a time. A ‘next’ button appeared on the application window which allowed the participant to display the succeeding task. For each task the participant was assigned three minutes. While the tasks were presented in the application window, the MS Word file was simultaneously opened on the screen behind the window containing the tasks. Consequently, the participant was able to view the task to be performed as well as the MS Word file where the execution of tasks was performed (as shown in figure 18).

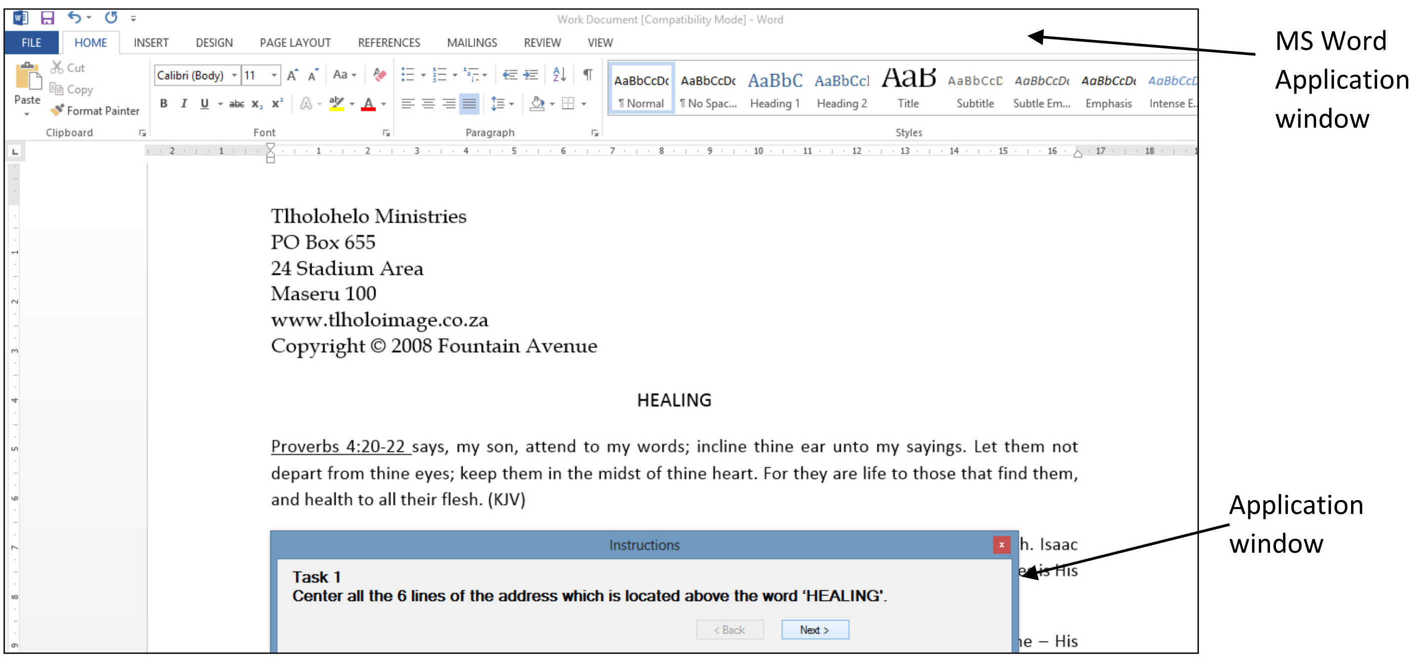


Figure 18: Task to be performed in the MS Word application behind

In the following section, the protocol that was followed with each participant in the actual study is stipulated.

3.7.3.2 Protocol for conducting the study

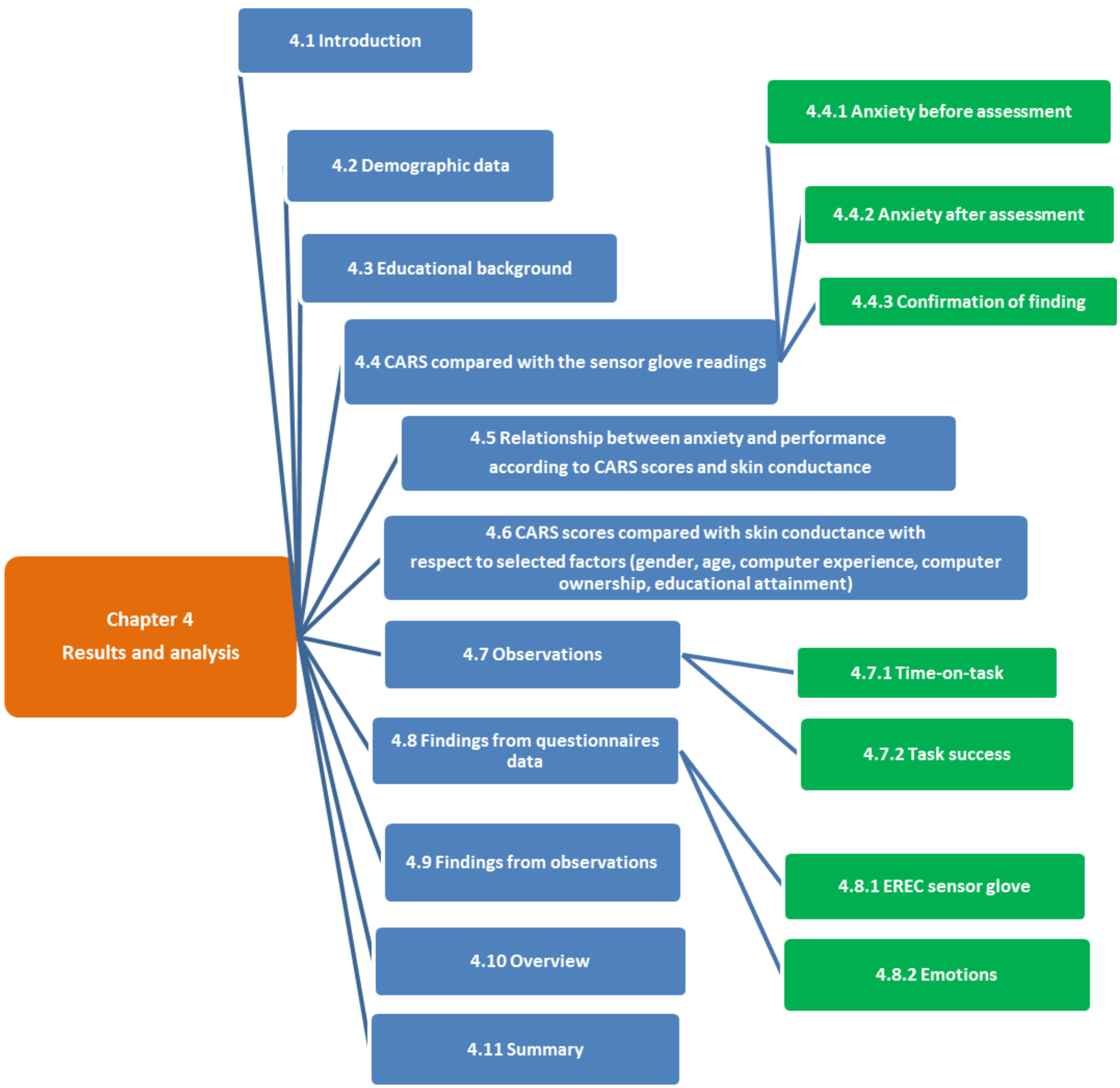
1. The participant was welcomed into the usability lab by the researcher and her assistant. The researcher introduced her assistant to the participant, and issued the participant a chair to sit on.
2. The researcher explained the purpose of the study and what was required of the participant. The researcher explained that the instruments would not harm the participant in any way.
3. If the participant agreed to continue with the study he/she was issued a consent form (see Appendix D) to read and sign as an indication of accepting the terms involved with participating in the research study. Clarification was given where the participant needed it. The participant was made fully aware that he/she could withdraw from participating at any time for whatever reason he/she had. The researcher also signed the consent form.
4. After signing the consent form, the researcher assisted the participant to wear the sensor glove on the left hand.
5. Since the sensor glove took some time to detect resistance readings, the participant was asked to firstly complete the pre-test questionnaire and the CARS. When filling in the questionnaires, the participant was given the opportunity to ask questions and receive clarification or language interpretation where needed.
6. As soon as the sensor glove detected the skin resistance measurements, the researcher entered the participant’s details (name and surname) via the EREC application software and stored it in the MS Excel application.
7. The researcher explained to the participant that the MS Word file would be opened and nine tasks would appear one at a time on the screen. The participant was expected to execute each task and click the ‘next’ button after completing a task. It was also explained that each task was allocated a maximum of three minutes after which the participant would be asked to stop even if the task was not completed. The participant was allowed to ask questions where more clarification was necessary.
8. After the explanation, the participant was required to sit comfortably facing the computer.

9. When the participant was ready to begin, the researcher clicked on the ‘start’ button on the EREC application software which began capturing the skin resistance data of the participant. The researcher also started a program that launched both the MS Word file and a smaller window containing the task. The smaller window also had two buttons; the ‘next’ button for proceeding to the next task and the ‘close’ button for closing the window. The ‘close’ button was visible only when the last task was executed while the ‘next’ button was invisible with the last task.
10. When the participant began reading the task requirement, the assistant researcher recorded the start time. After task completion, the assistant researcher recorded the finish time. While the participant performed each task, the researcher observed and noted down the behaviours (e.g. fidgeting) of the participant. For each participant, the researcher also noted the tasks which were completed successfully and those which were not.
11. After completing the last task, the participant clicked on the ‘close’ button which closed the task window and the MS Word application. The researcher also stopped the EREC application which was recording and saving the skin resistance data.
12. The researcher assisted the participant with removing the sensor glove.
13. The researcher asked the participant to complete the post-test questionnaire and the CARS questionnaire. The researcher explained that the participant was not necessarily expected to complete the CARS the same way as before but that the CARS should be completed according to the way the participant felt having completed the tasks. The participant was encouraged to ask questions and receive explanation where needed.
14. The researcher read the responses in the post-test questionnaire and interviewed the participant to find clarity on the responses written in it.
15. After the interview, the researcher thanked the participant, issued him/her a thank you token and accompanied him/her out of the usability lab. The token was a R50.00 meal voucher which could be spent on the premises of the university where the data gathering took place.

3.8 Summary

In this chapter, the research design, sampling techniques, ethical considerations and methodology were discussed. These concepts were introduced and it was also mentioned how they were applied in this research study. In the following chapter, the analysis of the collected data in the research study is presented.

CHAPTER 4 MAP



CHAPTER 4: RESULTS AND ANALYSIS

4.1 Introduction

In the previous chapter, the various methods used to collect data and the methodology followed, were discussed. In this chapter, the analysis techniques, as well as the results thereof, are presented. The results include the participants' demographic data, comparisons of the anxiety data according to the CARS questionnaire and the EREC system. The discussion begins with the demographic data of the participants which was obtained from the pre-test questionnaire.

4.2 Demographic data

The sample consisted of 58 participants of whom 25 were males and 33 were females as shown in table 3.

Table 3: Gender of the participants

Gender	Frequency	Percent	Cumulative Percent
Male	25	43.1	43.1
Female	33	56.9	100.0
Total	58	100.0	

The participant's age ranged from 16 years to over 40 years. The largest proportion of participants (36.2%) was in the age group of 21 to 25 years, while only 3.4% of participants were older than 40 years, as shown in table 4.

Table 4: Age groups of the participant

Age groups (years)	Frequency	Percent	Cumulative Percent
16-20	7	12.1	12.1
21-25	21	36.2	48.3
26-30	12	20.7	69.0
31-35	10	17.2	86.2
36-40	6	10.3	96.6
> 40	2	3.4	100.0
Total	58	100.0	

The largest group of the participants (70.7%) spoke Sotho or Tswana, as their home language, followed by Xhosa (25.9%). Only one participant each (1.7%) spoke Afrikaans and Zulu as their home language. These groups were in the minority with 1 participant. Table 5 shows these figures.

