HUMAN COGNITIVE PERFORMANCE: A NEUROPHYSIOLOGICAL ASSESSMENT OF THE IMPACT THAT REVERSE ASSESSMENT PRIMING HAS ON MENTAL WORKLOAD, PERFORMANCE AND COGNITIVE EFFICIENCY DURING TRANSIENT INFORMATION PROCESSING

A Thesis submitted by

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Abstract

This study assessed cognitive efficiency (CE) during transient information processing by capturing the neural activity experienced during the completion of varying levels of cognitive processing. The study researched the impact of low versus high cognitive demand on transient information and the effect that reverse assessment priming has on overall neural activity, and the correlations of mental workload (MWL) with performance and with CE. In total, 13 university students and staff members from the University of Southern Queensland participated in both low and high cognitive demand level experiments. Experiment 1 consisted of a low level transient information processing task and Experiment 2 involved a high level transient information task.

All participants completed both control intervals and test intervals for both experiments. Test intervals included the provision of a reverse assessment priming strategy prior to the presentation of the Transient Information Processing Task (TIPT) stimuli. All students were asked to complete a handiness, demographic, general health and prior knowledge questionnaire to enable consistency across the experimental groups. Students were matched and presented with a TIPT whereby they were deemed to have no or very minimal prior exposure to and knowledge of the topic.

The TIPTs presented were either two minutes or four minutes in duration and were in auditory format. Topics were made up of an even mix of animals and countries. The study aimed to analyze the CE further; this was achieved by the students completing a written multiple choice assessment immediately following each TIPT. Results highlighted the extent to which working memory capacity depletes as the complexity of transient information increases. Whilst the assessment results demonstrated the students' working memory ability to process transient information, the procedure is difficult by nature owing to the inability of information to be decoded, processed and encoded without an opportunity to review and transfer it into a more permanent state or to link it to previous schematic networks.

Results emphasised the impact and benefit of using the reverse assessment priming strategy in reducing the cognitive demand placed on an individual by the MWL experienced so that human performance scores were augmented along with an increase in CE during transient information processing.

This study provides objective evidence that the MWL from a neurophysiological measure differs between a low cognitive demanding TIPT and a high cognitive demanding TIPT in both settings where subjects completed the low and high TIPT (control) tasks and the low and high TIPT reverse assessment processing stimuli (RAPS) (test) tasks. This enables an insight into the degree to which brain activity responds to a change in stimuli and, in particular, transient information whereby the individual is unable to make a more permanent record or has control over the speed or mode in which the information is presented in order to process the incoming information within working memory. The duration of each stimulus was what differentiated the low cognitive demanding task and the high cognitive demanding task; therefore results indicate that the longer that an individual attempts to process continually presented transient information, the more MWL increases. The neural activity increased in 91% of subjects between the low and high TIPT (control) tasks and 75% of subjects between the low and high RAPS (test) tasks.

Results indicated that the use of RAPS has a minimal impact on the MWL imposed during a low cognitive demanding TIPT. However, the use of RAPS can prove to be an effective strategy in reducing the MWL experienced during a high cognitive demanding TIPT. RAPS had a minimal effect on the low cognitive demanding tasks, although as the level of the task complexity increased so too did the positive impact of using RAPS. It has been established that the use of RAPS is an effective strategy to reduce MLW during a TIPT; in this study it resulted in a decrease of up to 34.64% in MWL.

The results of this study indicated that the use of RAPS resulted in a positive impact on the performance results achieved across both low and high level TIPTs in all possible situations. The study outcomes demonstrated that in 100% of subjects an increase was achieved in the human performance between the low TIPT (control) and low TIPT RAPS (test) tasks, recording an increase of up to 40% in performance scores achieved. Similarly, during the high TIPT (control) and high TIPT RAPS (test) intervals, wherever an increase was possible, 100% of situations experienced an increase in performance scores of up to 80%.

The findings demonstrated that the use of RAPS had a positive impact on, and promoted an increase in, the CE that can be achieved during a TIPT. This discovery plays an important role in the overall wellbeing of human capital; the emphasis placed

on human performance should no longer be at an individual’s expense. Human performance practices can utilise these findings to allow a balanced metric and enable a change in mind set from an outdated human performance paradigm to a truly human centered approach that considers the person’s cognitive capacity. CE has been increased as a result of using RAPS, demonstrating an 8% increase in subjects achieving an above average >0 CE score between the control and test intervals. This result supported the argument that RAPS had a positive impact on the overall CE achieved during a TIPT.

Certification of Thesis

This thesis is entirely the work of Kylie Hutchings Mangion except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

Student and supervisors signatures of endorsement are held at USQ.

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Dedication

I am dedicating this study to the person who planted the seed of belief: Mum, Janice Roslyn Hutchings, known as “Ma” by her grandchildren. Mum believed that her children would all achieve in their own way. She encouraged me to have trust in my own ability; I would not have embarked on this journey if it weren’t for her. This study would not have happened; the milestones achieved in order to be offered a doctoral opportunity are a direct result of the perseverance and self-efficacy instilled in us as children. The completion of this doctoral thesis is a culmination of paying respect to my mum for believing in me, giving back to her selfless nature and putting to good use the resilience that she showed us through her own life’s journey. Mum, it was your beautiful heart that left an impression that will last forever; thank you. I can only hope that I too can inspire my daughters also to work towards and follow their dreams and enjoy the opportunities that come their way.

Abbreviations

α	Alpha
β	Beta
CACL	Collective average cognitive load
CE	Cognitive efficiency
CL/CD	Cognitive load and cognitive demand have been used synonymously
EEG	Electroencephalogram
ERD	Event related desynchronisation
ERS	Event related synchronisation
HCD	High cognitive demand
HCEPM	Human capital efficiency performance and management
LCD	Low cognitive demand
MWL	Mental workload
ϴ	Theta
PARI	Phonological attention rehearsal interruption
RAPS	Reverse assessment priming strategy
TIPT	Transient information processing task
UHCI	Unique human cognitive investment
µV	Microvolts

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Chapter 1 Introduction

This introduction chapter aims to provide the contextual setting for the study - including the problems faced within the field of study, the explicit purpose of the research and the significance of this uniquely positioned multi-disciplinary investigation.

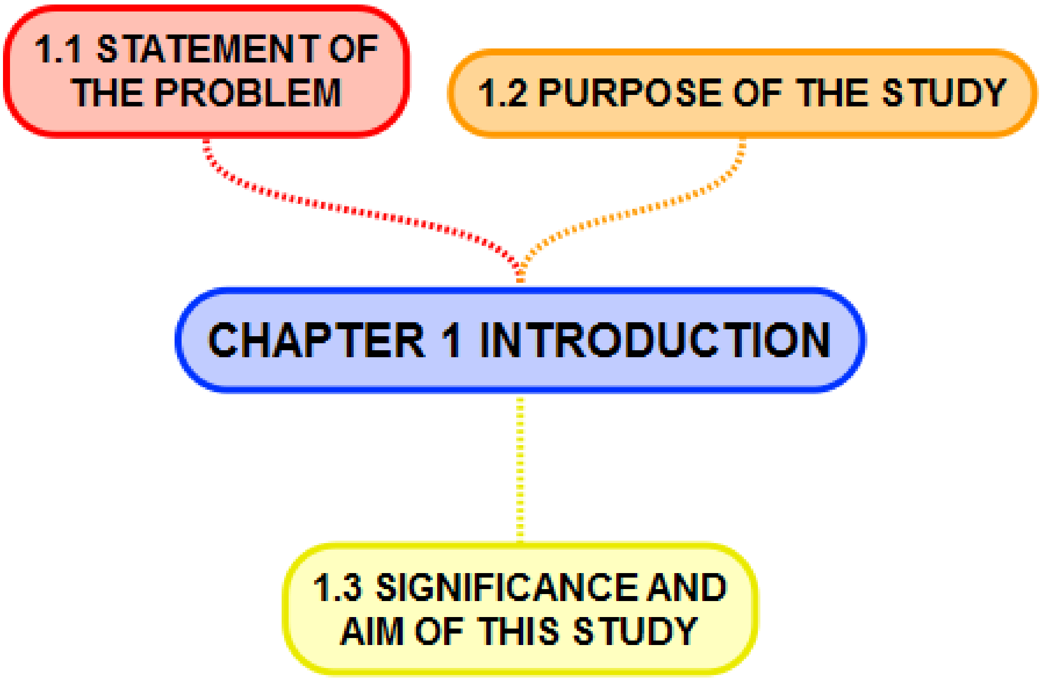


Figure 0-1 Chapter 1 Introduction flowchart

The world in which we live is busy and media rich, and it stops for no one. Very few people can get by without relying on the technologies of contemporary times. These technologies have been responsible for the increased development of multimedia learning solutions; which have provided positive outcomes and certainly more engaging experiences for learners. If we consider what has been done to the content of these solutions in comparison with a more traditional, paper-based format, we can observe changes to the demands on the audience, and how we view them together with alterations of the ways in which we review, process and recall these changes.

Yet the processing of the content within these solutions poses difficulties. In many multimedia solutions this problem is brought about because some or all of the content has now been transformed into a non-permanent, a transient format (Kalyuga, 2011). This brings with it complications: regardless of our professional capacity, educational achievements or personal situations, we are required to process information continuously and therefore a human-centred design approach is required. In order to achieve optimal human cognition and to process information in the most efficient manner, information should be presented with an understanding of human cognitive processing:

> Dealing with complexity has become one of the greatest challenges for modern societies. To reason and decide, plan and act in complex domains is no longer limited to highly specialised professionals in restricted areas such as medical diagnosis, controlling technical processes or serious game playing. Complexity has reached everyday life (Schmid, Ragni, Gonzalez, & Funke, 2011, p. 211).

Education and learning are reliant on the effectiveness of the design of instructional materials. Video using both visual and audio modes is one of the strategies used to present large, complex pieces of information. When referring to transient information as complex, the length of the material is typically what determines its level or degree of complexity (Leahy & Sweller, 2011). Depending on the nature of this strategy, information may be transient. From this perspective, this study explores the cognitive load experienced during transient information processing and examines the impact that reverse assessment priming has as a strategy for alleviating mental workload (MWL) and the overall level of performance and cognitive efficiency (CE) achieved.

Correlations are sought with how we learn, how we create new knowledge and the processes involved. Within the field of cognitive neuroscience, techniques such as electrophysiological and imaging techniques are being deployed by researchers to forge ahead in this multidisciplinary field (Ruiter, Kesteren, & Fernandez, 2012). Cognitive neuroscience and understanding the ways in which our brains operate are beginning to be recognised as playing an important part in improving educational practices (Ruiter et al., 2012, p. 226).

Educators and instructional designers are faced with a range of challenges, with a wide variety of formats to choose from to present the information. No longer are they responsible only for the selection and ordering or scaffolding of content; they need also to select the format and mode that will perform these functions in the most efficient manner (Reed, 2006). This reflects the view of Geake and Cooper (2003) that the research findings support the view that the educational field should in fact be “embracing rather than ignoring cognitive neuroscience” (Geake & Cooper, 2003, p. 1). Instructional designers need to build a repertoire of cognitive strategies as part of their design tool box. Like most tool boxes, not all tools suit all situations or solutions (West, Farmer, & Wolff, 1991).

The objectives, the content, the learners and the resources available will differ and so will the tools that should be selected. Instruction involves arranging and organising information with the aim of constructing knowledge as a permanent record held in an individual’s long-term memory that can be recalled when required (Sweller, 2008a). A knowledge of neurocognitive instructional strategies is beneficial to creating an effective learning solution as “an increased knowledge of brain function can inform and improve educational practice” (Ruiter et al., 2012, p. 226).

The relationship between cognition and instructional practices has been described by more than one theorist as being “intertwined”, firstly by Mayer (Mayer, 2002) and then in a more specific correlation with the architectural structures responsible for processing, whereby “instructional design and human cognitive architecture (HCA) are inseparably intertwined” (Sweller, 2004, p. 9). Without such knowledge of how we learn and process information, effective communicative and learning solutions are not possible (Mayer, 2002).

The outcome or result of learning can be viewed as a permanent change within the brain known as adaptive plasticity, occurring post stimulus (Bransford, Brown, Cocking, & United States National Research Council. Committee on Developments in the Science of Learning, 1999; Van Kesteren, Ruiter, Fernández, & Henson, 2012). It is how the stimuli, instructional event and information are structured and presented that will determine the effectiveness of the processing. According to Reed (2012), an understanding of how humans encode, store and modify information – the structural processes of cognition – should be the basis for how instructional information should be designed.

An understanding of the unique characteristics of the human cognitive system will enable the designer to maximise the efficiency (Sweller, 2008a) and take advantage of the strengths of our cognitive systems rather than hinder an individual's learning by over complicating how information is processed. " However, before we can realise such an intelligent support technology, further basic research of complex cognitive systems is needed" (Schmid et al., 2011, p. 212). Research into human cognitive functions provides the very insights needed, an "algorithm" for information design (Schmid et al., 2011, p. 212). A teacher's or a designer's knowledge of how we learn allows the selection of techniques that are conducive to achieving a particular educational goal (Bransford et al., 1999).

Without a framework on which to base systems, process, task and product designs, we cannot be clear about the degree of efficiency of each instructional strategy used, and in a multimedia world we can "run the risk of being unusual and entertaining but not effective" (Baggio, 2010, p. 1). With research amongst the cognitive science and psychology fields expanding, cognition is being viewed closely by educational and instructional specialists as playing a major role in the integration of new knowledge.

As a result of the cognitive research and new strategies that are aimed at aligning the educational design with the cognitive constructs and functions, teachers and instructional designers can no longer rely on the traditional techniques applied for decades in order to achieve their primary educational goal of new knowledge integration.

With more informed and refined methods now available, approaches to educational "design based on visual elegance, common sense and convenience are inadequate" (Chandler & Sweller, 1991, p. 294). Smith and Ragan (2005) defined instructional design as a "systematic and reflective process of translating principles of learning and instruction into the plan for instructional materials, activities, information resources, and evaluation" (p. 1). Achieving more effective learning practices can be realised with an understanding of "how people learn and think" (Mayer, 2002, p. 55).

In order for brain-based strategies to be adopted, long-term change in how educational professionals design learning solutions is needed, together with the ways in which they operate, and their designs and beliefs (Herson, 2006). Over two decades ago, the important role that cognitive science played in instructional design had been recognised: that cognitive science has become an integral part of the instructional design process (West et al., 1991). This study highlights the importance of understanding how the human cognitive architecture operates and therefore how different stimuli either contribute, impact or influence, aligning and further extending this analogy and scientific foundation on information design.

An issue that may arise when transient information is presented is the need to deal with or process the ongoing and consistent stream of information. Whilst such transient stimuli are attended to, the task of prioritising the incoming information will be a difficult one (Nobre & Stokes, 2011).

Based on a review of literature, there is little evidence of investigations into the neural activity during transient information processing with a view to achieving CE, and therefore to date no method or design strategy exists. Although it is well documented that mental overload affects efficiency (Xie & Salvendy, 2000), the aim of this study was to investigate and provide objective data that quantified the neural activity during information processing and in particular stimuli presented in a transient mode.

This study has particular interest in extraneous load, as a direct result of the instructional format, mode and strategies selected by instructional designers (Sweller, 2012; Sweller, Ayres, & Kalyuga, 2011f; Sweller, Van Merrienboer, & Paas, 1998)

In the next chapter, this study reviews and draws from relevant and acknowledged literature within the area of HCA), cognitive processing, working memory, cognitive load theory and cognitive load measurement, and in particular the use of neurophysiological measures to establish the neural activity during cognitive processing.

1.1 Statement of the problem

In recent history there remains a largely untold story: instructional practices, pedagogical strategies and investigation beyond teaching. The educational industry is occupied by a range of professionals who hold the belief that they offer effective learning experiences. The teachers themselves are the evaluators. In corporate arenas, where instructional designers are responsible for educating employees, it appears that there is a high level of competitiveness whereby designers, are extremely tight lipped about their approach and design rationale, which is a frustrating situation for the effectiveness of how learning is evaluated when an open and transparent analysis is required. Ultimately, a discussion may result about which strategies are being adopted, why they are being adopted and evidence for what designers are using to support their practices. Evidence to explore and improve the quality of educational practices further is not found within the confines of educational research. The scope needs to be broadened.

Despite the relevance and interrelated nature of education, psychology and neuroscience research, very little overlap of the three distinct areas is found in the literature reviewed and is rarely found in practice. Such consistency in the absence of research indicates the difficulty of coordinating the disciplines involved. Over the past three decades, the problem appears to have been placed in the too hard basket and it has proven difficult for a multidisciplinary approach to be adopted by those within the areas of neuroscience, psychology and education. Those who have made a concerted effort have been known to identify gaps in the literature and inconsistent investigations, while those working within such disciplines are making a difference and working towards understanding the science behind learning (Ruiter et al., 2012). Information processing and learning have received recent interest in studies under the banner of "cognitive science, which deals with the mental processes of learning, memory and problem solving" (Cooper, 1998, p. 1). Cognitive ergonomics or neuroergonomics is where cognitive science and mental processing address the zone of interaction between humans and information systems: therefore "clearly, information systems would be most effective if their design is informed by an understanding of the human-information interaction of their intended users" (Fidel & Pejtersen, 2004, p. 1). The way in which we perceive process and interpret information directly impacts on our capacity to perform.

To undertake this type of study requires the examination of HCA literature, with a particular focus on the sub-structure of working memory, its capacities, corresponding implications for instructional practices and neurocognitive instructional strategies aimed to reduce the cognitive load as a result.

This is an interdisciplinary study into human cognitive performance and efficiency, an approach known as neuroergonomics in an "area of research and practice that integrates understanding of neural bases of cognition and behavior with the design, development and implementation of technology" (Berka et al., 2007, p.

31). A human design approach is aimed at achieving the optimal in interaction between human processing systems and products.

The core and primary problem that exists today is that there is an absence of understanding of how the human cognitive processing system operates. Snippets of research exist into cognitive load; however, further research into how people respond in a neural sense to different stimuli is lacking.