Table 5: Participants' home languages

	Frequency	Percent	Cumulative Percent
Sotho/Tswana	41	70.7	70.7
Afrikaans	1	1.7	72.4
Xhosa	15	25.9	98.3
Zulu	1	1.7	100.0
Total	58	100.0	

The participants were required to indicate their level of education. The results are provided next.

4.3 Educational background

It was expected that the participants' highest level of education was Matric or Grade 12. However, the researcher was interested in knowing the number of participants who had completed Matric. The results displayed in table 6 indicate that 47 (81%) of the participants had completed Matric while 11 (19%) had not.

Table 6: Participants' educational background

Completed Matric or not	Frequency	Percent	Cumulative Percent
Completed	47	81.0	81.0
Incomplete	11	19.0	100.0
Total	58	100.0	

Having presented the demographic characteristics of the participants, the subsequent sections provide analysis of the data gathered using the CARS questionnaire and the EREC sensor glove.

4.4 CARS compared with the sensor glove readings of skin conductance

As mentioned in chapter 3, the participants were required to complete the pre-test, CARS and post-test questionnaires. With regard to the CARS questionnaire, comparisons were made between CARS scores and the skin conductance readings of the EREC sensor glove before and after the assessment. The comparisons were made to address the first hypothesis stated in section 1.4:

$H_{0,1}$: There is no correlation between CARS scores and conductance readings of the sensor glove before and after interaction with a computer.

In order to answer the above-mentioned hypothesis, it was important to establish whether the skin conductance measured by the EREC sensor glove and the CARS scores as measures of anxiety, provided different information regarding levels of anxiety before and after the assessment (interaction with the computer).

The results of the analyses regarding the above-mentioned hypothesis are presented next.

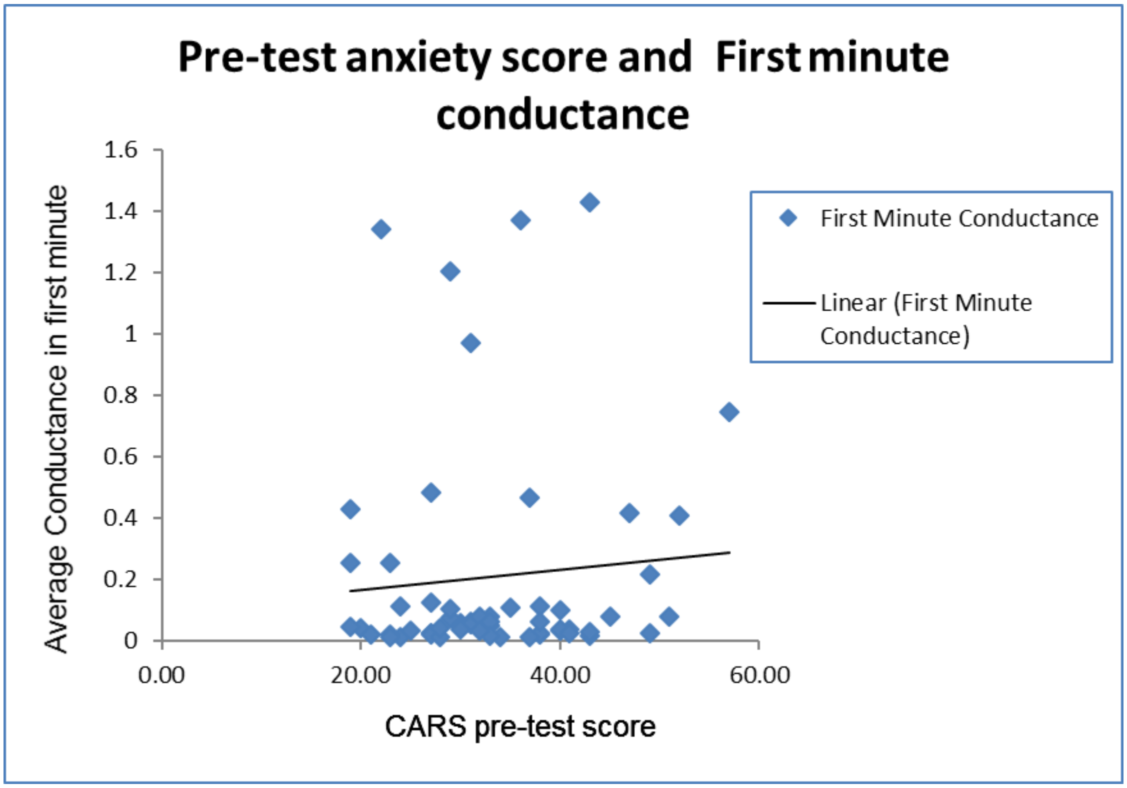
4.4.1 Anxiety before assessment

In order to determine whether the **sensor glove** and the CARS **pre-test questionnaire** provide the **same information** regarding anxiety **before the assessment**, a statistical test known as correlation was performed. The correlation tests whether two variables have a relationship and describes the degree of the relationship (Trochim, 2006). The following correlations were done:

a. The correlation between total scores on the CARS pre-test questionnaire and the average skin conductance readings during the first minute of wearing the glove was calculated.

   <u>Results:</u>
   There was **no significant correlation** ($r = 0.144$, $p > 0.05$) between the pre-test questionnaire score and the average skin conductance reading for the first minute.

   <u>Finding:</u>
   From this result we can conclude that the sensor glove (first minute) and the CARS pre-test questionnaire potentially provide different information regarding levels of anxiety before the assessment.



Graph 1: Pre-test anxiety score and First minute conductance

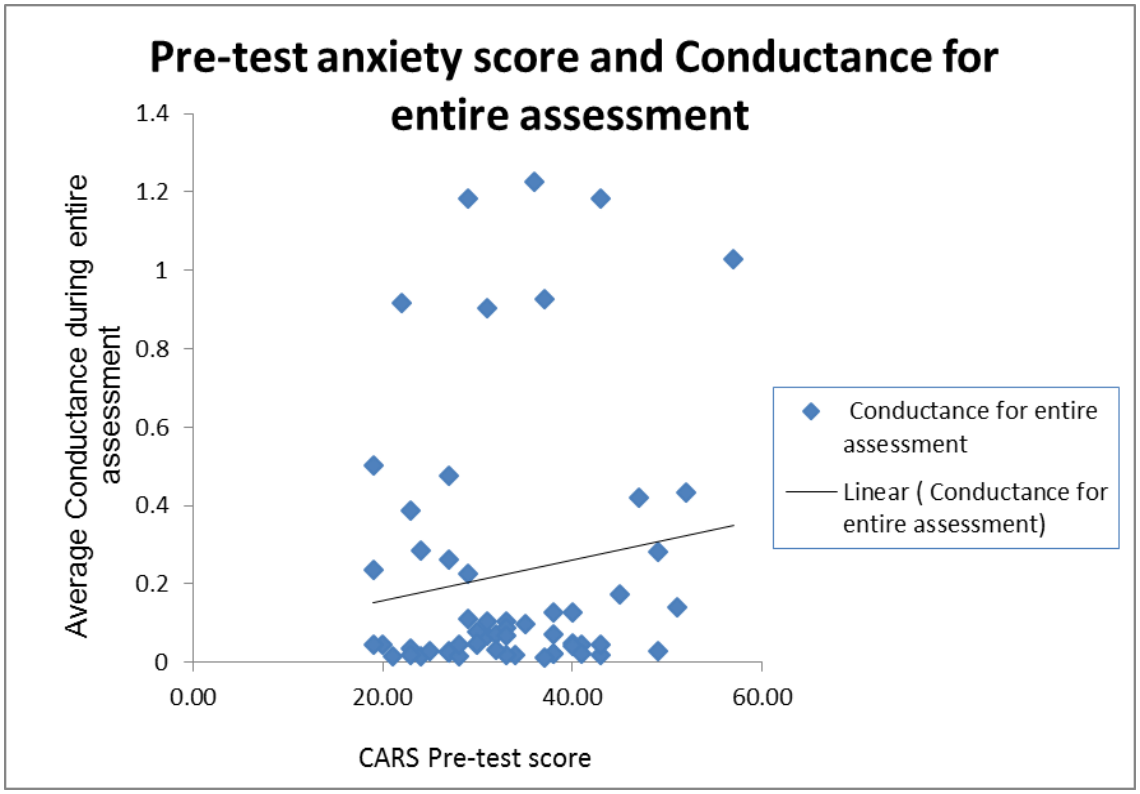
b. The correlation between total scores on the CARS pre-test questionnaire and the average skin conductance reading on the sensor glove during the entire assessment was calculated. This was done to investigate whether the result found in a. was caused by inaccurate reading of anxiety during the first minute.

<u>Results:</u>

There was **no significant correlation** ($r = 0.168$; $p > 0.05$) between the total scores on the CARS pre-test questionnaire and the average skin conductance reading on the sensor glove during the entire assessment.

<u>Finding:</u>

This result confirms the conclusion made in point a. The sensor glove and the CARS pre-test questionnaire potentially provide **different information** regarding levels of anxiety before the assessment.



Graph 2: Pre-test anxiety score and Conductance for entire assessment

4.4.2 Anxiety after assessment

In order to determine whether the **sensor glove** and the CARS **post-test questionnaire** provide the **same information** regarding anxiety after the assessment, the following analyses were done:

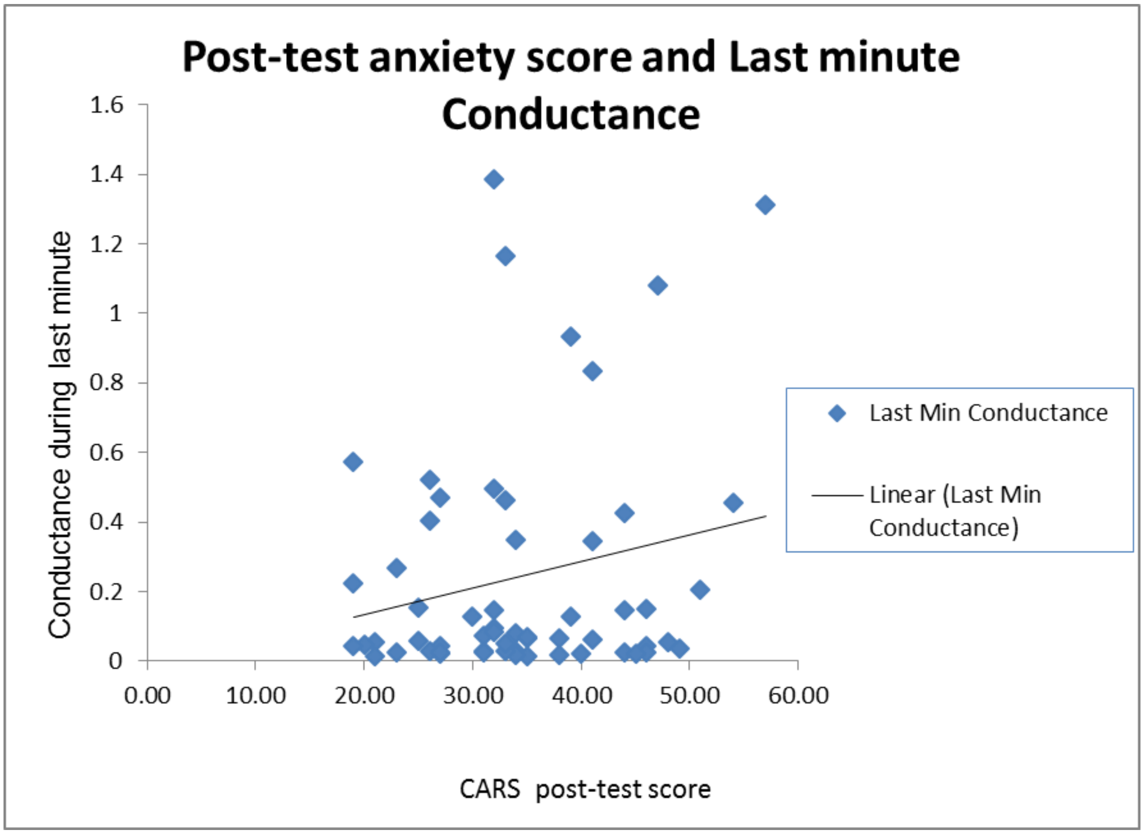
a. The correlation between total scores on the CARS post-test questionnaire and the average skin conductance readings during the last minute of wearing the glove was calculated.

<u>Results:</u>

There was **no significant correlation** ($r = 0.192$; $p > 0.05$) between the total scores on the CARS post-test questionnaire and the average readings during the last minute of wearing the glove.

Finding:

From this we can conclude that the sensor glove (last minute) and the CARS post-test questionnaire potentially **provide different information** regarding levels of anxiety after the assessment.



Graph 3: Post-test anxiety score and Last minute Conductance

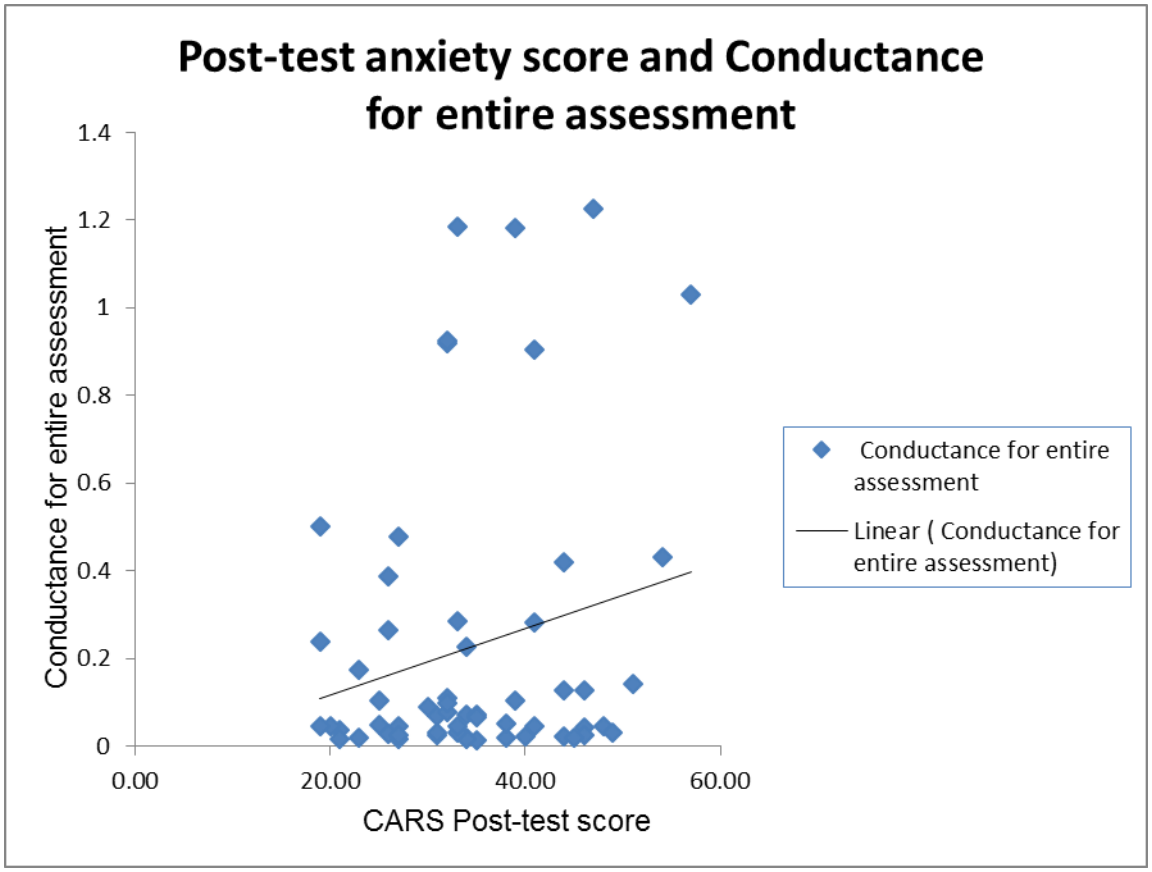
b. The correlation between total scores on the CARS post-test questionnaire and the average skin conductance readings on the glove during the entire assessment was calculated. This was done to investigate whether the result found in a. was caused by inaccurate reading of anxiety during the last minute.

Results:

There was **no significant correlation** ($r = 0.229$; $p > 0.05$) between the total scores on the CARS post-test questionnaire and the average readings of the glove during the entire assessment.

Finding:

This result confirms the conclusion made in point a. The sensor glove and the CARS post-test questionnaire potentially provide **different information** regarding levels of anxiety after the assessment.



Graph 4: Post-test anxiety score and Conductance for entire assessment

4.4.3 Confirmation of finding

In order to confirm the finding that the glove and the CARS questionnaires potentially provide **different information** regarding levels of anxiety, a statistical test known as a Multivariate Analysis of Variance (MANOVA) was conducted. This test allows for analysis of variance for multiple dependent variables by one or more factor variables. (Erdogan, 2009). To conduct the MANOVA the following was done:

Participants were divided into three categories: those with high anxiety scores, those with medium anxiety scores, and those with low anxiety scores, all according to the skin conductance readings of the sensor glove. The CARS pre-test scores and the CARS post-test scores were then compared among these three groups.

i. If the glove and the CARS questionnaires **provide the same information**, we would expect that there would be **differences** in the self-reported anxiety scores between these three groups.
ii. If the glove and the CARS questionnaires **provide different information**, we would expect that there would be **no differences** in the self-reported anxiety scores between these three groups.

Results:

No significant differences ($F = 0.798$; $p > 0.05$) were found in the self-reported anxiety scores (for the pre-test and the post-test) between these three groups.

Finding:

This result confirms that the sensor glove and the CARS questionnaire potentially provide different information regarding levels of anxiety.

From these results the first hypothesis $H_{0,1}$ cannot be rejected, since $p > 0.05$. Although statistical tests showed no significant correlations between CARS scores and the glove readings, the scatterplots reflect the small positive correlation between conductance measurements and CARS scores, possibly those correlations are small (and not statistically significant) because of much noise in the data. Note the scatterplots show the conductance measurements to be close to zero (below 0.2) for most subjects. However, for about 18 other subjects the conductance measurements are very variable, some values are up to about 1.2. Moreover, the researcher encountered a challenge of non-continuous measurements of skin conductance. With some participants the EREC glove momentarily stopped recording the skin conductance because the sensors of the glove were no longer in contact with the skin despite the Velcro straps that were used to tighten the sensors to the skin. This could have caused noise in the data.

A summary of the above-mentioned statistical tests concerning the anxiety according to the sensor glove and the CARS questionnaire is presented in table 7.

Table 7: Summary of findings regarding anxiety before and after assessment

Statistical test	Variables	Result	Finding
Correlation	CARS pre-test total score, skin conductance reading in 1st min	No significant correlation	Sensor glove (first minute) and CARS pre-test questionnaire potentially provide different information about levels of anxiety before the assessment.
	CARS pre-test total score, average skin conductance reading for the entire assessment	No significant correlation	Sensor glove and CARS pre-test questionnaire potentially provide different information regarding levels of anxiety before the assessment.
	CARS post-test total score, skin conductance reading in last min	No significant correlation	Sensor glove (last minute) and CARS post-test questionnaire potentially provide different information regarding levels of anxiety after the assessment.
	CARS post-test total score, average skin conductance readings for entire assessment	No significant correlation	Sensor glove and CARS post-test questionnaire potentially provide different information regarding levels of anxiety after the assessment.
MANOVA	CARS pre-test scores, CARS post-test scores (among 3 groups of different anxiety levels)	No significant differences	Sensor glove and CARS questionnaire potentially provide different information regarding levels of anxiety.

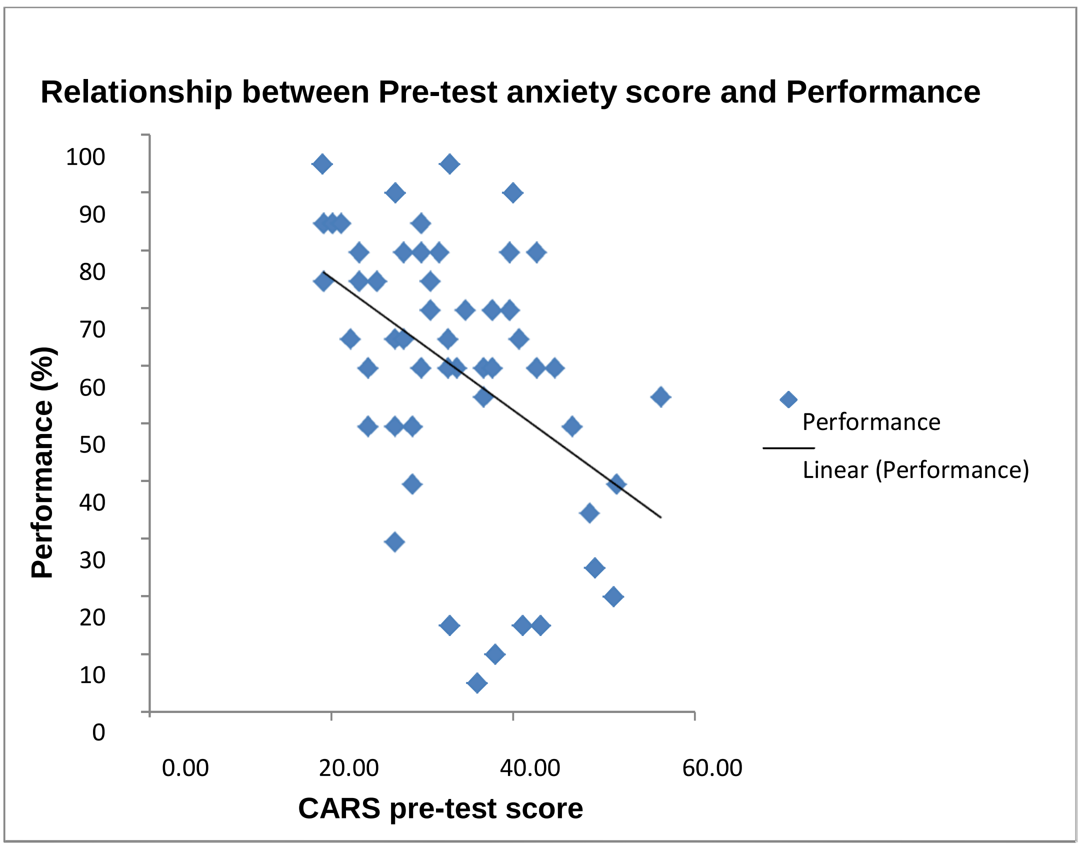
4.5 Relationship between anxiety and performance according to CARS scores and skin conductance

The following hypothesis was addressed by performing correlations between the CARS scores and performance, and the skin conductance readings with performance. Performance was measured as the percentage of tasks which were completed correctly by each participant.

$H_{0,2}$: There is no relationship between computer anxiety and performance as measured by a sensor glove and a computer anxiety questionnaire.

In order to determine whether there is a **relationship between anxiety and performance**, the following analyses were done:

a. Correlation between the CARS pre-test score and performance score.