1.2 Purpose of the study

Put simply, “information overload is a fact of life in the contemporary global networked society (Berka et al., 2007, p. 231). Cognitive research has resulted in theories that have been established to assist with the mental processes of the human cognitive system. In designing information to be processed attempts must be made to avoid overloading the “central bottleneck” (Schnotz & Kürschner, 2007, p. 470) of one’s cognitive system.

The purpose of this study is to capture the neural activity experienced during the completion of a transient information processing task and assessment, analyse the MWL experienced against the level of accurate information processed, stored and recalled, then establish the impact that the utilisation of Reverse Assessment Priming (RAP) had on the cognitive demand/MWL experienced, performance and the overall level of CE achieved.

This RAP strategy is designed to investigate further earlier event related potential research, whereby studies revealed that “recollection and familiarity have qualitatively distinct neural correlates” (Rugg & Curran, 2007, p. 256). It is hoped that these correlations will have a positive impact on processing information and reduce the decay of information and/or prompt attention to particular stimuli in order to increase the cognitive load and the level of accurately processed and stored information to achieve an overall higher level of human performance and CE. The ability to capture the continuous neural account of the MWL experienced in this study was crucial to establishing strategies to optimise human cognitive performance and efficiency in information processing (Berka et al., 2007).

This enquiry answers the following questions:

- How does the MWL differ between a low cognitive demanding Transient Information Processing Task (TIPT) and a high cognitive demanding TIPT?

- What impact does the use of Reverse Assessment Priming Stimuli (RAPS) have on the MWL imposed during a low cognitive demanding and a high cognitive demanding TIPT?
- What impact does the use of RAPS have on the performance results achieved across both low and high level TIPT?
- What impact does the use of RAPS have on the overall CE achieved across both low and high level TIPT?

1.3 Significance and aim of this study

The purpose of this study is to provide answers about how transient information is processed through the lenses of neural activity. The study highlights how MWL differs between low and high cognitively demanding transient information tasks. The study tests an information design strategy called reverse assessment processing stimuli (RAPS). The results demonstrate the impact that this strategy has on the MWL experienced from a neural perspective, the impact on human performance results achieved and the overall impact on the level of CE achieved during the presentation of information in a transient mode. The investigation into human cognitive performance is aimed at enabling designers to create and present instructional and communicative collateral that achieves optimal human cognitive performance.

The subsequent chapters cover the following topics; a review of relevant literature; research methods structure; tasks required for the experiment; data collection; data analysis; discussion and outcomes of the study.

Chapter 2 Literature Review

This chapter reviews current literature with respect to how we process stimuli within the human cognitive architecture (HCA) and highlights the impact that instructional design can have on the effectiveness of learning and information processing. Theories relating to HCA, working memory, cognitive load theory (CLT), cognitive load measurement, performance measure and physiological measures of MWL – are included in the review.

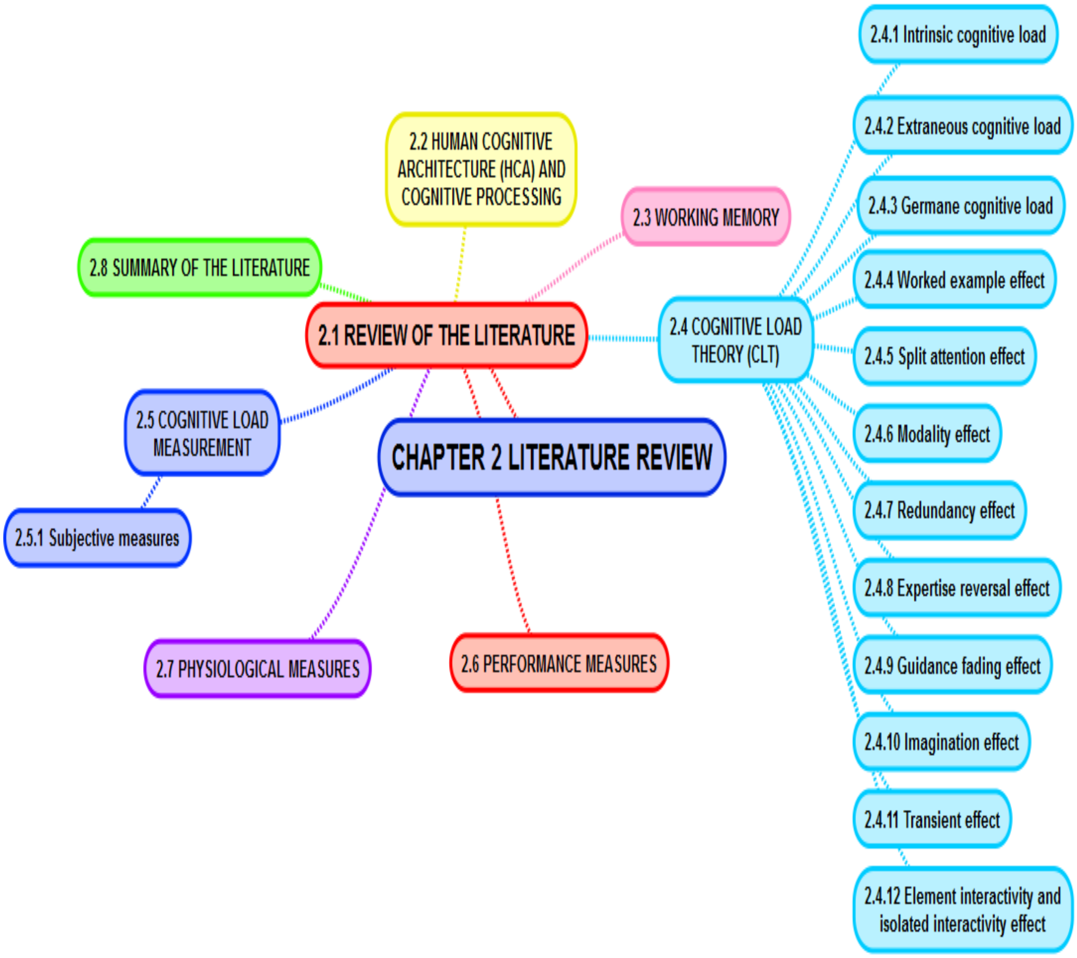


Figure 2-1 Chapter 2 Literature review flowchart

2.1 Review of the literature

Given that it is well recognised that the brain is the "main organ involved in learning" (Ruiter et al., 2012, p. 226), it is the system and the infrastructure used within it that form a logical starting point in this review of the literature. I begin by examining what is meant in the literature by the term "cognition" and the human structures that are believed to carry out the cognitive functions. A person's ongoing cognitive development relies on mental structures and internal processes; this is how we make sense of the world around us, and the environment and the information with which we are presented. Each of us creates mental representations, forms patterns and uses our own previous experiences and knowledge as a sounding board in order to understand and comprehend our surrounding environments (Bruner, 1966; Lee & Seel, 2012). We construct new knowledge.

Cognitive efficiency (CE) requires understanding and acknowledging the neurocognitive resources used during information processing, known as the HCA, a collective name given to the following interrelating sub-structures: sensory memory; working memory; and long term memory.

All of these sub-structures play a role in cognition; however, primarily cognitive studies "focus on a memory system that keeps active a limited amount of information for a brief period of time" (Smith & Jonides, 1997, p. 5). The working memory is a substructure of the overall HCA. An important feature lies in the limited capacity of this sub-structure as it poses limitations on cognitive processing. Kahnerman (1973) advises that "cognitive operations exhibit capacity limitations, such as increasing demands resulting in diminished performance" (as cited in (Gazzaley, 2011, p. 1415).

By viewing information as a load on cognitive resources, CLT labels these resources as effects and encourages the adoption of appropriate instructional strategies (Sweller, Ayres, & Kalyuga, 2011e) for the design and development that are imposed. The literature reviewed begins with the neurocognitive architecture responsible for information processing and narrows in on the working memory, where the components, their roles and their capacities are considered. The objective data in this study investigated the extent of the load experienced by working memory.

2.2 HCA and cognitive processing

What is it called when we identify an object, remember a person's name, read a sentence and comprehend what we have read or when we listen to our teacher's instructions? These are just a few examples of the very complex and diverse processes of human cognition (Ashcraft, 2006b). Cognitive processors are unavoidable, somewhat like an automatic function that operates on demand. Most people are not aware of, or at least do not consciously think about, their cognitive processing ability. Every decision is made up of many facets; solutions are a product of a process. Cognitive processing has a lot to answer for. Technology and research are enabling us to gain more and more of an understanding of how such operational functions are structured and work within individuals.

How we process information, think, learn and store information in memory are all processes of human cognition, responsibility lies with the HCA. The term architecture is appropriately referred to as an analogical expression of how the human cognitive structures are placed or organised and how these structures interact in order to fulfil their interdependent roles within cognitive processing.

The "architecture as a theory of cognitive capacity" is defined by (Pylyshyn, 1988, p. 3) as another way of looking at the role of the architecture, as a way of understanding the set of possible cognitive processes that are enabled by the structure of the brain. "HCA provides a generic framework of the information-processing stages that learners use to encode, store and modify information" (Reed, 2012, p. 1452). The HCA framework "refers to the manner in which the components that constitute human cognition are organised" (Sweller et al., 2011e, p. 15).

HCA has several structural components, which include: sensory memory; working memory; and long term memory (Hanham, 2011). External stimuli bombards our senses; we attend to selected information, discard other information, allocate our internal resources to allow processing of information, and liaise or consult our long term memory stores, all within seconds. The task of processing, as it is known, is complex and requires an interactive approach by the structures responsible. This would be the HCA and its substructures, which are concerned with completing cognitive functions and with how information is organised (Hanham, 2011; Sweller et al., 1998b).. The HCA "defines the elements and connections that take place in the human brain" (Frias-Martinez & Gobet, 2007, p. 292).

The HCA is well-represented in research, although several models exist. One example is the unified cognitive Adaptive Control of Thought – Rational (ACT – R) Model by Anderson (1983), which depicts visual and motor sensory buffers and clearly separates declarative and procedural knowledge – all of which is indicative of a coordinated systems model. In addition to this model by Anderson, there are others such as biologically inspired cognitive architectures (Goertzel, Lian, Arel, de Garis, & Chen, 2010).

Theoretical and computational models of cognitive architecture dominate the available literature. Examples include the ACT-R model (Goertzel et al., 2010, p. 31) and the ICARUS model by Langley, Laird, and Rogers (2009) that Goertzel et al. (2010) detail as an integrated architecture consisting of several modules: "a perceptual system, a planning system, an executive system and several memory systems" (Goertzel et al., 2010, p. 31). Each model, computational or not, represents in its own way the structural components of the memory systems, although they need to consider the unique capabilities of the HCA.

The working memory sub-structure is specifically responsible for recognising, encoding and decoding information. A process that takes the newly received information from the sensory memory and compares it with previously stored information in the long term memory is what is referred to as cognitive processing. Recent research by (Langley et al., 2009) about what cognition involves was summarised as the capabilities that architecture should support.

These cognitive processing capabilities include: recognition and categorisation; decision making and choice; perception and situation assessment; reasoning and belief maintenance; execution and action; interaction and communication; remembering; reflection; (Ashcraft, 2006b; Langley et al., 2009, pp. 145-149) and learning. In order for learning to take place, it requires the learner to make sense of the information, link it to previously stored material, position the information and restore the information beyond their short term memory. In doing so, they "must find the pattern" (Martinez, 2010, p. 63), so to speak. This is suitable and fulfils the general purpose of understanding the functionalities; however, to be fair, this is a mere summarisation. Therefore, to ensure that the literature is well represented and to demonstrate the extensive accountabilities held and performed by the human cognitive system, I highlight the Wei and Salvendy (2006) study of cognitive task analysis and design that aimed to develop a human information processing modelling and that used Fleishman's (1995) more comprehensive list of 21 cognitive abilities:

> Oral comprehension, written comprehension, oral expression, written expression, fluency of ideas, originality, memorisation, problem sensitivity, mathematical reasoning, number facility, deductive reasoning, inductive reasoning, information ordering, category flexibility, seed of closure, flexibility of closure, spatial orientation, visualisation, perceptual speed, selective attention, time sharing - as cited in (Wei & Salvendy, 2006, p. 357).

In order to perform these cognitive functions, as previously outlined, Ashcraft (2006b) supports the assumption of cognitive psychology: "mental processes exist, they can be studied scientifically and…people are active information processes" (Ashcraft, 2006b).

The scope of these cognitive processes that are carried out over several stages, have been known for decades, commencing with the transformation of incoming sensory information, reduction, elaboration, storage and the recovery of information (Neisser, 1967, p. 4). In a similar manner to this research, Langley et al. (2009) provide a collective summary of the functional capabilities that an HCA should support. The same authors also categorised an HCA with respect to its internal properties: as a "representation of knowledge, the organisation it places on that knowledge, the manner in which it utilises its knowledge and the mechanisms that support acquisition and revision of knowledge through learning" (Langley et al., 2009, p. 149). Sweller (2008a) believes that "the extent to which any instruction is effective depends heavily on whether it takes the characteristics of human cognition into account" (Sweller, 2008a, p. 370).

Five principles allow human cognition to be viewed according to its functionality: the information store principle (Sweller, Ayres, & Kalyuga, 2011b); the borrowing principle (Sweller, Ayres, & Kalyuga, 2011a); randomness as genesis principle, the narrow limits of change principle (Sweller, Ayres, & Kalyuga, 2011i); the environment reorganising principle (Sweller et al., 2011e); and information storage and retrieval principle (Sweller et al., 2011e). These principles may act as a framework for cognitive processing; however, a closer look at the sub-structure responsible for working memory is needed.

The HCA memory structure responsible for processing information is known as “working memory” and this system has “the capacity to deliberately control attention in order to hold and manipulate information” (Gevins & Smith, 2000, p. 829). Neural networks are built on successful information processing, and ongoing neurocognitive retrievals are the foundation for further successful cognitive processing. All stimuli should be compatible with the structure and functionality of the HCA in order to achieve successful knowledge integration and CE. “In such an architecture, the impact of cognitive load on knowledge acquisition is substantial” and requires a design approach that respects the limitations and constraints (Revithis, Wilson, & Marcus, 2010, p. 299).

The literature demonstrates a range of different strategies that may be applied to instructional design. West et al. (1991, p. 19) recommends taking a “hybridization, or combination of cognitive strategies” (p. 19) approach. The study of neuroergonomics brings fresh light to the design or at least the research informs design practices into how the brain responds in everyday contexts, linking cognition to behavior and therefore enabling an insight into better practices in the aim for efficiency (Parasuraman & Rizzo, 2006). Designing instructional material and using a cognitive strategies approach provide learners with “mental activity” opportunities to assist them in encoding the information, making sense of the new information and enabling them to store the important details in long term memory, building and further developing their own individual schema (West et al., 1991, p. 22). Cognitive design strategies may include reducing materials into bite sized chunks and presenting learners with limited new information. This is an example of a cognitive strategy that gives the learner’s cognitive processing system time to process the information successfully.

Other examples of cognitive strategies that are useful in instructional settings include concept mapping (West et al., 1991) and interactive animations, both of which have demonstrated the ability to impact on the degree of learning achieved (Verhoeven, Schnotz, & Paas, 2009). This requires designers to present the information in a visual format. The concept map acts as the vehicle to present a large amount of information in succinct concepts – hence the name - a design approach that immediately respects the learner’s cognitive system. The concept map is not too dissimilar to the way in which the learners very own schematic networks are formatted and therefore the process of making sense of information and positioning the concepts is undertaken with ease, the incoming information is aligned and enables the learner to process it easily. There are so many questions that can be answered in presenting a large, broad and detailed topic in a concept map. In acknowledging the ways in which the cognitive system operates and adopts a design approach with these considerations in mind, it is possible to save processing time and grant the learner a head start.

This mirroring of the learner's own filing system can assist in fast tracking the cognitive process. Initial questions that will be asked, such as "How broad is this topic?", "What are similar topics?", "Do I know any of these?", "In what order should they be filed?", "Are there any hierarchical relationships?" and "What other relationship exist among topics?" – are all answered within a very minimal timeframe by concept mapping. Learners will immediately be able to identify the interdependence, any distant relationships and the order of importance as well as a range of other factors. Despite the fact of how our schematic networks function and the part in which they play as expressed by Bartlett (1932) "conceptualises a schema as an organising and orienting attitude or effect resulting from the abstraction and articulation of past experience" there has been minimal research into how designs can assist cognitive processes (as cited in (Ausubel, 1967, p. 120).

There are more recent investigations in to the efficiency of human computer or human machine environments, a human factors approach is being taken with a specific focus on the mental workload (MWL) the demand placed on the human cognitive system and the degree in which an individual may be overloaded with a task, the assessment of the load and the human performance is being measured to establish the areas of impact that relate to design and human factors (Parasuraman & Rizzo, 2006). The field of cognitive ergonomics or neuroergonomics enables these investigations to bring the neural and cognitive activities of an individual in focus. Results from these types of human factors investigations will provide yet more strategies that can be applied on top of strategies that have been devised to date. Designers today need to be abreast of the functional workings of the HCA, the learner's prior knowledge, the resources available to them as designers and the information being presented to develop cognitively favourable solutions (West et al., 1991).

It is evident in the literature that an understanding of the roles and functions of the working memory is repeatedly found. However, there are also vague mentions, unresolved questions and ongoing research on the relationship, boundaries and interrelated components between attention and working memory; it is suggested that they overlap (Fougnie, 2008). It is not the existence of attention that is disputed by working memory theorists, but rather the timing of such a process. The attention given to stimuli can be influenced and driven by the perceptions of the person and/or it can be goal directed. It is obvious that the stimulus that is successful in gaining the attention of the working memory will maintain the foci and therefore the information presented will go on to be encoded (Gazzaley & Nobre, 2012).

During the review of the literature on the HCA, a particular focus was directed at exploring the working memories role and components. It was found that the work of Baddeley (1986) was primarily responsible for shaping the literature, facilitating ongoing research and proposing the "cognitive architecture of working memory" (Smith & Jonides, 1997, p. 8).