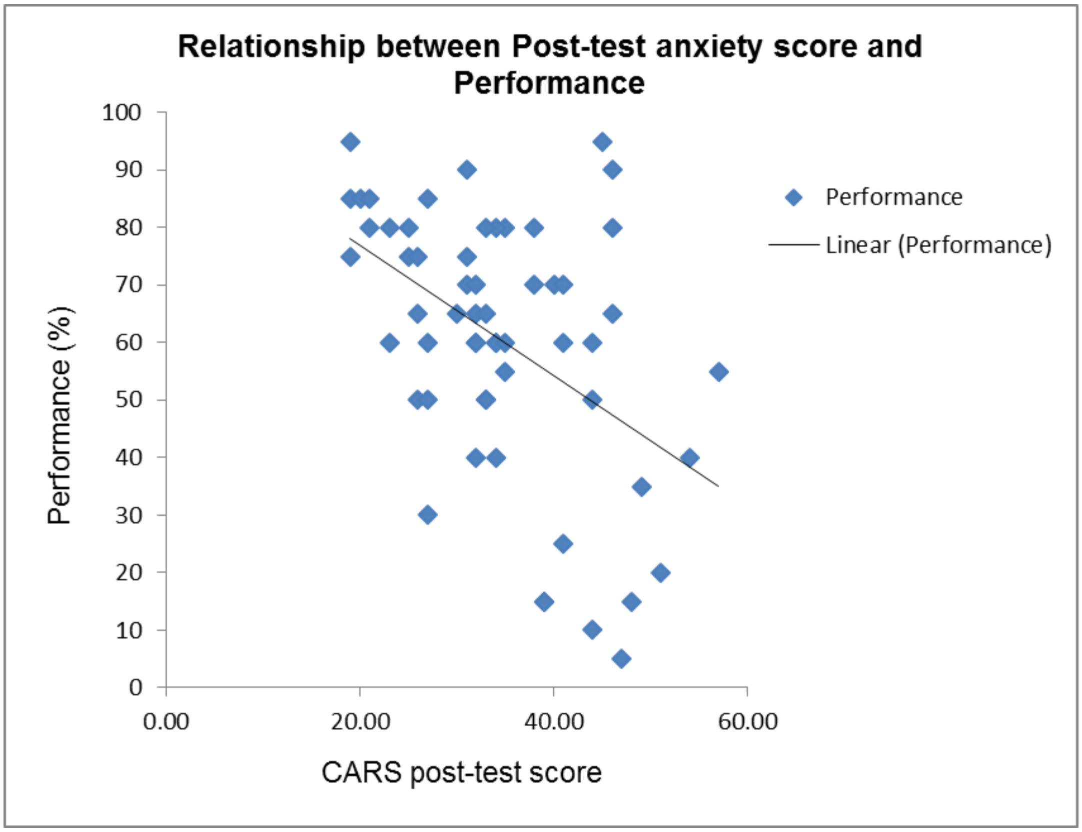


Graph 5: Relationship between Pre-test score and Performance

Result:

There was a significant negative correlation (r = -0.331; $p < 0.05$) between scores on the pre-test CARS questionnaire and performance in the assessment.

b. Correlation between the CARS post-test score and performance score.

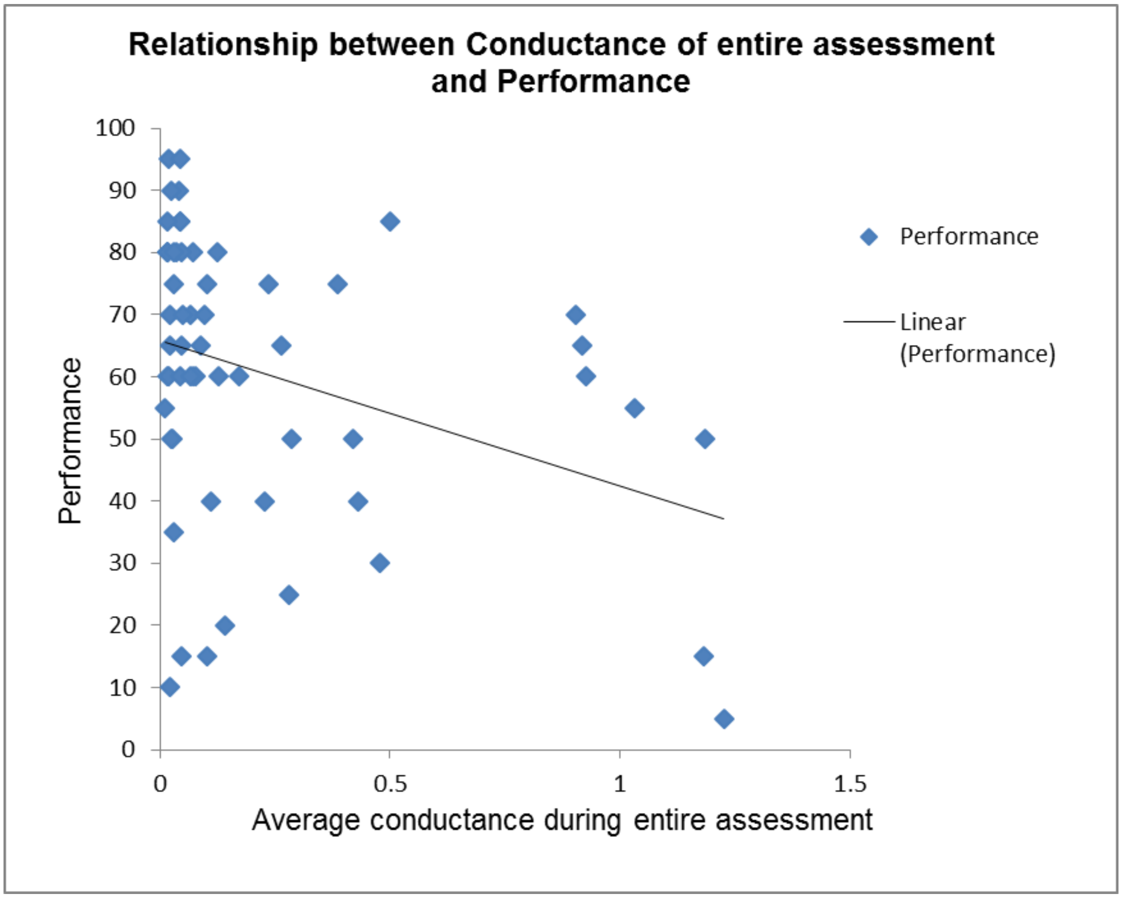


Graph 6: Relationship between Post-test anxiety score and Performance

Result:

There was a significant negative correlation (r = -0.332; $p < 0.05$) between scores on the post-test CARS questionnaire and performance in the assessment.

c. Correlation between average skin conductance readings on the sensor glove during the entire assessment and performance score.



Graph 7: Relationship between Conductance of entire assessment and Performance

<u>Result:</u>

There was a significant negative correlation (r = -0.300; $p < 0.05$) between average readings on the glove during the entire assessment and performance in the assessment. In addition, this correlation was almost exactly equal to the negative correlations found between performance and anxiety measured by the CARS questionnaires.

Finding:

The negative correlations between performance and levels of anxiety as measured by the glove and CARS indicate that the higher a person's levels of anxiety were, the poorer he/she performed on the assessment.

Considering the above-mentioned results, the second hypothesis, $H_{0,2}$ can be rejected at $p < 0.05$ in all the related tests.

The statistical tests and findings with regard to anxiety and performance are summarized in table 8.

Table 8: Summary of findings regarding anxiety and performance

Statistical test	Variables	Result	Finding
Correlation	CARS pre-test score, performance score	Significant negative correlation	The higher the levels of anxiety, the poorer the performance on the assessment.
	CARS post-test score and performance score	Significant negative correlation	
	Average skin conductance readings during the entire assessment, performance score	Significant negative correlation	

4.6 CARS scores compared with skin conductance with respect to selected factors

To address the following hypothesis, the CARS scores were compared with skin conductance measurements using a MANOVA test.

$H_{0,3}$: There is no difference in the anxiety information provided by a sensor glove and a computer anxiety questionnaire regarding selected factors (age, gender, computer experience, educational attainment, and ownership of a personal computer).

4.6.1 Factor 1: Gender

A one-way between-group multivariate analysis of variance was performed to investigate gender differences in anxiety. Two dependent variables were used: self-reported anxiety and skin conductance with the glove. The independent variable was gender. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance covariance matrices, and multicollinearity, with no serious violations noted. There was no statistically significant difference between males and females on the combined dependent variables, F = [0.916], p = [0.406]; Wilks' Lambda = [0.967]; partial eta squared = [0.033]. When the results for the dependent variables were considered separately, none of the differences reached statistical significance. An inspection of the mean scores indicated that females reported slightly higher levels of perceived anxiety (M = 35.0, SD = 9.53) than males (M = 32.1, SD =7.77), although, as indicated above, this difference was not significant. A non-significant difference was also discovered with the mean scores of the skin conductance where females had a lower anxiety (M = 0.2, SD = 0.33) than males (M = 0.3, SD = 0.39).

With reference to the above-mentioned hypothesis, $H_{0,3}$ with regard to gender cannot be rejected, $p > 0.05$.

4.6.2 Factor 2: Age

A one-way between-group multivariate analysis of variance was performed to investigate age differences in anxiety. Two dependent variables were used: self- reported anxiety and skin conductance with the glove. The independent variable was age. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance covariance matrices, and multicollinearity, with no serious violations noted. There was no statistically significant difference between individuals in the different age groups on the combined dependent variables, F = [1.166], p = [0.330]; Wilks' Lambda = [0.918]; partial eta squared = [0.042]. When the results for the dependent variables were considered separately, none of the differences reached statistical significance. An inspection of the mean scores indicated that individuals aged 36 years and above reported the highest levels of perceived anxiety (M = 36.9, SD = 8.48), followed by individuals aged between 16 and 25 years (M = 33.7, SD = 9.16), while the individuals aged between 26 and 35 years reported the lowest perceived anxiety (M = 32.7, SD = 8.79). However, as indicated above this difference was not significant. The difference of the mean scores according to the skin conductance was also non-significant and followed a pattern similar to the anxiety reported by the individuals. The highest level of anxiety (M = 0.5, SD = 0.56) was found among the individuals aged 36 years and above, followed by individuals aged between 16 and 25 years (M = 0.2, SD = 0.31). The lowest anxiety level (M = 0.1, SD = 0.29) was found among the individuals aged between 26 and 35 years.

According to the above-mentioned findings, the third hypothesis $H_{0,3}$ with regard to age cannot be rejected, $p > 0.05$.

4.6.3 Factor 3: Computer experience

A one-way between-group multivariate analysis of variance was performed to investigate differences among individuals with various computer experiences in relation to anxiety. Two dependent variables were used: self-reported anxiety and skin conductance with the glove. The independent variable was computer experience (in relation to the duration, i.e. years of using computer). Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance covariance matrices, and multicollinearity, with no serious violations noted. There was no statistically significant difference between individuals in the different computer experience groups on the combined dependent variables, F = [0.713], p = [0.585]; Wilks' Lambda = [0.948]; partial eta squared = [0.026]. When the results for the dependent variables were considered separately, none of the differences reached statistical significance. An inspection of the mean scores indicated that the individuals with less than 1 year computer experience reported the highest levels of perceived anxiety (M = 34.9, SD = 8.12), followed by the individuals with computer experience of more than 2 years (M = 34.1 SD = 12.21), while the individuals with computer experience of between 1 and 2 years reported the lowest perceived anxiety (M = 30.3, SD = 8.13). However, as indicated above, this difference was not significant. A non-significant difference was also discovered with the mean scores of the skin conductance where individuals with less than 1 year computer experience (M = 0.2, SD = 0.37) and those with computer experience between 1 and 2 years (M = 0.2, SD = 0.33) portrayed anxiety which is more or less equal. The lowest anxiety was found among the individuals with more than 2 years (M = 0.17, SD = 0.35).

Considering the above-mentioned findings, the third hypothesis, $H_{0,3}$ with regard to computer experience cannot be rejected, $p > 0.05$.

4.6.4 Factor 4: Computer ownership

A one-way between-groups multivariate analysis of variance was performed to investigate differences in anxiety among individuals who own computers and those who do not. Two dependent variables were used: self-reported anxiety and skin conductance with the glove. The independent variable was computer ownership. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance covariance matrices, and multicollinearity, with no serious violations noted. There was no statistically significant difference between individuals who owned computers and those who did not, on the combined dependent variables, F = [1.726], p = [0.188]; Wilks' Lambda = [0.940]; partial eta squared = [0.060]. When the results for the dependent variables were considered separately, none of the differences reached statistical significance. An inspection of the mean scores indicated that the individuals who did not own computers reported the highest levels of perceived anxiety (M = 34.7, SD = 8.96) than the individuals who owned computers (M = 30.5, SD = 8.06), however, as indicated above this difference was not significant. A non-significant difference was also discovered with the mean scores of the skin conductance where individuals who did not own computers exhibited more computer anxiety (M = 0.3, SD = 0.39) than those who owned computers (M = 0.1, SD = 0.14).