Depending on the type of content, the mode and format of the presented information, the learning experience itself, the types of emotions involved and the level of previous exposure, therefore, the existing schema, as well as the current knowledge base of the learner, may alter the parts of the brain involved in processing information (Ruiter et al., 2012; Sweller et al., 2011e; Van Kesteren et al., 2012). A person's schematic networks are an important consideration in learning and processing new information.

These current knowledge structures are the result of a range of prior experiences, events and stimuli processing. As these structures are added to and become more and more extensive, they allow learners to draw from a larger repository of information, their very own knowledge stores. "Each person has unique and pre-existing constellations of knowledge, beliefs and expectations stored in memory"; these are referred to as schemas (Hwang, Gotlieb, Nah, & McLeod, 2007). Schemas can be arranged in a generalised body of information or depending on the specific domain area they may become quite complex. How information is presented should encourage and assist learners to "activate various pre-existing 'packets' of knowledge" and to "reassemble and construct this knowledge into integrated new schema" (Bransford, 1984, p. 264).

The nature of these structures is what enables the long term memory to organise large amounts of information in a fashion that allows easy retrieval when required. Therefore, when a person has a previous experience, there will already be a predetermined storage location or at least somewhere to begin.

The function and purpose of the human long term memory have changed over the years and, with more and more research into the cognitive architecture of humans, our understanding of its role is improved. It was once thought to be a repository whereby information was stored as separate and isolated pieces of information (Sweller, 2008a). As this is no longer the case, information is now thought to be arranged into related material, which was a defining discovery in the research and named the "primary finding of the cognitive science revolution" (Sweller, 2008a, p. 371), thereby making the long term memory an important component and sub structure of the HCA.

There is no dispute about the long term memory's level of contribution to the overall role of the HCA. This being the case, having prior exposure to a topic will see that learners have information to draw on and therefore focuses one's attention and cognitive resources on processing incoming stimuli. The ability to access similar information that has been previously stored allows a seamless, faster and more efficient processing (Lee & Seel, 2012).

The cognitive architecture itself remains consistent across all humans; however, the spatial areas of the brain and the role of particular memory processes during cognitive processing may differ (Bransford et al., 1999). Research supports the theory that the "brain structure dictates that learning design should begin with what the learner knows" (Hendel, Oughton, Pickthorn, Schilling, & Versiglia, 2011). Central to all information processing, regardless of the mode, structure and level of expertise, is the HCA's working memory structure (Ruiter et al., 2012).

2.3 Working memory

A memory structure, "once referred to as short term memory, is often called working memory" (Smith & Jonides, 1997, p. 5) and is the structure responsible for reasoning, problem solving, capturing, representing and maintaining the details that are extracted from any stimuli and presented to the learner (Baddeley, 1986; Baddeley & Hitch, 1974; Carpenter, Just, & Reichle, 2000; Smith & Jonides, 1997).

According to Baddeley (2003, p. 189), “working memory involves the temporary storage and manipulation of information that is assumed to be necessary for a wide range of complex cognitive activities” (p. 189), or “representations from within long-term memory that are currently within the focus of attention” (Awh, Vogel, & Oh, 2006, p. 201; Van Kesteren et al., 2012). It is here that we “compare, contrast and compare” (Kirschner, 2002, p. 2) information.

The purpose of working memory can be explained as an individual’s ability to create links between individual unitary pieces of information in order to make an association and therefore make sense of (Shipstead, Lindsey, Marshall, & Engle, 2014) a process whereby new incoming stimuli stored on a temporary basis whereby it undergoes a rehearsal process within the working memory and its sub structures; the executive function of drawing from current knowledge schemas within long term memory is a continuous part of the processing (Revithis et al., 2010; Ruiter et al., 2012). An approach to learning design known as schema based learning was named as such due the way in which information would be presented, the format was presented in a format that took into consideration an individual’s prior knowledge therefore allowing the new stimuli to be links to all ready stored material within the learners schematic networks. A process or learning design approach that assists the working memory to process the incoming stimuli, identifying a link between the person’s current schema of stored knowledge and experiences, then linking these to the new information (Lee & Seel, 2012).

The actual process of processing new stimuli, using the current knowledge stores and applying the reasoning in order to solve a problem and match and store new knowledge into long term memory all extends the cognitive capacity of the individual. With each new piece of information successfully transferred from the working memory to the long term memory. This is when we have some level of prior knowledge and the new information or at least the concept is not being presented to learners for the very first time, meaning that they have preexisting network, concept or developed schema into which the new information can be assimilated. This has been called the “narrow limits of change” depicting how humans construct knowledge by relying on the long term memory stores and by using a series of “small incremental changes” (Sweller, 2008b, p. 373) to add new information to current knowledge in narrow increments. Of course, when a completely new concept is presented, it is possible to process that concept; it does, however, involve an extended process and new schema need to be developed.

Individuals' fluid intelligence is said to be derived from their cognitive capability – their ability to complete complex cognitive functions. At this stage it seems logical to define "complexity", or at least to ensure that an understanding of what is meant by complex can indeed vary. It can be safely assumed through research that cognitive complexity indicates that the level of difficulty in processing is increased. It should be considered, however, that the way in which or how this takes place may differ. Kurup, Bignoli, Scally, and Cassimatis (2011) discuss the causation of cognitive complexity and advise that this can be a result of several variables, "by adding sufficient rules or constraints to an original task description" (p. 281), therefore requiring learners to possess an increased "depth of detail and knowledge" (p. 281) in order to complete the task successfully, or when a problem is presented over a series of tasks.

The differences in schema connections held by an individual can be indicative of where learners are placed on the novice and experts scale; "a novice with far fewer prior connections cannot hold new information in isolation" (Hendel et al., 2011, p. 6). Research has demonstrated links between a person's level of expertise and established schema networks within the chess domain. Chess masters or those perceived as experts have large amounts of information stored in their long term memory. In the way of chess configurations, possible moves and therefore when faced with making a decision, solving a problem and taking their next move are all a reflection on the existing schematic networks that an individual chess player has developed as a result of being previously exposed to an assortment of chess positions and possible moves, strategies and winning solutions .

The cognitive processing is a matter of accessing and drawing from previously stored schema (Simon & Gilmartin, 1973; Sweller et al., 2011e). However, expertise or intelligence is not assessed only in relation to the extensive schemas that they have developed, although this is definitely a contributing factor. A person's ability to use these stored networks and to arrange chunks of information to assimilate new schema to existing schema further (Hendel et al., 2011) is where a person's real cognitive capacity can be measured. Using the mechanisms of working memory to accesses the schema and incoming stimuli in order to solve problems and "reason with novel information" (Shipstead et al., 2014, p. 116) relies on this ability. Sweller et al. (2011e) advise that, in the absence of prior knowledge and sufficient schema, novice learners need to go in search of possible solutions, whereas those with a more developed schema will be able to draw from these, utilizing and demonstrating of how applying "general principles of adaptive organisation and coherence maximisation" would be applied and to the learners benefit (Lee & Seel, 2012, p. 2946), which is how the HCA and in particular the working memory approaches reasoning.

The confusion within the literature and ongoing research on the nature and role of working memory has been acknowledged (Miyake & Shah, 1999; Richardson et al., 1996). It is undisputed, however, that "working memory plays an essential role in complex cognition" (Miyake & Shah, 1999, p. 1). There is evidence that, over the last few decades throughout the field, a range of terms and metaphors have been used to refer to working memory in an analogic manner, highlighting different characteristics that the structure and its purpose are thought to contribute these include: the "box" or "place", the "workspace" or "blackboard" the "mental energy" or "resources" metaphor and the "juggling" metaphor (Miyake & Shah, 1999; Smith & Jonides, 1997; Van der Linden, 1998).

According to Van der Linden (1998), in relation to the controversial argument of whether the working memory is in fact seen as a gateway to working memory or not, he continues to support this theory and also acknowledges it as a workspace that is accessed by both incoming stimuli and long term memory. Countless models exist to cover each theory and argument, each generally contradicting the other (Baddeley, 1986; Carpenter et al., 2000; Ericsson & Kintsch, 1995; Oberauer & Kliegl, 2006). Working memory has also been referred to as a mental blackboard with respect to its ability to capture and hold information for use in complex processing tasks (Baddeley & Hitch, 1974; Smith & Jonides, 1997) and to "highlight the temporary maintenance of information in a limited capacity system that promotes efficient access and updating" (Awh et al., 2006, p. 201).

In an attempt to help us to "better define and understand working memory", (Miyake & Shah, 1999, p. 3) carried out a systematic, comparison study of the prominent models of working memory. A series of eight questions was used to categorise the investigation, identify the main themes and characterise the theories. The questions fell into these areas: "Basic mechanisms and representations in working memory”; “the control and regulation of working memory”; “the unitary versus non-unitary nature of working memory”; “the nature of working memory limitations”, “the role of working memory in complex cognition activities”; “the relationship of working memory to long-term memory and knowledge”; ”the relationship of working memory to attention and consciousness” and “the biological implementation of working memory” (Miyake & Shah, 1999, p. 5).

Baddeley and Hitch (1974) used the term “working memory” as the title for the original three component functional model of working memory, as illustrated in Figure 2-3 which was originally coined in 1960 by Miller (1956), then used by Atkinson and Shiffrin (1968) and then adopted again by Baddeley (2010, p. 136) as the title for his new multicomponent working memory model. Research into the field of cognitive psychology and the part that working memory plays has relied heavily on the latest multicomponent model by Baddeley (2000) that sees an episodic buffer added, which “allows the binding of information to create integrated episodes” (Schmid et al., 2011, p. 7). There have been many models of working memory, such as the dual coding theory by Pavio (1986) that is not too dissimilar to the three component working memory model detailed in Figure 2-3 (Baddeley, 2000, 2003; Baddeley & Hitch, 1974), which also specifies that verbal and visual information is processed via separate systems. However, it is also thought to use a collaborative approach to assist in creating a representation of the material presented (Pavio, 1986). The concept of a working memory model allows researchers to “highlight the temporary maintenance of information in a limited capacity system that promotes efficient access and updating” (Awh et al., 2006, p. 201) in a graphical sense, a framework that follows the information from input to processing (Awh et al., 2006, p. 201).

This information needs rehearsing in order to maintain the information before it is lost. If it is lost at this stage, within the short term memory store stage, it cannot be retrieved and therefore never makes it to a long term memory store (Miyake & Shah, 1999).

Working memory at any one point is continuously required to be focusing on and evaluating the incoming stimuli. This is part of a search for relevance to the environment, and relevance to previously stored information held in long term memory stores, and also part of efforts to apply logical reasoning to identify the most suitable information to which to apply attention. Research illustrates the ongoing and continual processing of humans and in return labels humans as “active information processors” (Ashcraft, 2006b, p. 3). Working memory certainly has its job cut out: this reasoning, as previously mentioned, is ongoing in order to make sense of the new stimuli or to position the information. In this context, the purpose of assimilation is important: “it is not enough to simply have a collection of passive schemas; one must also know how to use them” (Lee & Seel, 2012, p. 2946). All of this takes place whilst individuals are resisting, avoiding, prioritising and controlling the allocation and direction of their conscious awareness (Shipstead et al., 2014).

The working memory relies on linking to the previously stored information. Research has shown “how we use our large store of information to impose order and meaning on our environment” (Sweller, 2008a, p. 373). Research has also shown how our existing knowledge, experiences and stored information influence our mental processing; this is known as the “top-down or conceptually driven processing” (Ashcraft, 2006a, p. 53). An individual’s existing cognitive structure of a topic is the dominating influential factor of learning within that field (Ausubel, 1967). These control processes of working memory are one of the main controversial topics surrounding working memory, first raised by (Atkinson & Shiffrin, 1968), as seen in Figure 2-2 and in Baddeley and Hitch (1974) revised working memory model, as shown in Figure 2-3.

The work of Baddeley and Hitch (1974) through their functional model “has introduced the concept and inspired decades of research into the capacities, properties and mechanisms of working memory” (RepovŠ & Baddeley, 2006, p. 5).

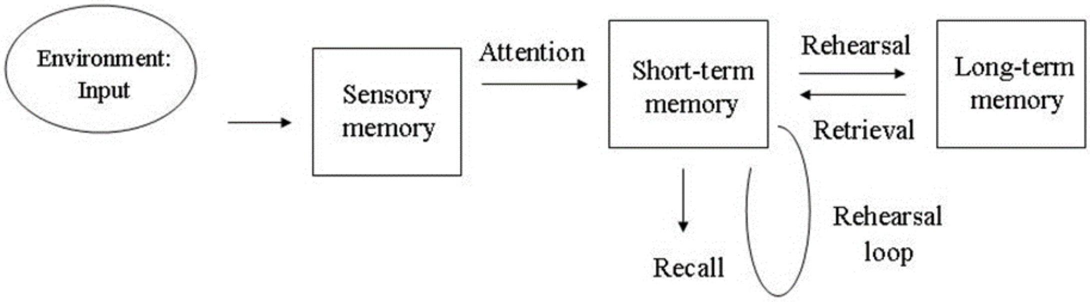


Figure 2-2 ***Flow of information through the working memory system (Atkinson & Shiffrin, 1968). Based on Atkinson and Shiffrin (1968) Copyright (1968) (Baddeley, 1998, p. 169)***

Despite their merits, none of these models has received the same amount of recognition and attention that has been received by the original three component model of working memory illustrated in Figure 2.3, as proposed by Baddeley and Hitch (1974). Baddeley and Hitch (1974) original model of working memory is shown to be divided into slave structures: one to attend to visual information; and the other to attend to acoustic information. A central executive system acts as the coordinator or hub between the two slave systems; it is responsible for combining information from both sources (Baddeley, 2003).

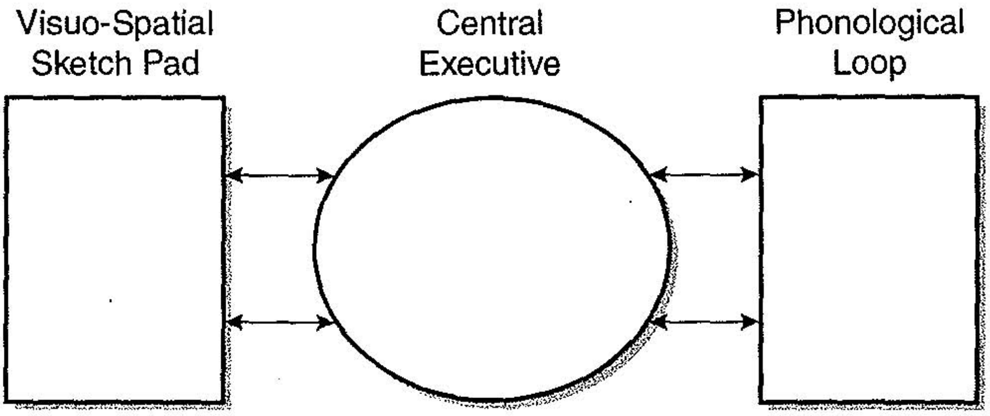


Figure 2-3 ***The original three component model of working memory proposed by A. Baddeley and Hitch (1974,) as cited in Baddeley, 2003, p. 191).***

It is thought that the working memory “is not…one monolithic structure but rather a system embodying at least two mode-specific components: a visuospatial sketchpad and a phonological loop coordinated by a central executive” (Kirschner, 2002, p. 2). The working memory model and its components, including the central executive, play an important role “in working memory tasks and processes” (RepovŠ & Baddeley, 2006, p. 13). According to (Baddeley, 1996), the central executive is responsible for “the ability to focus, to divide and switch attention and the ability to relate the content of working memory to long term memory” (RepovŠ & Baddeley, 2006, p. 13). The control or supervisory function is like the decision maker and coordinator of the other working memory sub components, the phonological loop and visuospatial channels and the link to the long term memory system (RepovŠ & Baddeley, 2006), as is seen in Figure 2-4. Furthermore, the HCA’s working memory is made up of two distinct channels: a visual and an auditory. The auditory channel, known as the phonological loop as named by (Baddeley, 2003), can be further broken down into two subcomponents. Baddeley (2003) proposed a structure for the phonological loop, comprising of several stages: Auditory Input – Phonological Analysis; Phonological Short Term Storage; Rehearsal Process; and Spoken Output (RepovŠ & Baddeley, 2006; Smith & Jonides, 1997).

According to this non-unitary model of working memory, the analysis of information begins with the storage of short term traces of auditory input; unfortunately these traces decay after a few seconds. The rehearsal stage provides the person with an opportunity to make a more permanent memory of the input; this stage acts as a refresher (Baddeley, 2003; RepovŠ & Baddeley, 2006, p. 191; Smith & Jonides, 1997). The results demonstrated during a verbal task experiment support a "two component architecture, with structures in the back of the brain mediating storage, and structures in the front mediating rehearsal" (Smith & Jonides, 1997, p. 8).

The continuous stream of auditory input may be detrimental to the successful storage and processing of information. Complex auditory stimuli sets without an opportunity for the phonological rehearsal stage to take place and a review of the stimuli will impede the ability to analyze, store and process the information and therefore the acquisition of new knowledge or skills (Chandler & Sweller, 1991). As the rehearsal stage entails an internal repeated backup of the spoken words or auditory stimuli, successful processing via the phonological loop relies on the vocabulary levels of the learner. "As the articulation operates in real time, the capacity of the phonological store is limited by the number of items that can be articulated in the time available before their memory trace has faded away" (RepovŠ & Baddeley, 2006, p. 7). This storage component of the phonological loop system is believed to have "evolved from the underlying language perception and productions systems, probably to facilitate the acquisition of language" (Baddeley, 1998, p. 235).

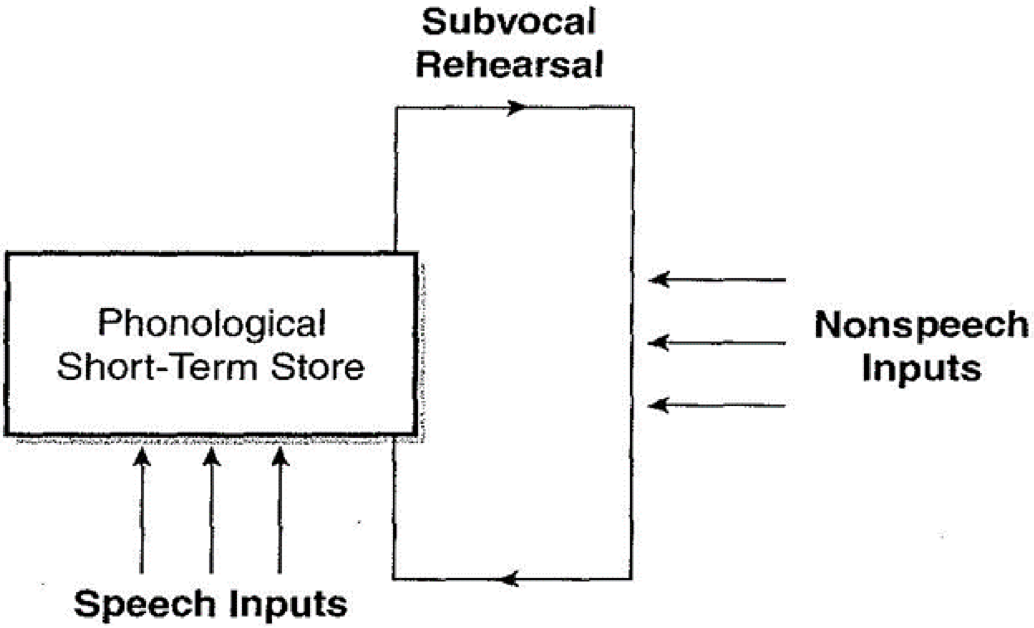


Figure 2-4 The phonological loop with the phonological store and the Articulatory Loop (Baddeley, 1986).

Importantly, it must also be noted that during the rehearsal stage, whereby an internal voice is repeating the audio input in an attempt to reinforce the storage process, articulatory suppression may be experienced and affect the ongoing input, especially with continuous audio (Baddeley, 2000). Note in Figure 2-5 that in the phonological short term store the auditory channel is responsible for the default receiving all auditory stimuli and rehearsing any non-speech input in a sub vocal manner.

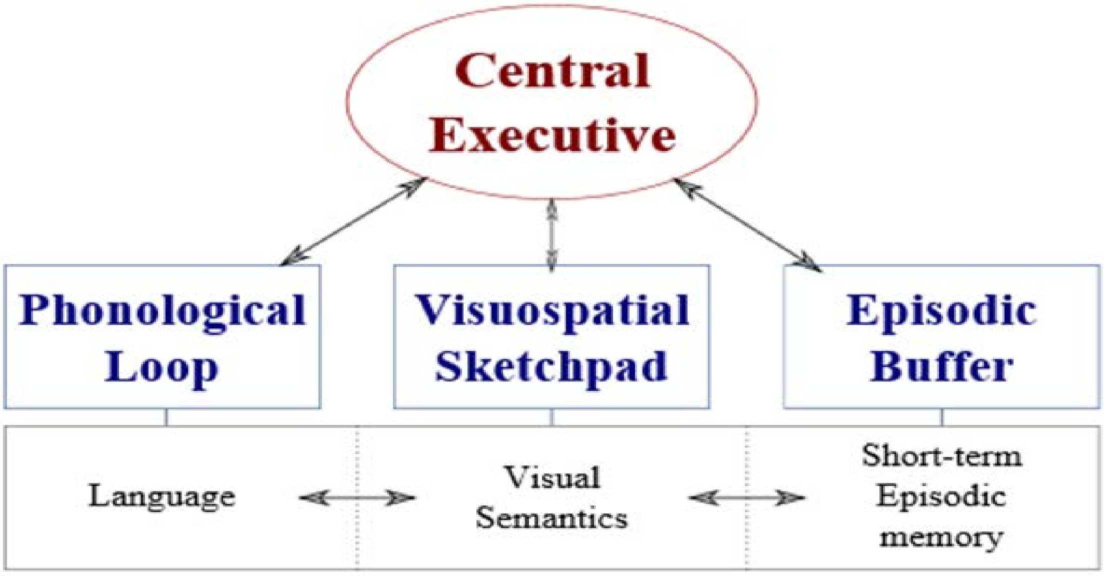


Figure 2-5 Latest multi-component model of working memory (Baddeley, 2000, p. 418)

Learning or extension of the neural networks is strengthened during the retrieval process and not necessarily during the initial processing stage – hence the need for re–exposure, repetition, review and rehearsal in order for the successful processing and storage of information. Schema acquisition and the effects of different stimuli formats have been heavily studied in recent years, such as presenting text only, diagrams separately, combining them or in multimodal formats, all in an attempt to work with the constructs of the HCA and the working memory components (Baddeley, 1998; Ginns, Chandler, & Sweller, 2003; Gog, Kester, Nievelstein, Giesbers, & Paas, 2009; Sweller & Chandler, 1994a; Wayne, Paul, & John, 2003).

As an example of how important the design and presentation are to the successful processing of information, a study by Baddeley and Levy (1971) showed that pairing words according to their semantic similarities demonstrated that by presenting information in a variation of formats such as in sentences had a positive impact on the ability to recall the words (Baddeley, Vallar, & Wilson, 1987). According to Baddeley et al. (1987), “subjects successfully recalled about five unrelated words; however they were able to recall up to 15 words when using sentences” as cited in (Schmid et al., 2011, p. 15). Mayer (2002) also supported aspects of cognitive theory whereby information is processed via a dual channel system, visual and audio (Baddeley, 1986, 1998, 1999b; Pavio, 1986; Sweller, 1999), where each of the processing channels has a limited capacity (Baddeley, 1986, 1999a; Schmid et al., 2011; Sweller, 1999). Typically arranging content to utilise both the auditory and the visual channels will further assist the processing of information (Mayer, 1999, 2001; Sweller, 1999).

The literature clearly defines the role that attention plays within the HCA as follows: “attentional enhancement for relevant stimuli and suppression of irrelevant stimuli” (Gazzaley & Nobre, 2012, p. 131). This is a gatekeeper role within working memory, a role that assists in allowing the limited capacity of working memory to focus on the important stimuli.

Over recent decades, one theory in particular has risen to the occasion and bridged the all too often ignored divide between education and cognitive psychology and is having an influential impact (Paas, Gog, & Sweller, 2010). This is the theory that considers the learner’s cognitive state, their cognitive capacity and the impact that instruction and its design have on the processing and successful integration of new information. This theory continues to focus on the need for matching instruction and cognition, its substructures such as working memory and their limitations. It is “a theory that integrates the origins of human cognition in evolutionary theory with the structures and functions of HCA to provide effective instructional design principles” (Sweller, 2008b, p. 370). This theory is (CLT).

2.4 Cognitive load theory (CLT)

Prior to delving into the depths of what CLT is and how it applies to instructional theory, the literature review has provided an overview of the HCA and working memory. A fair contextualisation of the development of CLT (Paas, Renkl, & Sweller, 2003; Sweller, 1994; Sweller, Ayres, & Kalyuga, 2011d) depends on an understanding of the human cognitive system as Sweller (2006) sees it. The human cognitive system has been referred to the “natural information processing system” (Sweller, 2006, pp. 165-166) comprising five foundational principles: the information store principle; the borrowing principle; randomness as genesis principle; the narrow limits of change principle; and the environment organising and linking principle. These five principles have played a foundational role in the development of CLT.

1. The information store principle acknowledges that “human cognition is dominated by the contents of long term memory” and an individual’s ability to learn and process new information relies heavily on what is already stored within one’s long term memory; it affects the way that information is perceived and how and where it is stored (Sweller, 2006, p. 165).
2. The borrowing principle implies that “almost all of the knowledge held in long term memory is borrowed from the long term memory of another individual by imitating what they do, listening to what they say or reading what they have written” (Sweller, 2006, p. 165). This process results in information from a person’s current long term memory stores being cross referenced and added to by the new information from the other person’s long term memory, hence creating all new schema to be stored in long term memory.
3. The randomness as genesis principle is the process that comes into play when there is insufficient information to draw from in long term memory to solve a problem. An individual is forced to generate moves randomly in order to

search for a solution; "effective moves may subsequently be incorporated into long term memory" (Sweller, 2006, p. 166).

4. The narrow limits of change principle indicate that the degree of change of new information that is stored in long term memory revolves around borrowing from others around or from random trialing moves in search of a solution and the long term memory stores. Owing to the nature of this what the human cognitive system rebounds off and between these tactics to create new information. Only a small or "narrow" (Sweller, 2006, p. 199) limit of change is seen.
5. The environment organising and linking principle illustrates how the unlimited amounts of information that can be stored in long term memory can be used by the working memory to organise information in relation to the surrounding environment, in turn changing the way in which the working memory may perceive, interact with and process the new information (Sweller, 2006).

With a greater insight into the importance of how the HCA and its important subcomponents interact, a closer look at cognitive load can be discussed. The concept of cognitive load can be explained as the load experienced, the mental resources allocated and the effort invested by an individual to complete a task (Jacek, 2010). Cognitive strategies are those processes that a person carries out in order to learn. As I have mentioned earlier, it is the role of the designer to understand what the learner is likely to have to do from a cognitive perspective, as a result of how the information has been designed.

The designer needs to plan ahead and plan the design according to the cognitive processes involved (West et al., 1991). Before CLT (Kalyuga, 2006; Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Sweller, 2012) existed, through what Miller (1956, p. 81) called "experiments on the capacity of people to transmit information" (p. 81), it was acknowledged that humans experienced difficulty in processing stimuli, noting that strategies to avoid these "informational bottlenecks" were already being developed (Miller, 1956, p. 95; Wei & Salvendy, 2006).

In an attempt to gain an understanding of the effects and impact among , instructional design and information processing in a broader sense, therefore enabling us to design more effectively for CE and learning construction, CLT as a theory was examined (Sweller, 2004). In particular, CLT “was formulated to take into account the duration and capacity of working memory when faced with novel information entering via sensory memory” (Sweller, 2004, p. 13). CLT was devised with an intention to consider the limited capacity of working memory, instructional strategies will aim to reduce the load experienced by working memory whilst promoting and encouraging the formulation of new knowledge (Sweller et al., 1998; Van Merrienboer & Ayres, 2005).

The majority of research into CLT has indeed maintained a focus on the reduction of load placed on an individual’s limited resources. However, there is evidence of efforts in the direction of not only reducing the load but also making a conscious effort to investigate and apply design features that encourage the learner’s investment of cognitive load for the good of learning and schema construction. Which elements of design and learning experiences will reduce the unwanted and detrimental cognitive load whilst at the same time promoting and encouraging the investment of the more beneficial cognitive load resources (Paas, Tuovinen, et al., 2003).

CLT offers “promising perspectives” (Kirschner, 2002, p. 9) for designing complex instructional material. It has been formulated “to encourage learner activities that optimise intellectual performance” (Kirschner, 2002, p. 1) and that therefore increase the effectiveness of the learning solution. Sweller (2008b) also intended the theory to assist in identifying more appropriate technologies that designers choose for instructional purposes. “The concept of mental load was initially introduced in the 1950’s and was based on the communication channel with limited capacity” (Kalyuga, 2009a, p. 35).

When workload was first investigated, the world and the workplaces involved more physical efforts. There is a somewhat different picture in today’s world: with the introduction of machines, the workload is that of mental capacity (Miller, 2011). How we process information and what demands are placed on our memories in order to carry out a task are all part of cognition. In the past, human performance was thought to include motor skills, knowledge based material and rules. In this age, with such advances in technology, the definition of human performance, what it includes and how it is measured have changed dramatically (Rasmussen, 1983; Wei & Salvendy, 2006). With jobs changing and roles evolving, the emphasis and demands of physical motor skills have shifted and a new prominence rests on cognitive capacity (Wei & Salvendy, 2006).

CLT (Paas, Renkl, et al., 2003; Sweller, 2012; Sweller et al., 1998) is a theory based on the mental load placed on a learner when processing information. It was developed on the basis of the three component working memory model (Baddeley, 2010; Baddeley & Hitch, 1974) in Figure 2-2; CLT acknowledges the limitations of working memory. Mental load is the demand placed on an individual as a result of external stimuli, task and environment, whereas mental effort is a subject analysis of the effort required and applied to complete the task (Sweller et al., 1998, p. 266). It should be noted that CLT supports and is built on the idea that learning occurs from drawing from the individual's current knowledge stored in long term memory.

A lifetime of experiences and exposure to information, the use of this information and the process of drawing, accessing and retrieving these details impact on the cognitive load and the resources used and therefore available. CLT principles acknowledge that learning occurs through the construction of such schematic networks. CLT strategies and effects demonstrate respect of a person's schematic networks potentially increase that individual's performance. As a result is more likely to transform one's cognitive capacity in dealing with the processing of a task from the status of high difficulty and inconsistency to a faster and more automated status.

CLT is designed around promoting instructional strategies that ensure that the acquisition of schema is uninterrupted and that it optimises the information processing of all stimuli (Lee & Seel, 2012; Sweller et al., 1998). By defining load in a mental processing sense, Jong (2010) chose to draw from the Merriam-Webster online dictionary stated that “load is something that is experienced whereas effort is something exerted” (Jong, 2010, p. 113). Furthermore, in the attempt to bring clarity to the definition amongst the ongoing and continually growing body of literature surrounding, supporting, investigating and in some cases contradicting mental load, workload and more recently cognitive load, it was noted that Wei and Salvendy (2006) avoid the confusion of defining mental effort and support the Proctor and Van Zandt's interpretation, simply assuming that MWL refers to the overall amount of work or effort synonymously required in order to complete the task at hand. In an attempt to address and manage load, independent studies were carried out by (Plass, Moreno, & Brunken, 2010). As a result, explanations of how different instructional design elements and strategies affect the brain were devised, including the birth of CLT (Paas, Renkl, & Sweller, 2004; Paas, Tuovinen, et al., 2003; Plass et al., 2010; Sweller, 1994, 1999; Sweller et al., 2011d; Sweller et al., 1998).

CLT considers the human neurocognitive architecture, appropriate information processing principles (Sweller et al., 2011d) and working memory limitations (Baddeley, 2010). In turn, CLT specifies neurocognitive instructional strategies designed to "facilitate the changes in long term memory associated with knowledge construction and automation" (T. Gog, Ericsson, Rikers, & Paas, 2005, p. 74). CLT supports the work of (Baddeley, 1986) model in that it assumes that the HCA system consists of separate channels for auditory processing and visual processing (Schnotz & Kürschner, 2007). The founders of CLT (Sweller et al., 2011d) categorise cognitive load into three distinct types: intrinsic cognitive load; extraneous cognitive load; and germane cognitive load (see Figure 2-5).

2.4.1 Intrinsic cognitive load

The level of cognitive load that is caused by the content itself can caused by the level of complexity, the depth of the material, however it is generally related to the degree of interactivity among the elements that are responsible for increasing the cognitive load (Sweller et al., 2011d). This is not necessarily the number of elements involved in learning a topic but the degree to which those elements need to interact in order for the learner to process and understand the material. This is referred to as the "intrinsic nature of the learning task" (Schnotz & Kürschner, 2007, p. 471).

A learner's working memory needs to attend to these elements simultaneously to process the information (Renkl & Atkinson, 2003). This is what is known as intrinsic cognitive load; this type of load cannot be altered by the designer (Cooper, 1998). It is, however, crucial that the designer is aware of the elements and how they interact to ensure that effective design strategies can be adopted.

2.4.2 Extraneous cognitive load

The most important type of cognitive load from a design perspective is extraneous cognitive load, as the extent of cognitive load experiences can be influenced by the designer. How the information is presented, the format in which it is displayed, the learning experiences and opportunities provided to the learner all affect the extraneous cognitive load (Schnotz & Kürschner, 2007). Furthermore, the mode selected, the way in which the information is segmented, how much, how little and in what order, are all examples of the design elements that can be altered and all contribute to increasing or reducing the extraneous cognitive load.

The design strategies that require students to engage in the material as part of the apparent learning experience, however, do not provide a direct benefit in constructing new knowledge or schema acquisition. This is what causes an increase in the allocation of valuable cognitive resources (Jong, 2010; Paas, Renkl, et al., 2003). This process is detrimental and hinders the individual’s learning. An example of this may be providing too much information at any one time, overloading the working memory and not allowing the learner sufficient time to process the material or forcing the learner to have to go in search of information that at this point in the learning process is difficult to locate (Jong, 2010). Extraneous “load is imposed solely because of the procedures being used” by the designer (Sweller et al., 2011d).

2.4.3 Germane cognitive load

Understanding each of these categories of cognitive load is important, given that the literature points out that the working memory has a limited capacity. Research indicates that the resources of working memory are pooled, albeit in a limited pool. This being the case, what happens when it comes time to allocating these ‘limited pooled’ resources? Stimuli are presented and the processing begins. Learners have little control over the allocation of working memory resources. They can determine the effort that they invest and this may be influenced by several factors, such as their overall motivation to learn the material, the way in which the material is presented, and the perceived and actual degree of difficulty. Sweller et al. (2011d) explains that the sum of intrinsic cognitive load is caused by a combination of both the load derived from element interactivity and the effort invested, adding this to the extraneous cognitive load (the load resulting from the design of the material) equates to the overall cognitive demand placed on an individual. This is then deducted from the working memory pool, the available cognitive resources available to be drawn from, should this exceed the resources in the pool, learning will not happen.

In the case where the design of information that is presented is of poor quality, the extraneous load will be very high and potentially leave insufficient resources to be allocated to the intrinsic load (Ayres & Paas, 2012; Paas et al., 2010; Sweller, 2008a; Sweller et al., 2011d).