Referring to the above-mentioned findings, the third hypothesis, $H_{0,3}$ with regard to computer ownership cannot be rejected, p > 0.05.

4.6.5 Factor 5: Educational attainment

A one-way between-groups multivariate analysis of variance was performed to investigate differences in anxiety among individuals who completed Grade 12 and those who did not. Two dependent variables were used: self-reported anxiety and skin conductance with the glove. The independent variable was educational attainment. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance covariance matrices, and multicollinearity, with no serious violations noted. There was no statistically significant difference between individuals who completed Matric and those who did not, on the combined dependent variables, F = [2.571], p = [0.086]; Wilks' Lambda = [0.913]; partial eta squared = [0.087]. When the results for the dependent variables were considered separately, none of the differences reached statistical significance. An inspection of the mean scores indicated that the individuals who had not completed Grade 12 reported the highest levels of perceived anxiety (M = 39.1, SD = 10.29) than the individuals who had completed Grade 12 (M = 32.5, SD = 8.13). However, as indicated above this difference was not significant. Similarly, the difference of the mean scores according to the skin conductance was non-significant. The individuals who had not completed Grade 12 exhibited more anxiety (M = 0.3, SD = 0.39) than those who had completed Grade 12 (M = 0.2, SD = 0.35).

Referring to the above-mentioned findings, the third hypothesis, $H_{0,3}$ with regard to educational attainment cannot be rejected, p > 0.05.

An overview of the findings in relation to the five independent variables is depicted in table 9; the dependent variables are self-reported anxiety from CARS and skin conductance with the sensor glove, for all five independent variables.

Table 9: Summary of findings regarding anxiety and selected factors

Statistical test	Independent variables	Means			Statistically Significant
			CARS	Glove	
One-way between-groups multivariate analysis of variance	Gender	Males	M = 32.1, SD = 7.77	M = 0.3, SD = 0.39	No
		Females	M = 35.0, SD = 9.53	M = 0.2, SD = 0.33	
	Age	16 to 25 years	M = 33.7, SD = 9.16	M = 0.2, SD = 0.31	No
		26 to 35 years	M = 32.7, SD = 8.79	M = 0.1, SD = 0.29	
		36 years and older	M = 36.9, SD = 8.48	M = 0.5, SD = 0.56	
	Computer experience	Less than 1 year	M = 34.9, SD = 8.12	M = 0.2, SD = 0.37	No
		Between 1 and 2 years	M = 30.3, SD = 8.13	M = 0.2, SD = 0.33	
		More than 2 years	M = 34.1, SD = 12.21	M = 0.17, SD = 0.35	
	Computer ownership	Own computer	M = 30.5, SD = 8.06	M = 0.1, SD = 0.14	No
		Do not own computer	M = 34.7, SD = 8.96	M = 0.3, SD = 0.39	
	Educational attainment	Completed Grade 12	M = 32.5, SD = 8.13	M = 0.2, SD = 0.35	No
		Did not complete Grade 12	M = 39.1, SD = 10.29	M = 0.3, SD = 0.39	

4.7 Observations

When the participants performed nine tasks on the computer, two measurements were recorded, namely the time-on-task and the task success rate. These are represented in the subsequent sections.

4.7.1 Time-on-task

A maximum of three minutes was allocated to each of the nine tasks that a participant was required to perform in a word processor application. Time-on-task was recorded for each task and when three minutes had elapsed the participant was asked to stop and continue with the next task, even if the current task was incomplete. Table 10 depicts the average, minimum and maximum time-on-task for each of the nine tasks.

Table 10: Average, minimum and maximum durations of tasks

Tasks	Average time-on-task (mm:ss)	Minimum time-on-task (mm:ss)	Maximum time-on-task (mm:ss)
Center	1:13	0:08	3:00
Change to Italic	0:49	0:06	3:00
Change line spacing	2:01	0:15	3:09
Cut & Paste	2:16	0:38	3:02
Change font size	0:39	0:06	3:00
Bold	0:37	0:06	3:00
Underline	0:56	0:13	3:00
Bullet	1:37	0:25	3:01
Save document	2:41	0:29	3:00

From table 10, it can be depicted that the last task 'Save document' was performed in the longest time (average = 2 min, 41 s), followed by 'Cut and Paste' (average = 2 min, 16s). The task which took the shortest time to be implemented was 'Bold' (average = 37 s) followed by 'Change font size' (average = 39 s).

4.7.2 Task success

The following table depicts an overview of the tasks which were accomplished successfully regardless of the extent in which they were accomplished – task success. The task success is reported as the percentage of participants who completed the task.

Table 11: Task success rate

Tasks	Task success (%)
Center	84.2
Change to Italic	84.2
Change line spacing	43.9
Cut & Paste	43.9
Change font size	84.2
Bold	93.0
Underline	89.5
Bullet	77.2
Save document	10.2

Table 11 shows that the task ‘Save document’ has the lowest task success rate, which means that the majority of participants failed to complete this task. However, the task ‘Bold’ was completed successfully by almost all participants. This finding is in agreement with the one made in 4.7.1 regarding the two tasks ‘Save document’ and ‘Bold’. This shows that the task that most participants failed to complete was the task that required the longest time to be performed.

In the following sections, a summary of the qualitative findings from the questionnaires as well as from observations is presented.

4.8 Findings from questionnaires data

The following are the findings made from the data collected from the pre-test and post-test questionnaires where different themes were discovered.

4.8.1 EREC sensor glove

Most of the participants described the glove using phrases such as “interesting” and “comfortable”. They stated that the glove did not disturb or distract them when performing the tasks on the computer although they were “conscious” that they were wearing it.

4.8.2 Emotions

The participants felt excited, afraid, neutral and frustrated while using the computer. However, the majority of them felt excited when they thought of using a computer, while they were using it, and even after using it. Regarding the tasks which they performed, the majority of the participants described that they were stressed rather than anxious or afraid. Most participants were stressed by the task “Save document”. The reasons that participants provided for being stressed and/or anxious include the following:

- Lack of knowledge on how to perform the task (example of expressions used: “I didn’t know how to do it” and “I had no idea where to find it”)
- Difficulty in performing the task (examples of expressions used: “It was tricky to do it” and “I struggled to do it”)
- Consciousness of time (examples of expressions used: “I ran out of time”, “I wanted to do it quickly” and “time was running out and I was not doing it”)
- Exercised caution to avoid mistakes (example of expressions used: “I was careful not to do mistakes” and “I was afraid of making mistakes, I didn’t want to do mistakes”)
- Uncertainty whether a task was performed correctly (examples of expressions used: “I didn’t know whether I did it correctly” and “I was not sure whether it was correct”)
- Lack of remembrance (examples of expressions used: “I know how to do it, but I couldn’t remember”, “I forgot how to do it”)
- First time experience (“It was my first time to do it”)
- Lack of confidence to execute the task correctly (“I didn’t trust myself to do it” and “I didn’t think I could do it”)

4.9 Findings from observations

The researcher observed the participants as they were executing the tasks. Some behaviours exhibited by the participants who were failing or struggling to perform the tasks were:

- Fidgeting in the chair
- Tapping fingers on the table
- Moving closer and away from the monitor
- Exclaiming in bewilderment or disappointment
- Sighing
- Shaking head in denial
- Constant blinking of eyes
- Trembling hands
- Uttering words (for example, words that pleaded with computer to do something)
- Staring at the monitor
- Holding the face with two hands with elbows on table

The researcher noticed that among the tasks that were performed, almost all the participants struggled with the last task, which was to save the document in a specified location. When they had to complete this task, most participants exhibited some of the above-mentioned behaviours. These behaviours were also noticed when participants performed the few beginning tasks. The researcher also observed that the majority of the females demonstrated the above-mentioned behaviours than the males did.

4.10 Overview

The findings from the statistical tests suggest that the EREC sensor glove and the CARS questionnaire potentially provide different information regarding levels of anxiety (no correlation between sensor glove and CARS questionnaire). However, a negative correlation was found between performance and anxiety. This relationship indicates that, as might be expected, the higher a person's levels of anxiety were, the poorer he/she performed on the assessment.

No significant differences were found regarding anxiety with respect to five factors (gender, age, computer experience, computer ownership, and educational attainment) when measured by the CARS questionnaire and the EREC sensor glove.

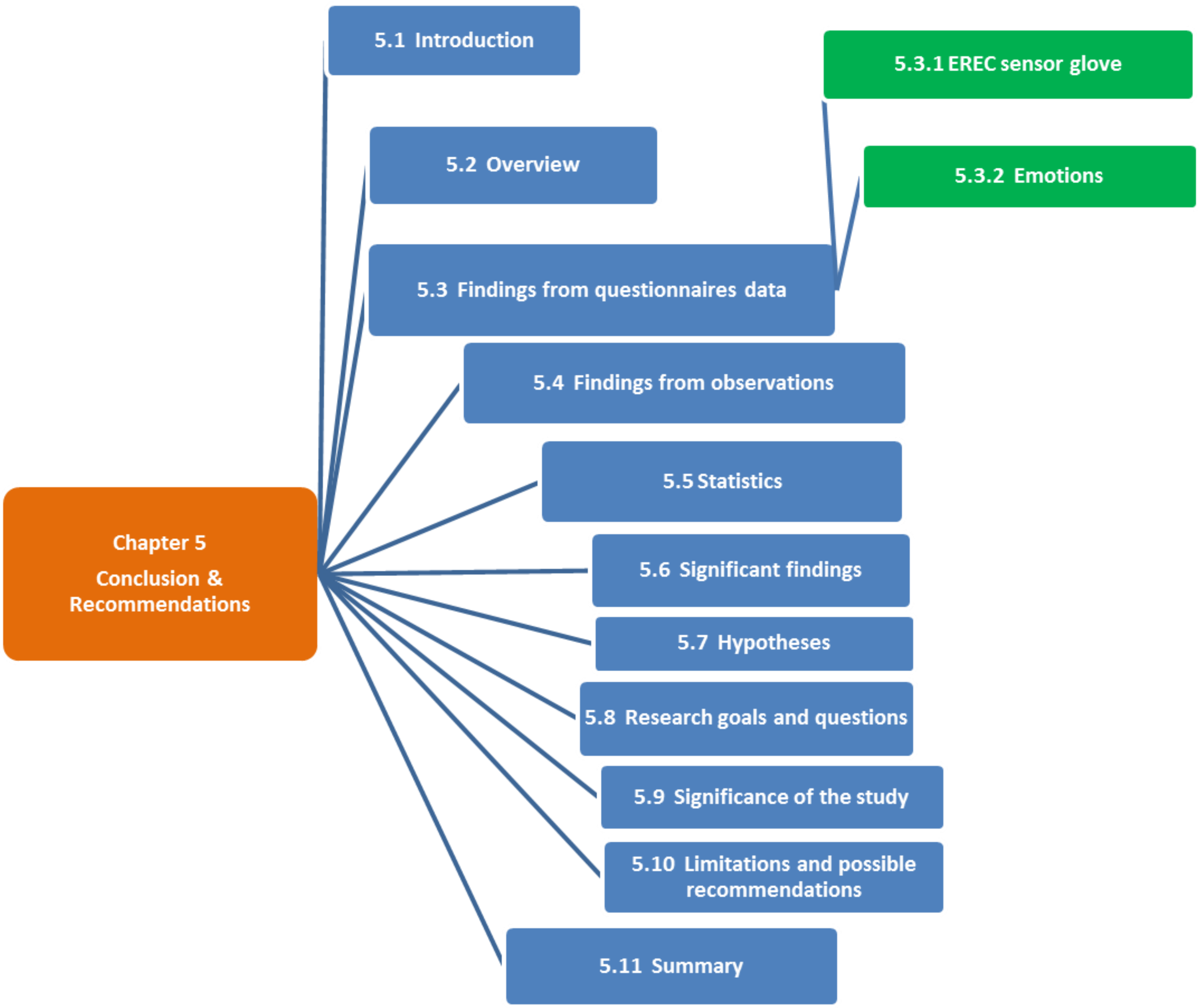
Regarding time-on-task and task success rate, the task (Save document) which most participants failed to complete successfully was the task that required the longest time to be performed. Conversely, the task (Bold) which was performed successfully by the majority of the participants, took the shortest time to be completed.

The majority of the participants reported to have experienced stress rather than anxiety when performing the tasks. The participants provided various reasons for experiencing stress/anxiety while performing the tasks. These reasons include experiencing difficulty to perform the tasks, and first time experience with executing certain tasks. The participants who struggled or failed to complete the tasks exhibited behaviour that could indicate anxiety or stress.

4.11 Summary

In this chapter the analysis of the data and findings were reported. In the next chapter the discussion will be on conclusions and recommendations.

CHAPTER 5 MAP



CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The previous chapter entailed analysis and findings of the empirical data. In this chapter conclusions based on the findings are drawn and recommendations for further research studies are made. The discussion commences with a summary of the study including the purpose for conducting the study.

5.2 Overview

In chapter 1 an introduction which provided a background about the study was made. Also included in the discussion was the problem statement, research questions, hypotheses, goals of the study, overview of the methodology, framework of the dissertation, limitations of the study, and the motivation that led to the research study. Chapter 2 discussed the research studies pertaining to computer anxiety, its correlates and existing measurements thereof. The measurements included anxiety questionnaires and instruments that measure physiological signals. The discussion in chapter 3 was based on the research design and the methodology employed to conduct the research study. The components of the research design were introduced and the specific components utilised in the research study were mentioned. In chapter 4 the analysis of the data and findings were presented.

Most of the research studies that investigated computer anxiety relied solely on questionnaires. As mentioned in section 1.1, this approach may lead to inaccurate results because questionnaires depend on the subjective responses of the participants. Taking this issue into consideration, the first goal as stated in the problem statement (see section 1.3), was to establish whether using a sensor glove provided complementary knowledge to an existing computer anxiety questionnaire when compared to anxiety questionnaires and observations. The second goal was to compare the computer anxiety of participants using a sensor glove and an anxiety questionnaire with relation to performance. The last goal was to compare the computer anxiety of participants using a sensor glove and an anxiety questionnaire with relation to the factors age, gender, computer experience, educational attainment, and ownership of a personal computer. To accomplish these goals, the following data collection methods were employed: CARS questionnaire, pre-test and post-test questionnaires, EREC sensor glove and observations. From the problem statement, three hypotheses were established.

In the following sections, discussions in relation to the findings from the questionnaires and the observations are presented.

5.3 Findings from questionnaires data

The following discussion is based considering the findings made in section 4.8 regarding the sensor glove and the emotions experienced by the participants.

5.3.1 EREC sensor glove

Since most participants found the glove to be “interesting” and “comfortable”, and that it did not disturb nor distract them (see section 4.8.1), it can be concluded that the sensor glove, as a measuring tool, is appropriate and can therefore be recommended for other studies.

5.3.2 Emotions

As stated in section 4.8.2, the participants experienced various emotions, which included excitement, anxiety (or fear) and frustration, while using the computer. It can be expected that the participants were excited and anxious at the same time because experiencing something interesting for the first time can be exciting. At the same time one can be somewhat afraid of the unknown. The feeling of frustration can also be expected when one fails to execute tasks especially when one “was careful not to do mistakes” or one felt that “time was running out and I was not doing it”, as some of the participants reported. It is most likely that participants experienced frustration which led to stress as they were performing the last task which most participants failed to complete. The majority of the participants mentioned that they felt stressed while performing the last task.

5.4 Findings from observations

Some behaviours exhibited by the participants who were failing or struggling to perform tasks (for example, sighing, shaking head in denial, and constant blinking of eyes) were observed by the researcher as mentioned in the previous chapter (see section 4.9). Some of the behaviours (for example, trembling) were mentioned in literature (Mayo Clinic, 2012; MedlinePlus Medical Encyclopedia, 2011) as behaviours common to individuals experiencing computer anxiety or stress. However, the researcher cannot state assuredly that the participants experienced anxiety or stress from the observed behaviours of the participants because the exhibited behaviours somehow overlap as signs of anxiety or stress.

In the subsequent sections statistical findings are reported.

5.5 Statistics

The following statistical tests were performed to determine the relationships between the following variables:

a. A correlation between *total scores on the CARS pre-test questionnaire* and the *average skin conductance reading during the first minute* of wearing the glove;
b. A correlation between *total scores on the CARS post-test questionnaire* and the *average readings on the glove during the entire assessment*;
c. A correlation between *total scores on the CARS post-test questionnaire* and the *average readings during the last minute of wearing the glove*;
d. A correlation between *total scores on the CARS post-test questionnaire* and the *average readings on the glove during the entire assessment*;
e. A MANOVA between three categories of anxiety levels according to the sensor glove (*high anxiety scores, medium anxiety scores* and *low anxiety scores*);
f. A correlation between the CARS pre-test score and performance score;
g. A correlation between the CARS post-test score and performance score;
h. A correlation between *average skin conductance readings on the sensor glove during the entire assessment* and *performance score.*

i. A MANOVA where dependent variables were self-reported anxiety and skin conductance with the glove. Independent variables were:
    - Gender
    - Age
    - Computer experience
    - Computer ownership
    - Educational attainment

5.6 Significant findings

Significant findings were not found in almost all the statistical tests performed. The statistical tests where significant findings were established were in relation to the relationship between anxiety and performance where significant negative correlation between the following variables were found:

a. The CARS pre-test score and performance score (significant negative correlation ($r = -0.331$; $p < 0.05$));
b. The CARS post-test score and performance score (significant negative correlation ($r = -0.332$; $p < 0.05$));
c. The average skin conductance readings on the sensor glove during the entire assessment and performance score (significant negative correlation ($r = -0.300$; $p < 0.05$)).

Considering these results on their own, it can be concluded that a relationship between performance and anxiety exist; the higher a person's levels of anxiety were, the poorer he/she performed on the assessment.

Having reported on the significant findings, the discussion focuses to the hypotheses that were tested.

5.7 Hypotheses

$H_{0,1}$: There is no correlation between CARS scores and conductance readings of the sensor glove before and after interaction with a computer.

Concerning the results of the correlation performed in sections 4.4.1, 4.4.2 and 4.4.3, where no significant results were found ($p > 0.05$), the above mentioned null hypothesis can be rejected. It can be stated therefore that the sensor glove and the computer anxiety questionnaire potentially provide different information regarding anxiety experienced before and after interaction with a computer.

$H_{0,2}$: There is no relationship between computer anxiety and performance as measured by a sensor glove and a computer anxiety questionnaire.

With regard to the second null hypothesis, a significant negative correlation in all three comparisons ($p < 0.05$) was found (see section 4.5). As a consequence, the second hypothesis cannot be rejected.

$H_{0,3}$: There is no difference in the anxiety information provided by a sensor glove and a computer anxiety questionnaire regarding the selected factors (age, gender, computer experience, educational attainment, and ownership of a personal computer).

Pertaining to the third null hypothesis, no significant results ($p > 0.01$)[1] among the selected factors (age, gender, computer experience, educational attainment, and ownership of a personal computer) were found on the combined dependent variables (self-reported anxiety and skin conductance with the glove) (see section 4.6). The null hypothesis can thus be rejected. It can therefore be stated that a sensor glove and a computer anxiety questionnaire provide different anxiety information regarding the selected factors (age, gender, computer experience, educational attainment, and ownership of a personal computer).

5.8 Research goals and questions

In view of the research goals, questions and findings made in this study, conclusions were drawn.

[1] Due to the number of MANOVA's that needed to be conducted, a Bonferroni adjustment was applied to the significance level. Thus, only p values smaller than (0.05/5) = 0.01 were considered significant.

The first goal was to establish whether using a sensor glove provided complementary knowledge to an existing computer anxiety questionnaire when compared to anxiety questionnaires and observations. Considering that it was found that the sensor glove and the CARS questionnaire provide different information regarding anxiety experienced before and after interaction with a computer (see section 5.7), a possible interpretation exists. It could be that the sensor glove does not measure the same variable as the CARS anxiety questionnaire. The CARS questionnaire has been validated as a measurement of anxiety while the sensor glove has not been validated for that specific measurement. The sensor glove measured skin conductance or GSR which according to literature (Healey, 2000; Lin & Hu, 2005; Picard, 1997), has been used successfully to measure stress. What remains to be investigated is the relationship (or a distinction) between computer anxiety and stress because it is evident that they, though different, are very closely related.

The second goal was to compare the computer anxiety of participants using a sensor glove and an anxiety questionnaire with relation to performance. This goal was achieved and the finding stated that a relationship between anxiety and performance probably exists. The relationship is that the higher an individual's levels of anxiety were, the poorer the individual performed on the assessment. This finding was also established by Glaister (2007) and Parayitam (2010). However, it was in disagreement with the finding of Olufemi and Oluwatayo (2014) who found no difference in performance scores. This also brings up the issue that it is difficult to distinctly separate stress and anxiety as previously mentioned. This issue is in agreement with what was found in the observations. The task that the participants failed to complete was the one reported to cause the highest stress. In effect, the majority of the participants indicated that they experienced stress rather than anxiety as they were performing the tasks.

The third goal was to compare the computer anxiety of participants using a sensor glove and an anxiety questionnaire with relation to the selected factors (age, gender, computer experience, educational attainment, and ownership of a personal computer). The findings indicated that although differences were found among the five selected factors, those differences were not statistically significant. This was found considering the CARS scores and the sensor glove readings. Since CARS has been validated, its results would be more reliable in this regard even though the sensor glove also provided similar results. It can therefore be concluded that computer anxiety was the same regardless of the age, gender, computer experience, educational attainment, and ownership of a personal computer.

With reference to age, the findings in this research study are in agreement with the findings of Hismanoğlu (2011) and Ademola and Idou, (2013). The findings of this research study state that no significant difference was found with regard to gender and computer anxiety. This finding was also discovered in a number of research studies (Ademola & Idou, 2013; Havelka, Beasley, & Broome, 2004; Olatoye, 2009; Shah et al., 2012). Regarding the influence of computer experience on computer anxiety, the findings from this study disagree with a number of findings such as Bovée, Voogt, and Meelissen (2007), Broos (2005), and Talebi, Zare, Sarmadi, and Saeedipour (2012). Perhaps the measure which was used for computer experience was insufficient for this particular study. Incorporating multiple measures (for example, duration of computer use, and number of hours per week of using a computer) might have given results that agree with the various literature studies. In this study, the number of hours per week of using a computer could not be used as a measurement for computer experience because the question was ambiguous to the participants. Some participants were rather confused with whether to mention the period when they attended the free one-week training program where they used the computer for 2 hours every day or the period preceding the training where they used a computer in varying hours per week.

The findings of this study relating to educational attainment disagree with the findings of Tuncer et al. (2013) who stated that educational attainment is inversely correlated to computer anxiety. The findings also differ from the findings of the study conducted by Simsek (2011) where educational attainment was found to correlate positively with computer anxiety. Pertaining to the last factor, ownership of a personal computer, the findings of this research study agree with the findings of Hismanoğlu (2011) who found no significant difference between individuals who owned personal computers and those who did not.

The first research question was stipulated as follows:

- *To what extent does a sensor glove add value in measuring computer anxiety during usability testing when compared to anxiety questionnaires and observations?*

With regard to the above-mentioned research question, it can be concluded that the sensor glove does not add value. Instead, the sensor glove may add value when measuring stress because the skin conductance (measured by the glove) correlated with the performance. Skin conductance was used where a relationship between stress and performance was established in the research study conducted by Lin and Hu (2005).