If the cognitive resources of working memory have not already been exhausted by intrinsic and extraneous load, the learner then has the opportunity to allocate resources by means of invested effort. It is this load, the germane cognitive load, that is advantageous to the learning experiences as opposed to detracting from them (Gerjets & Scheiter, 2003). Germane or effective cognitive load is due to beneficial cognitive processes like these required in the schema construction process such as “interpreting, exemplifying, classifying differentiating and organising” (Jong, 2010, p. 109) and others like elaborations, abstractions, comparisons and inferences that are encouraged by the instructional presentations (Gerjets & Scheiter, 2003, p. 33) that see limited cognitive resources maximised throughout the learning process. The view is held that to develop effective instruction it is not sufficient just to reduce extraneous load but it is also necessary to design in order to increase germane cognitive load simultaneously (Paas et al., 2004). Figure 2-6 illustrates the breakdown of cognitive load.

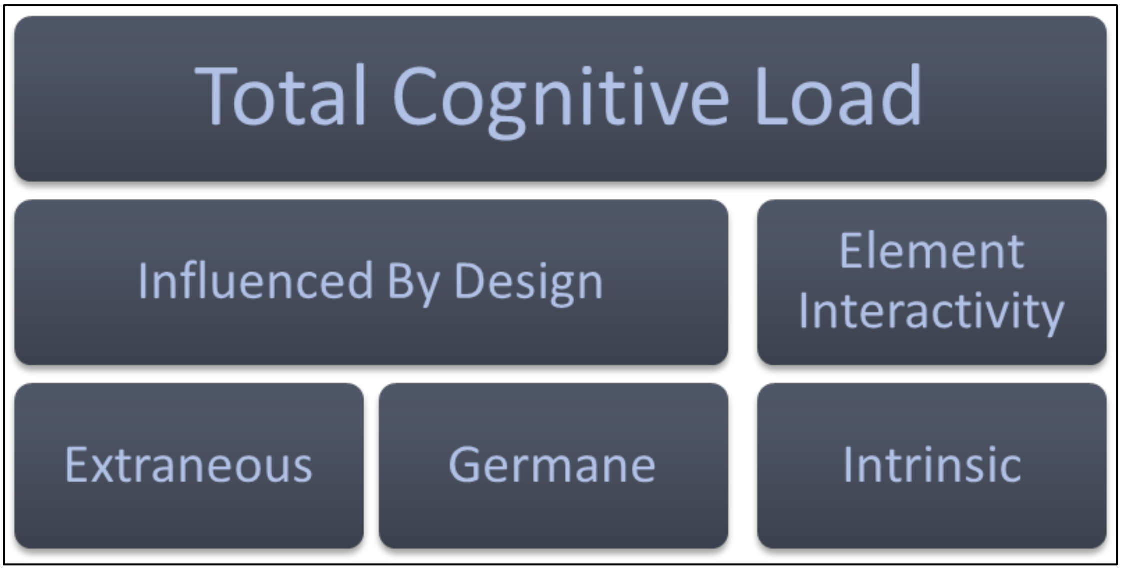


Figure 2-6 Breakdown of total cognitive load according to the CLT

As we learn through the processing of new information, we are continually building new schemas, through adding to current and creating new networks, bubbles, pockets or packets of knowledge. They are, however, referred to as the result of a process. Information consists of several small elements, generally all in isolation, and as they come together they begin to make sense, and a new concept is formulated within our long term memory.

As elements of new information are presented in the form of stimuli, it is our job to decipher which individual pieces of information match one another and which pieces do not. In simple concepts, there may be only a couple of singular and isolated pieces that we are required to process, and these may be related to information of which we already have a prior knowledge and therefore they will be fast tracked and relatively easy to process. They already have somewhere to be stored and linked to; they are small in size and can be made sense of on their own. This is a situation where the intrinsic cognitive demand placed on a learner would be relatively low. The working memory is forced to touch base with the long term memory and search for a link as it always does but, as for searching for a place to be stored, its minimal and working memory is not required to hold a handful of different new stimuli and to match them in order to make sense of them. This is not to say that they will not be added to later or as part of a larger concept, but they are not reliant on other details to be understood in the first place; this is referred to in the cognitive load world as the degree in which elements of information interact, or element interactivity. They are “elements that must be processed simultaneously in working memory because they are logically related” (Sweller et al., 2011d, p. 58).

The cognitive load imposed by newly presented information will pose an intrinsic cognitive load owing to element interactivity and extraneous cognitive load as a result of the instructional design (Paas et al., 2010; Sweller, 1994, 2004, 2008a; Sweller et al., 2011d). Information that exceeds the “natural constraint” (Revithis et al., 2010, p. 299) of working memory will result in an overload and inhibit the learning process. Sweller et al. (1998) suggest that mental load can be a result of, and is influenced by, the level of interacting elements, otherwise known as being “high in element activity” (Kalyuga, 2009c, p. 35). Moreover, how the material is delivered is important, including both the instructional format (text and graphics) used and the modality (audio and visual) in which it is presented. Sweller et al. (1998b, p. 266) differentiate between mental load and mental effort: mental effort is “the amount of cognitive capacity or resources that is actually allocated to accommodate the task demands” (Sweller et al., 1998, p. 266).

Incoming information, the stimuli that are presented and require processing, is not typically organised identically to the way in which our current schema have arranged it, assuming that we have some prior knowledge. This causes the working memory to experience additional load, as this is a direct result of how the information is being presented and of the instructional design aspect (Sweller, 2008b). Sweller et al. (2011d) call this “extraneous cognitive load”. They suggest that using the CLT and its suggested instructional strategies will present information in a way that allows the learner to process it more easily and without unnecessary expenditure of cognitive resources. Performance issues and human efficiency are not only experienced by overloading the capacity of working memory; research acknowledges that “human task performance decreases if the MWL is too high or too low” (Wei & Salvendy, 2006, p. 353).

It has been suggested that “by simultaneously considering the structure of information and the cognitive architecture that allows learners to process that information” (Paas et al., 2004, p. 1) cognitive processing is enhanced. This will enable instructional designers to reduce the cognitive load placed on learners. Jong

(2010) also considers neurocognitive structures and processing as an effective approach to designing instructional materials in such a way that “optimises working memory capacity and avoids cognitive overload” (Jong, 2010, p. 105). Acknowledging the limitations of the working memory and the cognitive processes, and with the objective of reducing cognitive load on learners, Sweller (2008a, p. 374) generated a range of instructional effects, implications and strategies relevant to technology based instruction. CLT and the instructional strategies that have been developed are not, however, a one size fits all. Their appropriate design application and effectiveness are also dependent on the learner’s level of expertise, and in fact “the CLT effects that can be used to recommend instructional designs are only applicable to novices and can disappear or even reverse as a function of increasing expertise” (Paas et al., 2004). The tasks and the instructional methods selected to present the material are dependent on the learner’s prior knowledge and level of expertise (Paas et al., 2004).

2.4.4 Worked example effect

In a learning context, it can be typical to find learners placed in situations where they are required to solve a problem. When examining the relationship between the solution and goal of the proposed problem and the mental demand that was placed on the learner, a high degree of mismatch was found by Chandler and Sweller (1991). The two were viewed as being out of sync and without a relevant proportion of alignment. Research also showed that, despite the high demands placed on the learner, it was not unusual for the problem to be solved. In some cases, the learner was unaware of the actual underlying elements of the problem; traditional methods of searching for solutions, with very few examples provided, were deemed to be detrimental to learning and an ineffective instructional strategy by Chandler and Sweller (1991) (see Appendix A).

Conventional methods found to be used in problems solving include search strategies such as “trial and error” and “means-end analysis” (Cooper, 1990, p. 2), both methods sending the learner in search of pieces of a solution, without explicitly providing them with the necessary guidance required. These methods certainly have their place within instruction for the more expert learner, even though the more novice learner may strike it lucky and, in a one off or even several times, may stumble upon the correct solution to the problem. The novice learner will require an approach that provides sufficient guidance, such as a full worked example (Cooper, 1990). Sweller and Cooper (1985) found that using worked examples as opposed to the more conventional methods of problem solving proved to be a more positive and effective instructional approach (Chandler & Sweller, 1991).

Worked examples are a strategy that would assist in avoiding or at least limiting the level of interference during the learning process (Chandler & Sweller, 1991). Instructional strategies such as using worked examples allows for more effective outcomes than if the instructional design requires learners to go in search of solutions, especially if they are novices (Spanjers, Gog, & Van Merrienboer, 2012). So how and why does the use of worked examples alleviate the mental load placed on learners? For example, as mentioned, it is beneficial to structure incoming information in a format or order that will assist the learner to process it. If learners have no prior knowledge of the problem or the specific topic, they are therefore faced with a situation where a high degree of cognitive load will be placed on them.

A recommended strategy (Sweller, 2008a; Sweller, Ayres, & Kalyuga, 2011j) is to provide an actual sample of the problem and solution, and of all steps in between, in order to show explicitly to learners the problem that they are required to solve, the state in which it is considered solved and the necessary steps involved in reaching that point. A problem consists of several components: the problem proposed; the solution to solve the problem; and the steps involved in arriving at that point. Mapping out exactly what is required assists learners in creating their very own schema on the new topic (Spanjers et al., 2012). This provides them with the links and the new stored knowledge that will walk them through solving the problem; they now have something that is stored in a familiar format from which they can draw from. Removing the need for the working memory to go in search of information, identify the relationship and discard irrelevant information ensures that the working memory resources are maximised (Sweller, 2008a; Sweller et al., 2011d).

Contrary to the worked example effect detailed above, presenting problems in more of a typical format whereby a learner is not given an ideal state in which to arrive is known as the goal free effect or when the given state is partially provided the completion problem effect (Sweller, Ayres, & Kalyuga, 2011g, 2011k) (see Appendix A).

2.4.5 Split attention effect

There are different effects such as the spilt attention effect whereby the learner is presented with information from two sources; this is information that cannot be understood in isolation and therefore requires the learners to play the matching game whilst attempting to make sense of the information. When instructional design fails to consider the effects that multiple sources of information have on learners' cognitive systems it is likely to be a cognitively inefficient process (Sweller, 2008a; Sweller et al., 2011d).

If material is interrelated and relies on other information to make sense of it and to be processed by the learner, attempts should be made to reduce the matching and searching processes that will be carried out. Clear and concise links between one piece of information and the other should be made (Sweller, 2008a). This can be done by providing the labels on a diagram or setting content out in relative lists, including directions or illustrations, to assist the learner to see how each piece of information relates to the others.

If the information is to be processed in a particular sequential manner, then this should be made clear, which removes the need for the learner to comprehend the order and placement of elements as the processing needed to complete this would definitely increase the cognitive resources unnecessarily, before any actual domain content is attended to. Splitting the attention of the learner in fact prioritises the cognitive resources by providing a direction to the allocation of working memory resources. This approach provides a short cut, to the content that can be processed.

2.4.6 Modality effect

Similar to the split attention effect a strategy such as presenting text that is accompanied by a picture in audio format rather than in written format is beneficial to learning; this is known as the modality effect (Brünken, Plass, & Leutner, 2004; Mayer & Moreno, 2003; Mousavi, Low, & Sweller, 1995; Plass et al., 2010; Seufert, Schütze, & Brünken, 2009; Sweller, 2004, 2008a; Sweller et al., 2011d). Kalyuga (2009b, p. 53) points out that using specific approaches such as "dual mode presentation does not reduce extraneous cognitive load but rather increases effective working memory capacity" (Kalyuga, 2009b, p. 53) (see Appendix A).

There is a technique that sees information distributed across both the auditory and the visual channels (Kalyuga, 2009b; Sweller et al., 2011d), in doing so reducing the load placed in a single channel and therefore avoiding the possibility of an overload of cognitive functioning capacity (Kalyuga, 2011). Research has indicated that “modality effect” as devised by Sweller (2008a, p. 375) was specifically catering to the working memory model by Baddeley (1998) that illustrated that the human cognitive processing system consisted of dual channels, an auditory and a visual. By presenting the stimuli utilising several different channels, the different processing channels would be maximised and consequently would “expand the effective size of working memory in an instructionally favorable manner” (Sweller, 2008a, p. 76).

2.4.7 Redundancy effect

The redundancy effect refers to an instructional design that includes information that is not necessary for learning to take place (Sweller, 2008a; Sweller et al., 2011d). All too often we see information repeated, and repeated, time and time again. It is a well-known fact that learning requires multiple exposures to a new concept and that mastery of a task will require the learner to complete the task several times. However, when information is presented, especially new information to which learner have had no or very minimal previous exposure, they therefore have no prior knowledge stored in long term memory from which to draw. The learner is then completely reliant on only the details presented in order to process the new information. There is a risk in providing information repeatedly. More often than not, this situation occurs when identical information is presented to the learner in different formats or modes (Sweller, 2008a; Sweller et al., 2011d).

The human brain has an innate urge to look for what is different, compare different pieces of information and map those pieces in relation to one other. This is a part of the process that the working memory goes through; it is what makes the working memory an effective “active processor” (Ashcraft, 2006a, p. 3). It can only be assumed that this concept has been misinterpreted by designers and that this misinterpretation has caused a design flaw of including identical information more than once. This is not to say that additional material to enable revision is not required. It is however pointing out that when this is done, it should be clearly stated and avoids the learners thinking that the repeated material is new information. Coming back to the definition of the redundancy effect of including information that is not required for learning this can also include the use of images or diagrams, narration, lists or any information that is not required in order to make sense of the content (Sweller, 2008a).

The working memory spends its valuable limited resources on “attending to unnecessary information and attempting to integrate it with essential information” (Sweller, 2008a, p. 376) therefore absorbing working memory capacity that otherwise could have been utilised for learning. A simple design rule is that less is more, keep the information relevant and avoid wasting working memory resources on processing unnecessary information.

2.4.8 Expertise reversal effect

The expertise reversal effect is linked with or at least reflects the redundancy effect, in that, when the audience of learners has different levels of expertise from novice to expert, naturally an expert will have a more extensive schema built from previous experiences and knowledge stores. This knowledge will be drawn from the long term memory; as a result, the information required for more expert learners will differ from that needed by novice learners. Expert learners will not need some of the basic concepts, again causing then to waste resources on attending to redundant information if it is present (Sweller, 2008a; Sweller et al., 2011d). Careful consideration should be taken in understanding the audience and their level of knowledge. A short pre assessment or questionnaire may be a useful tool to assist in the assessing the specific domain being presented.

2.4.9 Guidance fading effect

An effect related to the expertise redundancy effect and the worked example effect, considers the level of expertise of the learner and adjusts the number and depth of details presented in order for learning to take place, remembering that, when a learner has increased knowledge, less information is required than that of a novice. A step back from providing a full worked example is required for the more experienced learner. This is known as the guidance fading effect, whereby, as the learner’s schema increases in a particular domain, the guidance required should be appropriately reduced (Sweller, 2008a; Sweller et al., 2011d) hence the guidance fading effect. Like the redundancy effect, this is an instructional design strategy that relies on the designer establishing the level of experience and prior knowledge of the audience in order to design effectively according to the guidance fading effect (see Appendix A).

2.4.10 Imagination effect

Again, when a designer has established that the audience has a level of prior knowledge, more appropriate design strategies should be included (Paas et al., 2004). Given that they have established schema from which to drawn, an effective strategy can be to encourage learners to imagine a situation, a process or solution to a problem (Sweller, 2008a). This strategy also aligns with the guidance fading effect; not all details need to be provided. Designers want the learner to use the information provided and imagine. This strategy causes learners to rehearse the solution, rethink the details that they have already transferred to long term memory and map them accordingly to answer the question or to complete the task presented.

The imagination effect not only encourages learners to revisit the information provided but also forces them to revisit the information already stored. This is an effective strategy to strengthen the already created schema and the transfer of the new information. This is yet another strategy that requires learners to have an already established relevant schema. If this is not the case, the instructional design strategy will be likely to be ineffective. Learning will be inhibited as novice learners will not have been provided with the necessary information and they will have insufficient prior knowledge from which to draw in order to complete the task.

2.4.11 Transient effect

Other effects exist such as when information that is presented disappears before the working memory has the necessary time to process it; this, is known as the transient effect. In many instructional solutions traditionally printed text will appear on screen that appears only for a minimal amount of time, or the text is not written text at all and is presented in auditory format as a narration (Kalyuga, 2011) Simple oral instructions from a teacher or audio instructions are deemed to be transient. Actually, “by its very nature, all speech is transient” (Sweller et al., 2011d, p. 220).

Writing transient information is an attempt to transform its transient nature into a more permanent one (Sweller et al., 2011d). Sweller et al. (2011d) define the “transient information effect as a loss of learning due to information disappearing before the learner has time to adequately process it or link it with new information” (p. 220).

In order not to inhibit learning or the successful processing of information the level of cognitive load needs to be monitored and in some cases reduced (Kalyuga, 2009b). In the case of dealing with transient information, careful consideration is required; consideration should be given to whether the information is simple or complex and the duration of the auditory information being presented. Transient information is not reserved for spoken and auditory formats. Images, diagrams and illustrations that may in a traditional sense be presented in a static format, when they are presented in an animation or, simulation or on screens that have a limited display time, are also then categorised as transient (Kalyuga, 2011). No longer does the audience have unlimited time to read and process the infomation. No longer can the information be referred back to at leisure. This information is transient in nature and unless the audience makes a concerted effort in some way to capture and record the information in a more permanent format, the information will be lost. The concerns do not stop here. Already we have established that the audience cannot review transient information as they would with traditionally presented material. Depending on the duration and speed at which the material is being presented, this will affect whether the audience actually has any opportunity to capture a more permanent record to allow time to process and make sense of the material. Whilst they are attending to the capture and recording of the material they will naturally miss out on what is continually being played out in front of them.

If we were to consider only the content and not the prior knowledge of the target audience, we are faced with a range of considerations that should be taken into account. The depth of content the level of difficulty of the content the quantity of information and length of the solution are all additional factors in understanding the impact that presenting information in a transient format may have. In particular, as the length of the spoken text increases the level of cognitive processing increases and requires more from working memory. In this situation, the working memory is being asked to hold more information, whilst still referring to long term memory in order to make sense of the new incoming details and to link these details with current schema. This is all whilst more information is flooding in through the phonological channel (Mayer, 2001).

Logically the duration and length of material presented can become more complex and impact on the cognitive demand on the audience. It is hypothesized that "complex information may impose an overwhelming working memory load when presented in transient" format (Leahy & Sweller, 2011, p. 943). The presentation of transient information may very well engage learners and require them to pay attention to an onslaught of information; this also requires learners to process information simultaneously (Mayer, 2001). Hence the overloading of the working memory, while on the other hand the application of different instructional effects may alleviate the cognitive demand. Further research about and adoption of such effects should be applied, because for multimedia formats to be an effective mode of learning the degree of transiency should be known and evaluated in accordance with the cognitive demand being placed on the audience (Mayer, 2001). This may require extending the length of time that information is presented on screen, providing the operator with the ability to replay or pause segments, - providing opportunities for the capture and recording of a more permanent record, and if necessary changing or combining the format or mode used to present information (Mayer, 2001).

The point that spoken text is transient by nature has encouraged research into testing the impact that this transience has on the modality effect. Research showed that using self-paced or web-based instruction did not itself have an impact on the modality effect. However, further findings highlighted that when the spoken text was of any significant length, learners ran the risk of missing out on vital information (Kalyuga, 2011).

Over recent years, changes have occurred in the way that we are learning and designing instruction. From this perspective more research into cognition has called for further investigations (Schnotz & Kürschner, 2007). These important changes have meant that more technology is available and that therefore there are new ways to present instructional material, such as animations whereby a series of sequential frames appears and disappears. CLT continues to evolve and the effectiveness of each new strategy is under scrutiny. Research has established that the use of transient information is unfavourable to the learning process (Ayres & Paas, 2012).

2.4.12 Element interactivity and isolated interactivity effect

Additionally, simple techniques cannot be overlooked, such as arranging information so that it is segmented into small, meaningful units or implanting tracing tools that allow learners to keep important details at hand. A list of devised strategies can be seen in Appendix A that have been tested and delivered in the form of instructional design effects; "each technique has been studied as an experimental effect using randomised, controlled experiments in which an instructional technique generated by CLT is compared to an alternative, usually more traditional technique" (Sweller, 2008a, p. 374).

Literature supports the theory that not only instructional designers but also information designers in general need to be conscious in their use of design strategies as the structure, mode, format and overall presentation of information abound in a world with so many options, and such large amounts of information that require processing in today's world, in order to create solutions and material that meet the design objectives of achieving efficiency in information processing and designing for effective learning. Without the use of instructional design strategies that reflect the HCA, it can be said that instructional design practices are highly influences on the designers own experiences (Sweller et al., 2011d). It is important to remember that, when the cognitive load is not due to the complexity of the domain specific content, or the level of element interactivity, load inflicted exclusively by the way in which the material is designed increase the cognitive load unnecessarily and opportunities exist to decrease this load by applying appropriate human architectural design strategies (Sweller et al., 2011d). The instructional strategy designed to address the transient effect can be seen in Table 2.1.

Effect Name	Transient Effect
Effect descriptor and cognitive implication	Information that is presented and disappears is known as the transient effect. Oral instructions from a teacher or audio instructions are transient. “By its very nature, all speech is transient” (Sweller et al., 2011f, p. 220). Writing transient information is an attempt to transform its transient nature to a more permanent one (Sweller et al., 2011f). Sweller et al. (2011f) define the “transient information effect as a loss of learning due to information disappearing before the learner has time to adequately process it or link it with new information”(p. 220).
Instructional strategy	The learner is presented with an opportunity to turn the transient information into a more permanent one; this may be in the form of mental rehearsal or noting information down.

Table 2.1 Transient information, effect and suggested strategy (Sweller et al., 2011f, p. 220)

Across the literature about research into schema theory, cognition, memory and learning it is CLT that brings together the understanding that working memory is under pressure during the construction of new schema. As a more and more complex schemas are built an individual’s ability to process information within working memory increases owing to the way in which the information is formatted. The information is categorised into relevant chunks and therefore enables the working memory to tag larger pieces of information under the one banner.

Making the recall, further reference, matching and processing dimensions of a larger collection of information streamlined rather than working memory attempting to search for and process individual pieces of unrelated, uncategorised and singular pieces of data is important. All strategies of CLT acknowledge learners current schema and the capacity of human working memory through the simultaneous processing, the integration process and the consolidation process where information is integrated into single elements (Gerjets & Scheiter, 2003).

2.5 Cognitive load measurement

Cognitive load reveals the mental load being imposed upon a person during a task. The ability to measure or establish a metric provides an invaluable insight into an individual’s cognitive position; increased cognitive load can increase stress, impede performance and lead to poorer outcomes (Chatterjee, Das, Sinharay, & Pal, 2015). Cognitive load is measured to evaluate and predict an individual’s cognitive capacity, a practice that is being widely adopted across a range of disciplines, including education, human factors, corporate, military, engineering and information design (Jacek, 2010). Measuring and monitoring an individual’s performance and evaluating one’s efficiency are not new. As technology advances, more and more demand exists to gain further insights into how individuals perform from a mental or a cognitive perspective.

The measurement of cognitive demand or load is not simple and has seen a variety of methods explored and has remained a hot topic over the past two decades; varying methods have been explored and as technology advances the preferences change (Paas, Van Merrienboer, & Adam, 1994). Three main methods of measuring cognitive load, workload or cognitive demand are seen in the literature; subjective measure options, performance measures and physiological measures (Jacek, 2010; Miller, 2011; Revithis et al., 2010; Siyuan, Julien, & Fang, 2011). From a dimensional perspective research has conceptualised the measurement or cognitive or mental load into three main areas of focus: external contributing factors; those that are imposed by the task or the environment; and internally evoked load being the level of effort allocated by an individual in order to process the stimuli presented and to complete the given task. These two measures are combined and considered the mental effort from a human perspective; research indicates that a third measure has been seen to add another dimension to the measurement of cognitive load. The level of performance achieved in the task (Paas & Adam, 1994).

Very little research has demonstrated an attempt to scale the measures in any way according to a range of possible influential factors that may impact on the scores. Subjective techniques have been used in the past and continue to dominate the practice of measuring cognitive load. A cycle of inaccuracies may be experienced in adopting a merely subjective approach whereby depending on the tasks complexity, the outcomes may be altered from a range of elements such as individuals’ perceptions of the task, their motivation and their innate desire to allocate working memory resources to a task (Paas & Adam, 1994).

Performance based metrics are in no way exempt from such possible flaws. Scaling should be considered in order to plot the subject’s level of experience and years of experience within a specific domain. Rarely if ever will it be determined that all individuals are situated in an identical schematic position and therefore performance scores are required to reflect the true status if the outcome metrics are to be indicative of an individual’s performance measure.

The focus of the researcher, the subjects and the resources available influence the methods used. The ability to measure cognitive demand/MWL and working memory capacity (WMC) is high on the agenda within psychology research today. Such metrics can be seen as “predictors of a wide range of human abilities” (Foster et al., 2015, p. 1) in such areas as educational, developmental and social spheres by Engle (2002), Kail (2007), Lee & Park (2005), Schmader & Johns (2003) as cited in (Foster et al., 2015, p. 1). WMC has a reputation of providing an account of individuals’ fluid intelligence (Gf) and even more importantly their level of reasoning capacity (Foster et al., 2015; Harrison, Shipstead, & Engle, 2015). Put simply “WMC refers to the effectiveness of the working memory for a given individual” (Harrison et al., 2015, p. 1).

2.5.1 Subjective measures

In a review by Schüler, Scheiter, and Genuchten (2011) into the “role of working memory in multimedia instruction” (p. 389) “tasks to measure working memory capacity” (p. 393) used by researchers according to the working memory sub systems involved were tabled (Schüler et al., 2011). These tasks included the digit span task (Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999; Spreen & Strauss, 1998; Waters & Caplan, 1996); Wechsler (1958) the VPT task, by (Baddeley, Della Sala, Papagno, & Spinnler, 1997; Della Sala et al., 1999) the reading span task (Conway et al., 2005; Daneman & Carpenter, 1980; Kane et al., 2004; Lehman & Tompkins, 1998; Waters & Caplan, 1996) the operational span task (Turner & Engle, 1989) and the counting span task (Engle, Tuholski, Laughlin, & Conway, 1999).

The most common data collection tool for estimating workload measures by far is the subjective measure whereby the subjects complete a post task questionnaire; generally based on the use of “rankings or scales to measure the amount of workload a person is feeling” (Miller, 2011) as cited by (Shriram, Sundhararajan, & Daimiwal, 2009, p. 5). This is a self-reporting option that is generally preferred owing to its ease of implementation, low cost and non-intrusive manner. Subjective measures are able to provide an insight into the “state of the user and are important for assessing users’ perceptions of the task” (Jacek, 2010, p. 4). Is this the most appropriate option to use for measuring the cognitive load demanded or one’s response to particular stimuli? This is not a view not shared by all: for instance, the use of such a static method fails to assess “the dynamic changes in cognitive load” (Jacek, 2010, p. 4).

Subjective methods in particular, are those completed post task and that are not able to indicate the fluctuation of mental investment throughout the learning event. Jong (2010) holds the belief that when post testing strategies are used in an attempt to measure the cognitive load experienced, those who scored low indicated clearly that the cognitive demand was too high. What was it that contributed to the overload is left to the imagination, as a self-reporting strategy that is influenced by individuals' perceptions, their current schema networks and instructional design components result in an inability to provide instantaneous measurement that cannot pin point causal stimulus during an event (Jong) questions “whether an average load over the whole process is the type of measure that does justice to principles of cognitive load theory” (p. 115). Jong (2010) points out that, in many cases where cognitive load is at the focal point of a study, a failure to measure cognitive load directly is apparent and results are heavily drawn from subjective post-test measures. Arguably Paas (1992) nine-point scale is a well-accepted instrument for documenting the mental effort of participants. Research indicates that different studies use a range of scales and terminology from mental effort and task difficulty when asking learners to rate their experiences (Jong, 2010). There are inconsistencies in the scores that can be captured; students' perceptions have been known to be skewed between the correlations of task complexity and the mental effort consciously allocated to completing those tasks. This raises concerns over the validity of measureable outcomes without the use of complimentary metrics as a support measure, or at least the ability to gain true and accurate metrics across subjects that are free from the unavoidably varying levels of perception, a by-product that comes with the territory of subjective techniques. Researchers hold the opinion that there have been sufficient consistencies achieved in the use of rating scales to capture mental effort, task difficulty and performance scores either during or post the task period. “Despite these differing procedures, subjective measures or mental effort have been surprisingly consistent in matching performance data predicted by CLT with few discrepancies or contradictions” (Wei & Salvendy, 2006, p. 74). Figure 2-6 displays the model used when subjective scales are paired with task assessment scores as a measure of cognitive load.

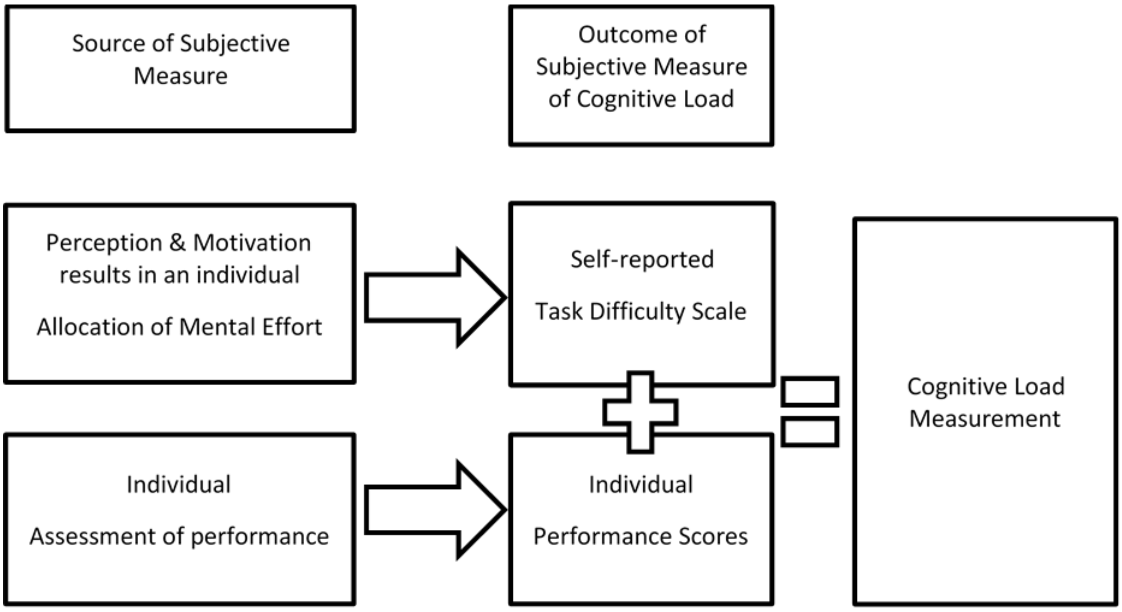


Figure 2-7 ***A subjective approach in the measurements of cognitive load***
Using the combination of self- reported task difficulty scale measures to indicate the mental effort required and the results achieved in an assessment task to indicate the individual performance.

Despite this method having been somewhat altered to suit particular studies, Paas (1992) supports the original nine-point scale and it remains popular as a subjective method to measure cognitive load. The subjective nature raises doubts about the ability to gain a true insight into the neural activity, the brain’s real response to changes or continuous cognitive demands. It is not without scrutiny as Brunken, Plass, and Leutner (2003) raise the question of such an interpretation and the link between an individual’s invested effort and the cognitive load experienced. Nor does literature provide a strong argument to support subjective self-reporting methods of measuring cognitive load. From a time, effort and result perspective, it is not known what individuals are considering when scoring the load. It is thought that “considerations show that the time aspect is not well considered when measuring cognitive load” and how that then has effected the overall completion and therefore cognitive load experienced (Jong, 2010, p. 120).

It is well reported that there are downfalls in using self- reporting methods “good data depends on participants being able and willing to reflect deeply on their performance and their work” (Crandall, Klein, & Hoffman, 2006, p. 13).

2.6 Performance measures

Generally, the use of performance to indicate the cognitive demand is directly derived from the result of a subject’s ability to perform a given task successfully (Shriram et al., 2009). There is also another technique using a secondary task, commonly known as the dual task method. This approach, however, uses the secondary task once again to evaluate the results and the ability to complete the primary task from a capacity perspective. How much mental load did the secondary task demand and what capacity was left to complete the primary task (Miller, 2011). Performance measures are able to take account of several components and to make comparisons in a relative sense against other individual results. Data used include accuracy levels, the number of errors and the time taken to complete the task (Jacek, 2010). Using an object oriented task design model can be effective. In particular, the OOCATD model is an alternative method of looking at cognitive task design and performance (Wei & Salvendy, 2006). The OOCATD model is unique in that it "breaks down the perception and cognitive processes into more details including 11 cognitive models: five functional modules (information interface, information handling, plan and schedule, execution and monitor), two resource modules (attention and memory) and four support modules (communication, learning, motivation and environment)" (Wei & Salvendy, 2006, p. 362).

The use of such a model provides managers and designers with a framework by which they can evaluate the individual's performance throughout the duration of a cognitive task as each sub function is isolated, therefore providing an opportunity to map the task into a linear diagram to and assign the appropriate sub tasks according to the overall task and purpose (Wei & Salvendy, 2006). This approach to the evaluation of human cognitive performance prioritises interface design and human computer interactive tasks, they are however not exclusive and can be easily reused in a variety of settings (Wei & Salvendy, 2006). Owing to the OOCTAD model's "faster development, higher quality, easier maintenance, reduced costs, increased scalability better information structure and increased capability" (Wei & Salvendy, 2006). Wei and Salvendy (2006) propose the use of the OOCTAD model to be used not only to design cognitive tasks but also to evaluate task performance and therefore to allow corporations also to use it as a tool in their personnel selection processes.

2.7 Physiological measures

An increase in cognitively demanding tasks within the workforce, ever increasing technologies that have resulted in more and more information to be processed and the need for objective methods in measuring the cognitive demand, mental fatigue and risk of overload have all seen an increase in the use of objective physiological measures (Holm, Lukander, Korpela, Sallinen, & Müller, 2009). A physiological measurement method "is a factually based concept that relies on evidence that increased mental demands lead to an increased physical response from the body" Miller (2011, p. 5); (Moray, 1979; Shriram et al., 2009). Smith and Jonides (1997) studied the working memory from a neuroimaging perspective and their results showed that there was an increase in "activity with increasing memory load" (Smith & Jonides, 1997). Physiological measures have the capacity to provide researchers with a continuous account of the cognitive load experienced (Shriram et al., 2009), thus allowing the option to review the cognitive load in time locked intervals, continuous periods of time and/or averages of periods of time and relate this back to the stimuli presented.

This approach is invaluable in the ongoing research into cognition as a tool that impacts on educational developers. A new field of computational neuroscience is opening up the use and adoption of technology in understanding the activity within neural networks. The field of neuroscience uses technology such as electroencephalography (EEG) to collect data. It not only extends the current literature on cognitive behaviour and learning but also satisfies the increasing need for better "biologic accuracy" (Ashby & Helie, 2011, p. 273).

There are other physiological measures being widely used to measure cognitive load (Shriram et al., 2009) such as functional near infrared spectroscopy (fNIRS) (Jacek, 2010), eye tracking (Gog et al., 2009; Jacek, 2010; Van Gerven, Paas, Van Merrienboer, & Schmidt, 2004) such as eye movement (Ahlstrom, 2005; Ahlstrom & Friedman-Berg, 2006) activity blink rate or pupil dilation. Heart rate (cardiac response) is the most common of the physiological measures according to (Miller, 2011) however, this is disputed as to its accuracy and validity by Pass and Merrienboer (1994b) as cited in (Jong, 2010). As with most methods, there are pros and cons. For instance in using "pupillometry, the observation of the dilation of the eyes pupil" (Jainta & Baccino, 2010, p. 1) is an effective technique for identifying levels of mental processing activities. However, this technique comes with the complication that the pupil also responds to changes in spatial stimuli and changes in light, causing difficulties in differentiating the "cognitively induced" (Jainta &

Baccino, 2010, p. 1) responses from those that have resulted from other non-cognitive causal stimuli.