The second research goal was stated as follows:

- *To what extent is computer anxiety influenced by age, gender, computer experience, educational attainment, and ownership of a personal computer according to the anxiety questionnaire and the sensor glove?*

Pertaining to the second research question, it can be concluded that computer anxiety was not influenced by age, gender, computer experience, educational attainment, and ownership of a personal computer according to the anxiety questionnaire and the sensor glove.

5.9 Significance of the study

There are limited research studies related to computer anxiety in Africa. Moreover, the literature revealed that more research in RSA was necessary using both subjective and objective measures. This study has managed to investigate computer anxiety using the subjective (scores from an anxiety questionnaire) and objective (conductance data from the sensor glove) measures and similar findings regarding computer anxiety and performance were established. The findings state (and substantiate the literature) that the higher the anxiety levels of an individual, the poorer they are likely to perform.

Additionally, the findings indicate that in the sample that was investigated for this research study, computer anxiety was not affected by gender, age, computer experience, computer ownership, and educational attainment. This finding is also confirmed by using both the conductance data from the sensor glove and the scores obtained from an anxiety questionnaire.

For these reasons, this study adds to the understanding regarding computer anxiety in the South African context.

5.10 Limitations and possible recommendations

It is worth mentioning that this study had limitations which could have influenced the outcomes. The limitations are discussed here, as well as possible recommendations for follow-up studies.

Firstly, the skin conductance readings of one minute before and after interaction with the computer, which were compared with the scores on the CARS pre-test and post-test questionnaire may not have been optimal. This could have resulted in the results of no correlation between the sensor glove and the CARS. There was no literature found that stated the optimal duration for reading the conductance. The researcher suggests that a research study could be conducted where an optimal time could be established for measuring the conductance using the sensor glove.

Secondly, the researcher found it rather thought-provoking that the sensor glove and the anxiety questionnaire provided similar findings regarding the correlation between computer anxiety and performance, yet they provided different findings regarding anxiety before and after assessment. Moreover, the findings from using the sensor glove and the anxiety questionnaire yielded similar results regarding the five correlates of computer anxiety. These findings call for deeper investigation in relation to objective and subjective measures of computer anxiety in the context of South Africa.

Thirdly, direct observation was conducted while the participants were performing tasks in this study. Since the participants were aware that they were being observed, there is a possibility that the results were biased. Perhaps a study conducted with participants who are oblivious of being watched would produce different results.

Fourthly, since the start of this study, newer and improved versions of the sensor glove have appeared on the market. However, the glove used in this study was small and volatile (as mentioned in section 3.7.2.2). Using the improved version of the glove in similar investigations might provide interesting results.

The final recommendation for follow-up studies is to establish the relationship between anxiety and stress. Perhaps a study could be conducted where both anxiety and stress questionnaires are employed. The data from the two questionnaires could be compared to conductance data from the sensor glove. It is probable that the findings of such a study would provide more insight about anxiety and stress when interacting with a computer. A study that utilised a stress questionnaire and conductance data (Lin & Hu, 2005) has already been performed. However, an anxiety questionnaire was not included in that study.

5.11 Summary

In this chapter an overview of the study was presented. The goals and hypotheses were revisited as the conclusions from the findings were established. The limitations of the study were also discussed, and the suggestions for further studies which could improve the current study, were made.

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APPENDICES

Appendix A - Computer Anxiety Rating Scale[2]

INSTRUCTIONS: Please read each item below and respond to it by choosing one of the responses on the scale from (1) to (5), where (1) = strongly disagree and (5) = strongly agree. Do not write in numbers between these choices, only numbers 1, 2, 3, 4, or 5 are options.

	Strongly disagree				Strongly agree
1. I feel insecure about my ability to interpret a computer printout.	(1)	(2)	(3)	(4)	(5)
2. I look forward to using a computer.	(1)	(2)	(3)	(4)	(5)
3. I do not think I would be able to learn a computer programming language.	(1)	(2)	(3)	(4)	(5)
4. The challenge of learning about computers is exciting.	(1)	(2)	(3)	(4)	(5)
5. I am confident that I can learn computer skills.	(1)	(2)	(3)	(4)	(5)
6. Anyone can learn to use a computer if they are patient and motivated.	(1)	(2)	(3)	(4)	(5)
7. Learning to operate computers is like learning any new skill - the more you practice, the better you become.	(1)	(2)	(3)	(4)	(5)
8. I am afraid that if I begin to use computers I will become dependent upon them and lose some of my reasoning skills.	(1)	(2)	(3)	(4)	(5)

[2] Heinssen, J., R., Glass, C, and Knight, L. (1987). Assessing computer anxiety: Development and validation of the Computer Anxiety Rating Scale. *Computers in Human Behavior*, 3, 49-59. Retrieved 28 July, 2010, from http://www.usm.maine.edu/com/carssc~1.pdf

9. I am sure that with time and practice I will be as comfortable working with computers as I am in working with a typewriter.	(1)	(2)	(3)	(4)	(5)
10. I feel that I will be able to keep up with the advances happening in the computer field.	(1)	(2)	(3)	(4)	(5)
11. I dislike working with machines that are smarter than I am.	(1)	(2)	(3)	(4)	(5)
12. I feel apprehensive about using computers.	(1)	(2)	(3)	(4)	(5)
13. I have difficulty in understanding the technical aspects of computers.	(1)	(2)	(3)	(4)	(5)
14. It scares me to think that I could cause the computer to destroy a large amount of information by hitting the wrong key.	(1)	(2)	(3)	(4)	(5)
15. I hesitate to use a computer for fear of making mistakes that I cannot correct.	(1)	(2)	(3)	(4)	(5)
16. You have to be a genius to understand all the special keys contained on most computer terminals.	(1)	(2)	(3)	(4)	(5)
17. If given the opportunity, I would like to learn about and use computers.	(1)	(2)	(3)	(4)	(5)
18. I have avoided computers because they are unfamiliar and somewhat intimidating to me.	(1)	(2)	(3)	(4)	(5)
19. I feel computers are necessary tools in both educational and work settings.	(1)	(2)	(3)	(4)	(5)

Appendix B- Computer Experience: Pre-Test Questionnaire

Please fill in this questionnaire with all honesty. All information will be handled confidentially and will be used for the purpose of the research only.

Indicate your choice by ticking the appropriate answer. Only tick one option, unless being advised otherwise.

Demographic data

1. Gender
   ☐ Male ☐ Female
2. Which age group (in years) do you belong to?
   ☐ 16-20 ☐ 21-25 ☐ 26-30 ☐ 31-35 ☐ 36-40 ☐ >40
3. What is your home language?
   ☐ English ☐ Sotho/Tswana ☐ Afrikaans ☐ Other, specify:_____________

Educational background

4. Have you completed grade 12 or matric?
   ☐ Yes ☐ No

5. If your answer to question 4 is 'yes', please answer the following questions:
   5.1. When did you matriculate?
   ☐ Before 2007 ☐ In 2007 ☐ After 2007

   5.2. What symbol did you obtain in grade 12?
   ☐ A ☐ B ☐ C ☐ D ☐ E ☐ F

   5.3. Did you study Mathematics as one of your grade 12 subjects?
   ☐ Yes ☐ No

   5.4. If you studied Mathematics in grade 12, on which level?
   ☐ Mathematical literacy
   ☐ Mathematics
   ☐ Mathematics Standard Grade
   ☐ Mathematics Higher Grade

   5.5. If you studied Mathematics at grade 12, what symbol did you obtain?
   ☐ 1 = 80% and above
   ☐ 2 = 70% and above
   ☐ 3 = 60% and above
   ☐ 4 = 50% and above
   ☐ 5 = below 50%
6. If your answer to question 4 is 'no', what is your highest level of education?
   ____

Computer experience

7. Do you consider yourself as computer literate?
   ☐ Yes ☐ No
8. If your answer to question 7 is no, please answer the following two questions:
   8.1. Would you like to become computer literate?
   ☐ Yes ☐ No
   8.2. Why?____
   ____
9. For how long have you been using a computer?
   ☐ Less than 1 year ☐ Between 1 and 2 years ☐ More than 2 years
10. Do you own a computer?
    ☐ Yes ☐ No
11. If you do not own a computer, where do you access it?
    ☐ Internet café ☐ School ☐ Other, specify:___________
12. At what age (years) did you start using a computer? Choose appropriate age range.
    ☐ <5 ☐ 5-12 ☐ 13-20 ☐ 21-28 ☐ 29-36 ☐ >36

13. On average, how many hours in a day do you spend using a computer?
    ☐ Less than 1 hour
    ☐ Between 1 and 2 hours
    ☐ Between 2 and 3 hours
    ☐ More than 3 hours

14. On average, how frequently do you use a computer in a week?
    ☐ Once ☐ 2 times ☐ 3 times ☐ 4 times ☐ 5 times ☐ >5 times

15. Which programs have you used on a computer? You may tick more than one option.
    ☐ Microsoft Office Word ☐ Microsoft Office PowerPoint
    ☐ Microsoft Office Excel ☐ Microsoft Office Access
    ☐ Internet Explorer ☐ Firefox
    ☐ None of the above
    ☐ Other(s), Specify:____

16. How do you feel when you have to use a computer? You may tick more than one option.
    ☐ Excited ☐ Afraid ☐ Neutral ☐ Frustrated ☐ Other, specify:___________
17. How did you feel when you first started using a computer? You may tick more than one option.
    ☐ Excited ☐ Afraid ☐ Neutral ☐ Frustrated ☐ Other, specify:___________
18. If your answers in question 16 and 17 are different, what changed your feelings about computers?
    ____

Thank you for your time.

Appendix C- Computer Experience: Post-Test Questionnaire

Please fill in this questionnaire with all honesty. All information will be handled confidentially and will be used for the purpose of the research only.

Indicate your choice by ticking the appropriate answer. You may tick more than one option.

1. How did you feel when you *thought* of using a computer?
   ☐ Excited ☐ Afraid ☐ Neutral ☐ Frustrated ☐ Other:_____________
   ____
2. How did you feel *while you were using* the computer?
   ☐ Excited ☐ Afraid ☐ Neutral ☐ Frustrated ☐ Other:_____________
   ____
3. How do you feel *now after* using the computer?
   ☐ Excited ☐ Afraid ☐ Neutral ☐ Frustrated ☐ Other:_____________
   ____
4. Were there times when you felt anxious/afraid or stressed while you were performing the following tasks using the computer? If so, please tick in the appropriate box and state why you think you experienced the feeling.

Tasks	**Anxious/ Afraid**	**Stressed**	**Reason**
4.1. Center 6 lines			
4.2. Changing to Italic			
4.3. Change line spacing			
4.4. Cut & Paste			
4.5. Change font size			

Tasks	Anxious/ Afraid	Stressed	Reason
4.6. Bold			
4.7. Underline			
4.8. Bullet			
4.9. Save document			

5. If you did not feel anxious/afraid or stressed, please answer the following two questions:
   5.1. Why do you think you were not anxious/afraid or stressed? ____________________
   ____
   ____
   5.2. Which tasks do you think can make you feel anxious/afraid or stressed? ___________
   ____
   ____

6. For the following questions, please tick in the box that best describes your experience with the tasks mentioned in question 4.

	1 Strongly agree	2 Agree	3 Not sure	4 Disagree	5 Strongly disagree
6.1. I found the tasks to be frightening.					
6.2. I found the tasks to be boring.					
6.3. I enjoyed performing the tasks.					
6.4. I found it easy to perform the tasks.					
6.5. Performing the tasks was exciting.					