The methods, tools and techniques used, therefore the metrics at hand, vary depending on the objectives of the research, the study aim, the subjects, the resources readily availability and the timing and expertise of those conducting the study. Understandably the level of intrusiveness continues to play a major role in the adoption of physiological measures of cognitive load (Jong, 2010).

Electroencephalography a method that records neural activity is widely accepted as the most accurate technique for measuring MWL (Jacek, 2010; S. Miller, 2011). The equipment needed to capture brain activity using the electroencephalogram method is expensive and requires specialist training to operate, and also to interpret the results (S. Miller, 2011). Attractively electroencephalography (EEG) allows the continuous measurement of brain wave activity in correspondence with participants' information processing with or without the participant being consciously aware (Antonenko & Niederhauser, 2010). Researchers have proven that it is possible to gain an objective insight into the level of cognitive processing taking place. This can be achieved by using the EEG method. EEG is a technique that is increasing as technology becomes within reach and more affordable: however, unfortunately it still remains out of reach for the majority within the late fields of education and cognitive psychology.

EEG is an unobtrusive means of providing instantaneous data collection (Hope, Wang, Wang, Ji, & Gray, 2011). As (Jong, 2010) also argues the physiological measurement approach enables a more in depth analysis to take place", as (p. 120). On the other hand there is no way of gaining an insight whether those that rate a task as high on the measurement scale are those who take longer to complete the task and vice versa. However the data collected is timed down to seconds, allowing matching of the physiological response, event related brain potentials, the electrical activity generated (Paas & Van Merrienboer, 1994) and the correlating stimuli provided. Using EEG to study cognitive load allows "greater precision than can be achieved by behavioral techniques alone"(Hillyard & Marta, 1983, p. 55).

EEG is the recording of brain activity; this neural activity is represented in graphical waveforms of differing frequency ranges. Each range indicates a particular level of brain consciousness and activity. EEG is often referred to as being viewed in either continuous format or specific time locked epochs. The continuous recording is looking at the entire time recorded, establishing patterns within the waveforms, whereas the time locked epochs are specific time blocks that are analysed with respect to a particular event in time. Typically, when a stimulus has been presented, a method using the identification and analysis of its Event Related Potentials (ERP) is used. The ERPs are “reflections of patterned neural activities associated within formational transactions in the brain” (Hillyard & Marta, 1983, p. 34).

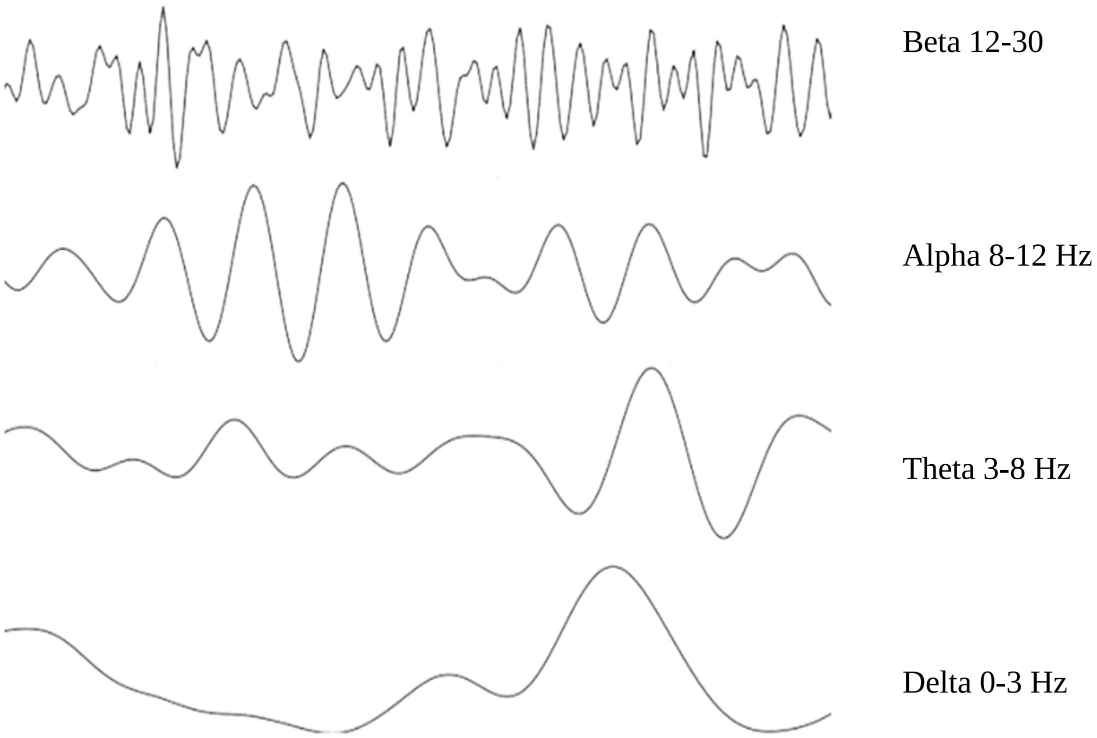


Figure 2-8 Brainwave rhythms

Brain rhythms can be seen as pulses on a screen in Figure 2-8. Research indicates that the alpha rhythm is the most stable of all the brain rhythms (Maltseva & Masloboev, p. 3), demonstrating that memory mechanisms may be provided by theta rhythms (Gevins, Smith, McEvoy, & Yu, 1997). Alpha and theta combined signals have also been reported to contribute to memory performance (Klimesch, 1996, 1999; Maltseva & Masloboev).

There are many theories as to the use of neural data to infer and interpret the band waves in ongoing EEGs. Mental load can be determined when there is an increase in Theta band and an increase in Alpha band (Gevins & Smith, 2000) whereas other interpretations require noting the alpha – theta band ratio in order to determine cognitive workload (Berka et al., 2007). Then there are those researchers that go that one step further and look at a combination of all band waves. Figure 2-8 displays the brainwave rhythms and their frequencies.

As a result of new technologies, past theories that identified particular areas of the brain, which were thought to be responsible for memory, such as the medial temporal lobe as reported in severe memory impaired patients by (Scoville & Milner, 1957) and information processing are changing (Simons & Mayes, 2008). From the medial temporal lobe to the prefrontal lobe the parietal cortexes have also been revealed through neuroimaging to play key roles in memory functions (Simons & Mayes, 2008, p. 1739; Van Kesteren et al., 2012). Research and literature have shown that particular areas of the brain are playing a more active role in in cognitive processing and therefore it is beneficial to be cautious about the different EEG devices available on the market today. Not all devices have the scalp coverage required to cover the important areas. Research has recently confirmed that “the leads corresponding to the left frontal lobe and right parietal-occipital lobe are in general most significant across the majority of subjects for analysis of the cognitive load” (Sinha, Chatterjee, Das, & Sinharay, 2014, p. 22). No doubt, given the unveiling of new technologies, more theories about the roles that each of the brain regions fulfils will evolve, expand, be disputed and amend the current literature.

Capturing neural data and analysing the data are separated by what and how the data are manipulated: again perception may play a role here. Depending on what the data are being used for, what it is that drives the collection of the data will typically influence how the data are dealt with. EEG is a medical collection tool whereby a neurologist looks for patterns in the neural activity and draws from these in order to establish a clinical diagnosis. EEG data that are captured with respect to investigating the levels of cognitive demand are placed upon an individual more of quantitative figure is sort. This enables a measurable level, a scale or a spectrum where results are plotted and interpreted. More often than not Event Related Potentials (ERP) are extracted from the data, which provide time locked pieces of data that allow the analysis of the specific neural response to a present stimuli or event.

When looking to investigate an overall measurement of an event such as the cognitive load experienced or the demand incurred during a task, continuous EEG recordings can be captured and averages of the neural data can be calculated. For measuring cognitive demand, EEG technology is an effective and accurate methodology. Depending on the objective, the use of ERP and continuous recording and data averaging are widely applied analysis techniques. Both of these techniques providing data that are being norm referenced against other individual data: for example, a single score will be established as a result of completing a task. These are important results: furthermore, the data may also have the ability to shed a different light if they can establish how individuals responded with respect to their own baseline status. Although there is similarity across the band power of the difference between brain frequency bands amongst individuals and tasks, research has established that brain function, or the behaviour and patterns of neural activity, change with age, volume and/or just between individuals (Klimesch, 1999; Niedermeyer, 2005; Nunez & Cutillo, 1995).

Since the early days of EEG analysis particular task demands have resulted in the desynchronisation or suppression of the alpha band (Klimesch, Doppelmayr, Pachinger, & Russegger, 1997) (see Figure 2-8). This provides yet another opportunity to use the Event Related Desynchronisation/Event Related Synchronisation (ERD/ERS) index as a metric to enable the difference to be highlighted from an individual’s baseline or reference interval to that of a test interval (Pfurtscheller & Lopes da Silva, 1999) (see Figure 2-9).

Figure 2-9 ***Alpha suppression.***

Alpha activity becomes visibly suppressed 10 seconds into the experiment when the participant opens her eyes and engages in a mental arithmetic task (Antonenko, Paas, Grabner, & van Gog, 2010, p. 430).

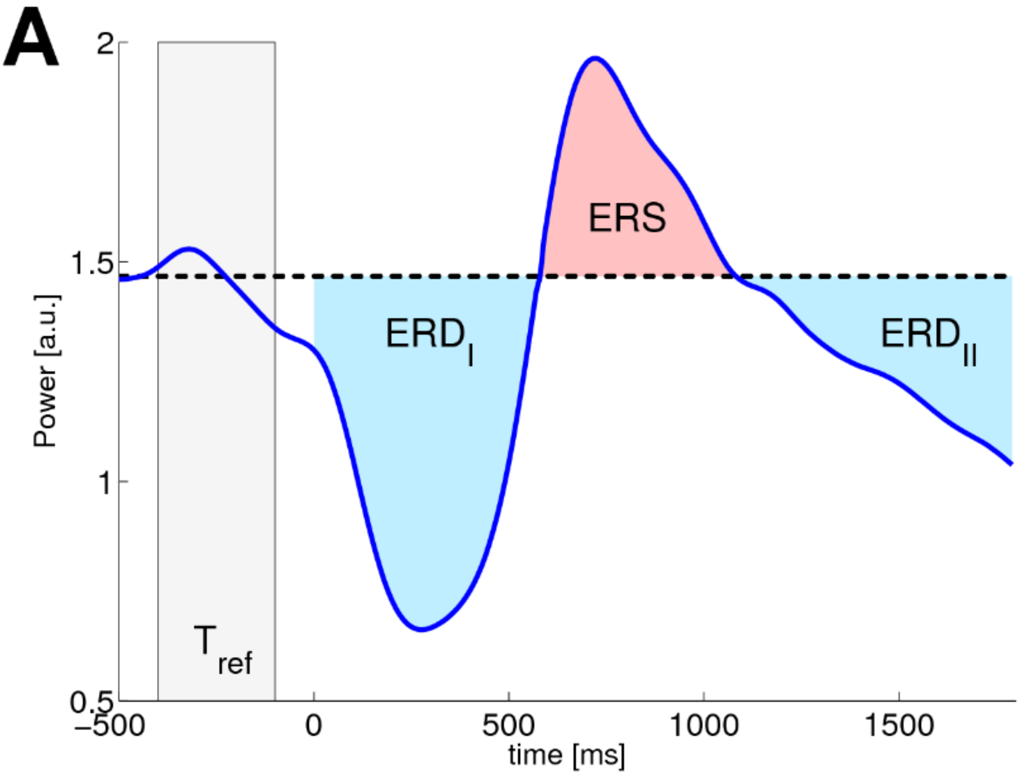


Figure 2-10 ***"Generalised ERD: measures the relative deviation of the event related dynamics (solid) from a constant baseline level (dashed) (Lemm, Müller, & Curio, 2009, p. 3).***
The baseline measurement is established from averaging out a 60 second eyes closed interval.

Using this EEG technique as an approach to interpret the deviation of band power that event-related desynchronisation/event-related synchronization ERD/ERS provides can allow a metric that differentiates the increase or decrease in mental load according to an individual's own level of resting neural activity from that of the neural activity during a cognitive demanding task. Obvious benefits would surely exist should this be coupled with the subjective forms of cognitive load assessments already discussed,

> By convention an ERD corresponds to a negative value, i.e., a decrease in power, while event-related synchronization (ERS) refers to an increased signal power. Note, changes of signal power are quantified only with respect to the deviation from a fixed, constant baseline level (Lemm et al., 2009, p. 1).

This technique provides an additional supportive measure of cognitive deviation that can be objectively captured and analyzed towards the establishment of an overall cognitive load experienced during a task. The nature of this additional approach is attractive in the sense of allowing the typical EEG averaging measures to be utilised as an indicator of where an individual sits amongst a particular cohort whereas the ERS/ERD provides an indicative and relevant measure of mental demand in accordance with the individual’s own cognitive operating capacity.

The use of ERD/ERS can be useful in determining the cognitive load experienced. Research has demonstrated that “task difficulty is one of the most powerful factors leading to the pronounced alpha desynchronisation” (Klimesch, 1996, p. 64). This method is used to provide a unique human cognitive demand measure (see Figure 2-10). The CE is established using instructional efficiency formula (see Figure 2-11).

$$\text{ERD / ERS \%} = \frac{\textbf{baseline interval band power – test interval band power}}{\boldsymbol{baseline\ interval\ band\ power}} * 100$$

Figure 2-11 ERD/ERS formula (Antonenko et al., 2010, p. 6)

$$\text{Efficiency} = \frac{\textbf{Z Performance – Z Mental Workload}}{\sqrt{\mathbf{2}}}$$

Figure 2-12 Instructional efficiency formula (Paas, Tuovinen, et al., 2003, p. 68)

2.8 Summary of the literature

The type of load also raises the valid concerns of the amount of cognitive load that is experienced and how it is measured in terms of a metric. Especially in subjective methods of measuring load, a problem exists in determining exactly to what the level indicated refers. Jong (2010) expresses view that the instantaneous cognitive load is that of the load at a particular point in the task whereas the accumulative load is the total load experienced across the entire task. The literature assumes that the use of subjective questionnaire type measures is used to measure the overall load and that physiological measures are more effective capturing the instantaneous cognitive load (Jong, 2010).

The literature has indicated that there is a general consensus about what makes up the HCA, and the memory systems involved in human cognition are well represented in a range of theories that are both computational and non-computational models (Anderson, 1983; Frias-Martinez & Gobet, 2007; Goertzel et al., 2010; Hanham, 2011; Sweller et al., 1998). The review of literature confirms that information processing is carried out through separate auditory and visual channels and that instructional implications exist as a result of working memory's limitations (Baddeley, 1986, 1999a; Mayer, 2002; Pavio, 1986; Sweller, 1999).

The original three component working memory by Baddeley and Hitch (1974) was illustrated in Figure 2-2. Later Baddeley (2010) revised this model by adding the fourth component of a central executive. The latest model is inclusive of the episodic buffer (Baddeley, 2000). These models are by far the most widely accepted and acknowledged within the literature. Importantly the model proposed distinguishes between how we process visual stimuli and auditory stimuli from the environment (Baddeley & Hitch, 1974; Reed, 2006). A model (Sweller et al., 2011d; Sweller et al., 1998) that was repeatedly referred to in the establishment of Sweller (1994) CLT, an accepted foundational framework of instructional strategies aimed at reducing the cognitive load placed on learners and therefore at encouraging the presentation of instructional material to achieve human CE.

Literature demonstrates evidence that CLT and the methods used to measure cognitive load have come under fire in recent years. New strategies are being sought to reduce the mental load placed on learners, especially within multimedia modes, from the use of cueing to reduce any unnecessary searching to understanding the learners prior knowledge (Ayres & Paas, 2012).

Only 13 years ago a research article tabled the “studies that measured cognitive load and calculated mental efficiency and the measurement technique they used” (Paas, Tuovinen, et al., 2003, p. 5), evidentially demonstrating the absence or utilisation of neurophysiological technologies. From 27 studies dated between 1993 and 2002, 1 used pupillatory response only, 1 used a secondary task method only, 14 used a 9 point rating scale only, 7 used a 7 point rating scale only, 1 used a combined 9 point rating scale and a heart rate variability technique, 1 used a combined 9 point scale and secondary task methods and finally 1 used a combined 7 point scale and a secondary task method (Paas, Tuovinen, et al., 2003) .

It is hoped that future research will utilise the advances in technology and see more adoption of the physiological measures to avoid the vagueness and remove the subjectivity of results. “Many studies in CLT make rather speculative interpretations of what happened with cognitive load during learning on the basis of learning performances” (Jong, 2010, p. 125). Utilising more advanced techniques also has the potential to explore areas of “functional anatomy and temporal dynamics of cognitive processes which are involved in interactive knowledge construction” (Verhoeven et al., 2009, p. 374) methods such as may include eye tracking and brain modelling . Not only are the depth and scope of cognitive research set to benefit from the continued movement in the direction of adopting more physiological approaches but also it makes way for a clear and more uniform set of metrics in measuring the mental load experiences and it removes the uncertainty of perception, specific peaks in load, overall load and the cross contamination of confusing effort with load.

In order to capture an objective and continual account of the level of cognitive demand experienced during the processing of stimuli, the EEG is a tested, accepted and non-intrusive option. In recent times with technology increasing and more competition the market has seen a range of low cost EEG devices being used in research studies. These do unfortunately “pose major challenges in signal processing as well as feature extraction” (Sinha et al., 2014, p. 1). High quality EEG options do remain expensive and require specialist skills for both recording and analysing data. Therefore, it is unfortunate that, despite the overall accuracy of the EEG and the solid benefits, the industry still sees the more subjective means of measurement as being widely used. This has resulted in the use of a multidisciplinary approach to cognitive neuroscience, education and psychology to enhance research. On the other hand literature that can improve instructional processes remains sparseA deeper understanding of the human response to varying forms of stimuli is required. In particular, in the varying models that are being used in today's organisations, whether they are internal communications, instructional solutions or systems design – transient information is found across all areas. The objective of this study is to investigate the MWL experienced whilst completing a low level and a high level transient information task and the effect that a nominated design strategy has on the MWL endured and the overall CE achieved.