6.6. I felt neutral when performing the tasks.					

7. Were you conscious that you were wearing the glove the whole time you were performing the tasks on the computer?
☐Yes ☐No

8. Did the glove disturb/distract you when you were performing tasks on the computer?
☐Yes ☐No

9. Which of the following best describes how comfortable you were with the glove?
☐ Very Uncomfortable ☐Uncomfortable ☐ Not sure ☐ Comfortable ☐ Very comfortable

10. Which of the following describes your general opinion about the glove?
☐Strange ☐Exciting ☐Interesting ☐Other, specify:_________________

11. Which statement best describes the amount of time taken to set up the glove to work?
☐ Very long ☐ Long ☐ Not sure ☐Short ☐Very short

12. Did wearing the heart rate monitor disturb/distract you when you were performing the tasks on the computer?
☐Yes ☐No

13. Would you participate again in a research study similar to the one you are in now?
☐Yes ☐No

14. If your answer to question 14 is 'yes', please provide your contact number.
Tel/Cell: _______________

Your participation is greatly appreciated. Thank you.

Appendix D- Consent Form

Research title: Comparing the Sensor Glove and Questionnaire as Measures of Computer Anxiety

Researcher: Tlholohelo Nkalai, Masters student at the Department of Computer Science and Informatics

Email: mohasoats@ufs.ac.za Tel: 051 401 2331

I state that I wish to participate in the research study conducted by Tlholohelo Nkalai at the Department of Computer Science and Informatics in the University of the Free State.

I understand that the purpose of the research study is to investigate the emotions that are experienced by users when using a computer. I understand that I will be asked to fill in 2 questionnaires firstly. Then I will perform tasks on the computer while wearing both a sensor glove and a heart rate chest belt. Neither the sensor glove nor the chest belt will harm me in any way. The tasks I will perform include using Microsoft Word. The researcher will observe me as I complete the tasks and afterwards I will be asked questions about my experience by means of questionnaires. The study is expected to take about 30 minutes.

All information collected in this study will be treated with confidentiality, and my name will not be disclosed at any time.

I understand that my participation is voluntary and that I am free to ask questions or withdraw from participating at any time without penalty.

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

Appendix E- Transportation Consent Form

Transportation to University of the Free State for Research Participation

I, ____________________ (Id nr: ________________________) declare that I have given **Mrs. Tlholohelo Nkalai** permission to transport me in her vehicle (VW Polo, with registration number AM104) from Mangaung University of the Free State Community Partnership Programme (MUCPP) center in Mangaung to the University of the Free State (UFS) main campus in Nelson Mandela Drive in Bloemfontein, and back to MUCPP.

I have volunteered to participate in a research study conducted by Mrs Nkalai in the Department of Computer Science and Informatics at UFS towards obtaining her M.Sc degree. The research will be conducted in the usability laboratory of the Department of Computer Science & Informatics with specialized equipment and therefore participants need to be transported to the main campus.

Mrs Nkalai has a valid driver's license and is a responsible driver. Therefore I will put no blame on her should we be involved in incidents of hijacking, an accident, or the like which are beyond her control.

PARTICIPANT

Name and surname: ____________________

Signature: ___________________

Date: ____________________

RESEARCHER: Tlholohelo Nkalai

Signature:____________________

Date:__________________

Appendix F- Tasks Performed by participants

<u>Tasks performed using Microsoft Word 2007</u>

<u>Instructions</u>*: Apply the following changes to the document you will open.*

1. **Center** all the 6 lines of text located above the word ‘HEALING’.
2. Change the format of the previous 6 lines to **italic**.
3. Change the **line spacing** of all the paragraphs to 2.0 (exclude the previous 6 lines).
4. Using **Cut & Paste**, remove the word ‘HEALING’ where it is and place it in the first line, as the title of the document.
5. Change the **font size** of the word ‘HEALING’ to size 14.
6. **Bold** the phrase ‘Proverbs 4:20-22’.
7. **Underline** the phrase ‘Exodus 15:26’.
8. **Bullet** the last 3 points using the bullets of your choice.
9. Save your document in C drive, however name it your own name and surname, for example, **Tlholohelo Nkalai**.

A B B R E V I AT I O N S

BAI: Beck Anxiety Inventory

BSCAS: Beckers and Schmidt Computer Anxiety Scale

CAIN: Computer Anxiety Index

CARS: Computer Anxiety Rating Scale

CAS: Computer Attitude Scale

EREC: Emotion RECognition system (also referred as sensor glove)

MANOVA: Multivariate Analysis of Variance

GLOSSARY

Anxiety

Anxiety is defined as “a feeling of nervousness, apprehension, fear, or worry”. Anxiety is expected in situations such as when one is anticipating of writing a test, examination or quiz. However, anxiety is problematic when it prevents one to sleep or to function. Physical symptoms of anxiety may be upset stomach, diarrhea, breathing difficulty, feeling as if you are going to faint or have a heart attack (Dryden-Edwards, 2007).

Computer anxiety

This is an emotional fear or phobia experienced by individuals when using computers or when thinking of using computers (Chua, Chen, & Wong, 1999).

Computer illiterate users

These are people who have slight or no experience with using computers.

Usability

The International Standards Organization Usability (ISO 9241 – 11) defines usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.” Effectiveness is defined as “accuracy and completeness with which users achieve specified goals” while efficiency refers to “resources expended in relation to the accuracy and completeness with which users achieve goals”. Lastly, satisfaction is defined as freedom from discomfort, and positive attitudes towards the use of the product” (ISO 9241 – 11).

Usability Testing

Usability testing is a process whereby a product is assessed to determine whether it is usable by the intended users in order to accomplish the tasks it was developed for

(Dumas & Reddish, 1999).

Physical awareness

This term is sometimes referred in literature as physical arousal. It has been used to describe the physical changes such as sweating or breathing, which are attributed to body changes in reaction to fear or anxiety or as a flight/ fright response.

SUMMARY

A vast amount of literature regarding computer anxiety exists. Consequently, a number of researchers have discovered different definitions for computer anxiety. Regardless of the numerous definitions, several researchers agree that computer anxiety involves emotional ‘fear’ or ‘apprehension’ when interacting or anticipating interaction with computers. Subsequently, some individuals who experience computer anxiety avoid using computers. This situation is undesirable because these days it is almost always a necessity for people to use computers in the workplace. It is therefore important to extensively investigate computer anxiety including measures which can be implemented to mitigate it.

Different findings about computer anxiety regarding the correlates: gender, age, computer ownership, educational attainment and computer experience, exist. For example, while some research findings state that females experience higher levels of computer anxiety than males, other research findings assert that males experience computer anxiety more than the females. The contradictory findings regarding the correlates of computer anxiety could be attributed to the fact that most of the research studies which investigated computer anxiety relied solely on existing computer anxiety questionnaires. Using questionnaires exclusively poses various limitations which include relying on the ‘subjective’ responses of the participants. This research study incorporated another measurement of computer anxiety in addition to an existing computer anxiety questionnaire named Computer Anxiety Rating Scale. This additional measurement was performed using an instrument that measured physiological signals of a participant. The instrument is called an Emotion RECecognition system (EREC). It measures skin temperature and skin resistance and heart rate. Apart from the mentioned two, other data collection methods were used which are pre-test and post- test self-developed questionnaires, observations and interviews.

With various measurements incorporated in this study, computer anxiety was investigated taking into consideration the following research questions:

- *To what extent does a sensor glove add value in measuring computer anxiety during usability testing when compared to anxiety questionnaires and observations?*

- *To what extent is computer anxiety influenced by age, gender, computer experience, educational attainment, and ownership of a personal computer according to the anxiety questionnaire and the sensor glove?*

From the findings of the study in relation to the first research question, it can be concluded that the sensor glove does not add value. Instead, the sensor glove may add value when measuring stress. This means that although the EREC sensor glove measures skin conductance, changes in skin conductance may indicate changes in stress levels rather than anxiety levels. Regarding the second research question, it can be concluded that computer anxiety was not influenced by age, gender, computer experience, educational attainment, and ownership of a personal computer according to the anxiety questionnaire and the sensor glove.

Keywords: Emotion Recognition system, computer anxiety, emotion, skin conductance, physiological signals, gender, age, computer ownership, educational attainment, and computer experience.

OPSOMMING

Daar is ‘n geweldige groot hoeveelheid literatuur beskikbaar ten opsigte van rekenaar-angstigheid. Gevolglik bestaan daar ‘n groot aantal verskillende definisies t.o.v. rekenaar-angstigheid. Ten spyte van die baie definisies, stem navorsers tog ooreen dat rekenaar-angstigheid emosionele vrees of vooropstelling insluit wanneer daar ‘n persoon met ‘n rekenaars werk, of selfs net daaraan dink dat hy met ‘n rekenaar moet werk. Die gevolg is dat sommige persone wat hieraan ly dit heeltemal vermy om met ‘n rekenaar te werk. Hierdie is nie die ideale toestand van sake nie aangesien dit bykans onmoontlik is om vandag sonder ‘n rekenaar in ‘n werkomgewing te funksioneer. Dit is daarom dit so belangrik is om deeglike navorsing te doen t.o.v. rekenaar-angstigheid, sowel as die maatreëls wat geïmplementeer kan word om dit aan te spreek.

Verskillende gevolgtrekkings rakende die korrelate: geslag, ouderdom, besit van ‘n rekenaar, opvoedkundige vlak sowel as rekenaar-ervaring bestaan. Byvoorbeeld, sommige navorsingsresultate dui daarop dat die vroulike geslag hoër vlakke van rekenaar-angstigheid ervaar as hul manlike eweknieë, terwyl ander verslae weer die teenoorgestelde aandui. Hierdie teenstrydige resultate rakende die korrelate van rekenaar-angstigheid kan toegeskryf word aan die feit dat die meeste van die navorsingstudies wat hierdie fenomeen ondersoek, gebruik gemaak het van bestaande vraelyste. Deur slegs van vraelyste gebruik te maak plaas ‘n geweldige beperking op die navorsingsresultate daar slegs staat gemaak word op die “subjektiewe” terugvoer van die deelnemers. Hierdie navorsingstudie het, bo en behalwe die bestaande vraelyste, ook gebruik gemaak van ‘n alternatiewe metode om rekenaar-angstigheid te meet, naamlik die “Computer Anxiety Rating Scale”. Hierdie addisionele meting is gedoen deur gebruik te maak van ‘n instrument wat die fisiologiese tekens van ‘n deelnemer meet. Hierdie instrument staan bekend as die “Emotion RECognition system (EREC)”. Dit meet ‘n deelnemer se vel-temperatuur, vel-weerstand sowel as die tempo van sy hartklop. Afgesien van bogenoemde twee metodes, is daar ook gebruik gemaak van ander metodes om data te ersamel, bv. pre- en post-toets, self-ontwikkelde vraelyste, observasies en onderhoude.

Deur verskillende metodes te inkorporeer in hierdie navorsingstudie, is rekenaar-angstigheid ondersoek ten opsigte van die volgende navorsigingsvrae:

- Tot watter mate voeg die gebruik van ‘n sensor-handskoen waarde tot die meting van rekenaar-angstigheid tydens ‘n bruikbaarheidstudie in vergelyking met rekenaar-angstigheid vraelyste en observasies?
- Tot watter mate word rekenaar-angstigheid beïnvloed deur ouderdom, geslag, rekenaar-ondervinding, opvoedkundige vlak en besit van ‘n persoonlike rekenaar na aanleiding van die angstigheid-vraelyste en die sensor-handskoen?

Dit blyk uit die resultate van die studie, ten opsigte van die eerste vraag, dat die handskoen nie waarde toegevoeg het nie. Inteendeel, die sensor-handskoen kan eerder met sukses gebruik word om stresvlakke te meet. Dit beteken dat, alhoewel die EREC sensor-handskoen vel-weerstand meet, veranderinge in vel-weerstand ‘n verandering in stresvlakke kan aandui eerder as angstigheidsvlakke. Ten opsigte van die tweede vraag, kan dit aanvaar word dat rekenaar-angstigheid nie beïnvloed word deur ouderdom, geslag, rekenaar-ondervinding, opvoedkundige vlakke en besit van ‘n rekenaar nie, aldus die resultate van die angstigheid-vraelyste en die sensor-handskoen.

Sleutelwoorde: “Emotion Recognition System”, rekenaar-angstigheid, emosies, vel-weerstand, fisiologiese tekens, geslag, ouderdom, besit van ‘n rekenaar, opvoedkundige vlak en rekenaar-ervaring.