Cognitive ergonomics are concerned with the MWL that an individual experiences as a result of undertaking a task. Cognitive ergonomics encourage the application of a human centered design approach to the development of products and systems. The aim of cognitive ergonomics is to use knowledge of how the brain responds to stimuli and tasks in order to design for achieving optimal efficiency in human interactions. It is hoped that an insight into the reverse assessment priming strategy and the use of transient information will be unveiled. The amount of information that we are required to process on a daily basis poses the risk of overloading an individual MWL capacity. Not only are they faced large amounts of information but that information can be in a range of different formats. The design may not be considerate of the human processing system and therefore may increase the difficulty and mental demand in order to process it.

Cognitive tasks involve an array of complimenting sub processes from perception, integration, encoding, decoding and synthesising to predicting, decision making and problem solving. All of these sub processes may be required to rely on stimuli presented and received if any of the sensory domains and current schematic networks, whilst applying the problem posed to the task at hand and meeting the objective of the communication.

The terms "MWL" and "cognitive load" are used interchangeably throughout this thesis depending on the context, the type of communication and the audience related to the respective terms. However, wherever humans meet communication in any form; wether that be in the way of products, processes and systems, the brain has a job to do. In order for the person to make sense of the stimuli presented and to take action, whatever that may be, a process or cognitive processing takes place. With technology, this is becoming increasingly more apparent that simply presenting more information does not mean that more information is processed successfully. The pace, the format and the design are all elements that require careful consideration, should the message be successful. Cognitive ergonomics enlist a human centered focus to the interaction between humans and systems in order to achieve optimal outcomes.

This study utilises several stages to establish the MWL experienced and the CE achieved during the processing of an auditory information piece. As humans, we face the risk of mental overload each time that we are presented with stimuli. Of course, stimuli, tasks and activities all vary in the design, presentation mode, format and level of complexity. Depending on all these variables the cognitive processing may be inefficiently carried out, leading to a range of consequences from low performance and errors, to the misinterpretation of information. Establishing exactly how we respond to particular stimuli that have adopted specific design principles, we are able to begin understanding how we can improve the design of information. There are many positives that can come from adopting a human centered approach; again this may be referred to as “cognitive design”, “cognitive engineering”,” cognitive ergonomics” and “understanding user experience (UX)”. Benefits include improved efficiency, safety, matching tasks to human capital capabilities, reduced human error, increased employee wellbeing, improved human performance, reduced accidents, reduced stress, and reduced costs.

This experimental human cognitive ergonomic study aimed to answer how the MWL differs as a task becomes more complex, and questioned whether neural activity increases or decreases or whether there is little change at all. The tasks that were used in the experiments are known as “transient information tasks” which are by nature known for placing demand on the working memory. This study proceeded to test a design strategy and to establish its effectiveness in reducing the MWL and more specifically the neural activity recorded during control and test intervals. Subjects completed post task assessments and therefore the human performance was measured and compared between low and high mental demanding tasks and across both control and test task intervals. The final measure of focus that was investigated was aimed at relating the data to the real world. It was not possible to match human capital to organisational tasks or design and to develop an instructional solution based purely on MWL measure or performance alone.

The aim was to establish the optimal balance in human capital performance between cognitive demand imposed in an individual, with the level of CE needing to be established. As expressed this required several information sources. To do so it was equally important to measure the MWL that was imposed by a task, the unique human cognitive investment (UHCI) made by each individual and the level of human performance achieved, which were required to formulate the overall CE. Each stage of the study fed into the next commencing with taking what is known from the literature and research about the HCA, human capabilities and limitations. Tried and tested information design strategies were reviewed and considered. This study tested a new strategy Reverse Assessment Priming Stimuli (RAPS). EEG methodologies were applied to provide objective neurophysiological measures in order to establish the MWL experienced. These together with performance scores of standard and specialised metrics were utilised to allow numerical and graphical representations of MWL, human performance and CE.

The next chapter details the methods applied, the data collection techniques, the transient information task, the reverse assessment priming strategy, the performance assessment task, the ethics and politics of the research and the measures and metrics used through the experiments.

Chapter 3 Research Method Structure

The previous chapter outlines the problems amongst instructional practices, details the purpose of the study and reviews current literature in respect to how we process stimuli within human cognitive architecture (HCA). Theories relating to cognitive load, working memory associated instructional effects and appropriate strategies are discussed together with the MWL measurement methodologies used amongst researchers.

This chapter details the research questions that the study aims to answer, the philosophy of the study, the methodological approach and technique. It provides an insight into the logistics and supporting background of the study and ethical and political considerations.

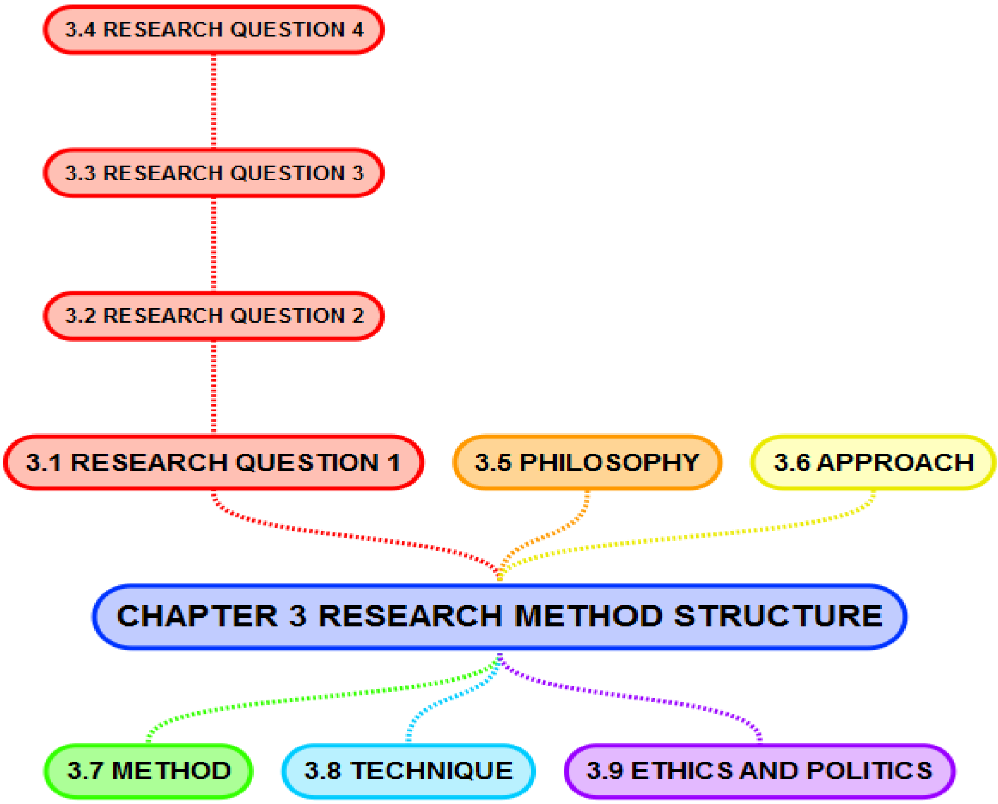


Figure 3-1 *Chapter 3 Research method structure flowchart*

Establishing cognitive efficiency (CE) is crucial when aiming to optimise human capital, requiring multiple input sources: from the cognitive stress placed on an individual to the performance levels achieved. Research and literature tells us that humans process information within an architecture that has natural limitations. To apply a human centered approach to organisational tasks, processes and instructional solutions, the capacity and limitations of HCA needs to form the basis of design.

Firstly, for an understanding of mental stress, cognitive demand being imposed during a task needs to be calculated. This can be done by establishing a reference or control stress measure and or levels across individuals. This study established the mental workload (MWL) between tasks of varying levels of complexity, between a subject cohort and a unique human cognitive investment measure. Sourced from neurophysiological records this data is coupled with human performance scores achieved during post task assessments to inform and answer the following research questions.

3.1 Research question 1

How does the MWL differ between a low cognitive demanding Transient Information Processing Task (TIPT) and a high cognitive demanding TIPT?

It was thought that in the search for effective design strategies, they should be tested on both low and high level workload scenarios as no impact or influence may be detected unless there was a sufficient increase in the level of task difficulty. There are many of these design principles, starting with the degree of contents element interactivity, format style chosen and presented modality.

3.2 Research question 2

What impact does the use of Reverse Assessment Priming Stimuli (RAPS) have on the MWL imposed during a low cognitive demanding and a high cognitive demanding TIPT?

Knowing that transient information poses a degree of difficulty and increases the MWL on the individual just by the nature of modality, a design strategy was selected that can avoid having to question whether there was any MWL at all. We are assured that regardless of the subject all tasks will pose a fair degree of cognitive difficulty. The subjects were prescreened to ensure that they did not have a solid prior exposure or knowledge of the topics used; therefore, this RAPS strategy would be the subjects' first real introduction to the subject, a priming exercise. Priming is well documented to assist across many areas of marketing and learning, directly linked to the assessment. The priming exercise has been arranged in this way as it has been well researched and established that the use of non-guided, open ended or means end analysis is ineffective with novice learners. All subjects were novices and the purpose was not to send the subjects off on a search, but to reveal the impact of a priming strategy that was directly linked to the assessment.

3.3 Research question 3

What impact does the use of RAPS have on the performance results achieved across both low and high level TIPT?

Not only did this study anticipate an impact on the level of mental load experienced whilst the subject was presented with the TIPT, it also sought to identify the degree to which the typical priming effect, as previously demonstrated in the use of priming, would carry over to the knowledge transfer stage and reveal an impact on the recall of information during the completion of the assessment following the TIPT.

3.4 Research question 4

What impact does the use of RAPS have on the overall CE achieved across both low and high level TIPT?

To conclude, in evaluating the impact of MWL and performance naturally, it was beneficial in a real world scenario to establish how this can be interpreted into an environment and context that may contain a large spectrum of subjects, varying levels of MWL and differing levels of expertise. Cognitive ergonomics is about how human interacts; business is more often concerned with the bottom line. To keep the focus on the human and how they are performing, it is important to establish a way to find the balance between performances and MWL. CE does just that, achieving the best possible human performance through human centered design which is not at the cost of the human mental wellbeing.

3.5 Philosophy

This chapter sets out the methods of quantitative investigation; the aim of this study formed an important stance during the literature review to establish the most effective approach. The current literature demonstrates a gap in the objective data being collected and applied in the design for efficient information processing. The multidisciplinary literature review enabled for this study to be designed filled the gap of neurophysiological objective data being collected, analysed and synthesised. The findings, albeit small will naturally have limitations that will be applicable to the broader applied cognition and human factors sector to inform the design and understanding of how the human processed transient information and the impact the Reverse Assessment Processing Strategy had on human efficiency and performance. Articles from neuroscience, education, psychology, human factors and cognitive engineering were reviewed, presenting patterns of either self-reporting post task or physiological methods within their respective fields of research. It was however evident that there remained a large partition or divide when it came to a multiple methods approach or when cross matching the fields and their typical approaches. The measuring of MWL has relied on subjective methods for decades. However, areas of research which relate directly to investigating the mental state of humans, such as psychology or neuroscience and even more so with the newer sub domains of cognitive psychology and cognitive neuroscience, have the access and means to explore MWL objectively. Using physiological data as a means to inform research provided a non-biased insight into the neural activity during a task. Within these areas the idealisation of linking the research of human information behavior to how we design it is not unheard of and has to some degree been voiced in information science (Johnstone, Bonner, & Tate, 2004) . It would appear that due to an array of factors, primarily according to literature, the difficulty is in accessing the equipment, the cost involved and level of intrusiveness. I speak from experience and vouch that there remains a huge divide or rather a wall of division between these research domains. Each field stands strong in its own right. Information science is new and attempts to break down these barriers. The use of technologies and accepted research methods within the cognitive science arena has not been explored sufficiently enough beyond the realm of the laboratory. An unfortunate situation with the human interaction and behavior study was that these techniques can provide high levels of objective data. Admittedly this approach does require specialist training in the use of the equipment and analysis of the data and may in most cases call for a multidisciplinary research team. First and foremost, until we understand the way in which behavior is altered as a result of human interaction with specific stimuli, we are unable to truly apply human centered designs to our communications, products, processes and systems (Fidel & Pejtersen, 2004). The objective of achieving human efficiency will remain as being measured in a fiscal metrics as opposed to “real” mental and human measures. Just as important as the research questions this study aims to answer, are the methodologies selected in this study. As this study was aimed to assess the overall efficiency during a task, it is acknowledged that this not only entails the human perception of task difficult human performance scores, but requires an insight into how the human operator responds to the MWL demanded during the task (Parasuraman & Rizzo, 2006).

3.6 Approach

Surveying would have been the easy choice, a self-reporting subjective approach certainly would have been possible. Historically this has been the methodology of choice given that obtaining the expertise and equipment necessary to collect, analyses and provide cognitive interpretation or as it is known MWL data has been out of reach for most.

An experimental investigation was selected as the most appropriate research methodology. This study aimed at examining the relationship of cognitive demand experienced between varying information design properties, the impact that reverse assessment priming had on the cognitive demand experienced and the performance results and overall CE achieved (Denscombe, 2003). The experimental approach allowed for the research design to encapsulate these factors within a controlled and credible study. Experiments allowed the researcher to segregate individual factors in order to examine them in detail, making the analysis of each element possible (Denscombe, 2003). The ability to do so also provided the opportunity to identify causal factors as the researcher maintained control over the introduction and removal of factors to the experiment. The experiments were designed to allow the researcher to observe the experiment at all times, again maintaining control of the experiment flow (Denscombe, 2003). Henceforth, this process allowed the researcher to make required adjustments to address any areas of concern such as interference with or corruption of data. The researcher was able to annotate the EEG recording when biological or environment interference was experienced, therefore reducing the need for any removal of unnecessary data or the exclusion of invalid data. The decision to conduct experiments was a strategic, careful consideration was required to ensure that the conditions in which the data were collected was controlled and maintained a high level of consistency which could be achieved throughout the duration of both experiments, all trials and across all subjects (Denscombe, 2003).

3.7 Method

This study set out to examine the effect of introducing an independent variable of reverse assessment priming stimuli during a transient information processing task. The aim was to establish the effect the introduction of this stimuli had on the cognitive demand/MWL experienced, performance and CE achieved. As there were changes in the control and test intervals, multiple trials which varied in the level of complexity, therefore assuming the difference in cognitive demand were critical to ensure that all factors were implemented at identical timed intervals and that all factors during the implementation of each experiment remained constant (Denscombe, 2003).

Prior to the EEG recording sessions subjects were also asked to complete a questionnaire which was designed to provide very basic demographic information, the handedness of the subject, age and more importantly the level of knowledge each subject deemed themselves to have on a pool of topics. A simply designed questionnaire which required the subject to indicate whether they had a low, average or high level of prior knowledge of the topics listed was employed (see Appendix G). Using a questionnaire enabled this data to be collected with ease, in an efficient and timely manner. The design was non-intrusive and encouraged subjects to complete the questionnaire without hesitation. As the questionnaire only required the subject to provide minimal information and a tick box capture for the majority of the data collection, this phase was completed with the maximum degree of control and consistency. This not only provided important information that would determine which stimuli would be used for the experiments it also acted as additional data that would be later used in the analysis stages of the study. This questionnaire aimed to simply determine a level of knowledge and wasn’t aimed at sparking a thought process or highlighting any particular topic to the subjects. It was designed so that the subjects could read and complete it without the need to ask any questions. To ensure simplicity, the questionnaire was redesigned several times to reduce its size to a single A4 document.

A third and final method of data collection used was documentation (Denscombe, 2003). A paper based assessment was presented to the subjects between each transient information processing task. Each assessment consisted of either five or ten multiple choice questions, again very simplistic in design and only requiring the subject to tick a box to indicate the answer they wished to select. Each subject was to complete this assessment in between tasks. It was requested of the subject that they refrain from asking questions, so it was important that the design of this document was self-explanatory, easily completed and not intimidating. The aim of this document was to collect important data that would make allowance for the impact that the reverse assessment priming stimuli had on the performance of each individual after the transient information processing task was complete with an additional measure to enable the analysis of the overall CE achieved by the subject.

For several reasons, an intentional decision was made by the researcher to adopt a multi-methods experimental approach. Firstly, quantitative data was sorted to allow for exact comparisons and accurate levels to be established across all subjects. The use of the EEG as the primary data collection tool was used to capture data with the maximum level of objectivity. Many research studies in the past have examined cognitive load using subjective methods and these have been accepted as an appropriate means of data collection, to date however the question of credibility remains. The researcher pursued this methodology to investigate the innate ability of an individual to successfully identify, evaluate and report on the difficulty of a task from a subjective standpoint and to further the field of research into MWL capacity and human cognitive performance.

3.8 Technique

The study took place within a private neurologist practice in Toowoomba Queensland, under the supervision and with the support of professional, trained and experienced EEG technicians. The equipment used was of commercial grade and used by the professional practice as part of their commercial activities. The data was collected during the month of July 2015.

A sequence of stimuli as seen in Figure 3-2 was presented to the subjects, whilst electroencephalography was used to record the neural activity. Before commencing the EEG recording processes instructions are read out to all participants to ensure they were aware of what to expect and to avoid delay during the EEG recording. Participants were asked to refrain from moving around during the two to four minutes of EEG recording, they had the opportunity between the presentation of each stimulus to stretch or move if required. The researcher and an EEG specialist from the clinic were present for all EEG sessions. All participants were seated in comfortable chairs during the EEG: the eye calibration stimuli were presented using a laptop and positioned at normal head height. Audio stimulus was presented via headphones to avoid any interruption or other noise. The neural activity was recorded through Compumedics Profusion 4 EEG software and monitoring on the screen.

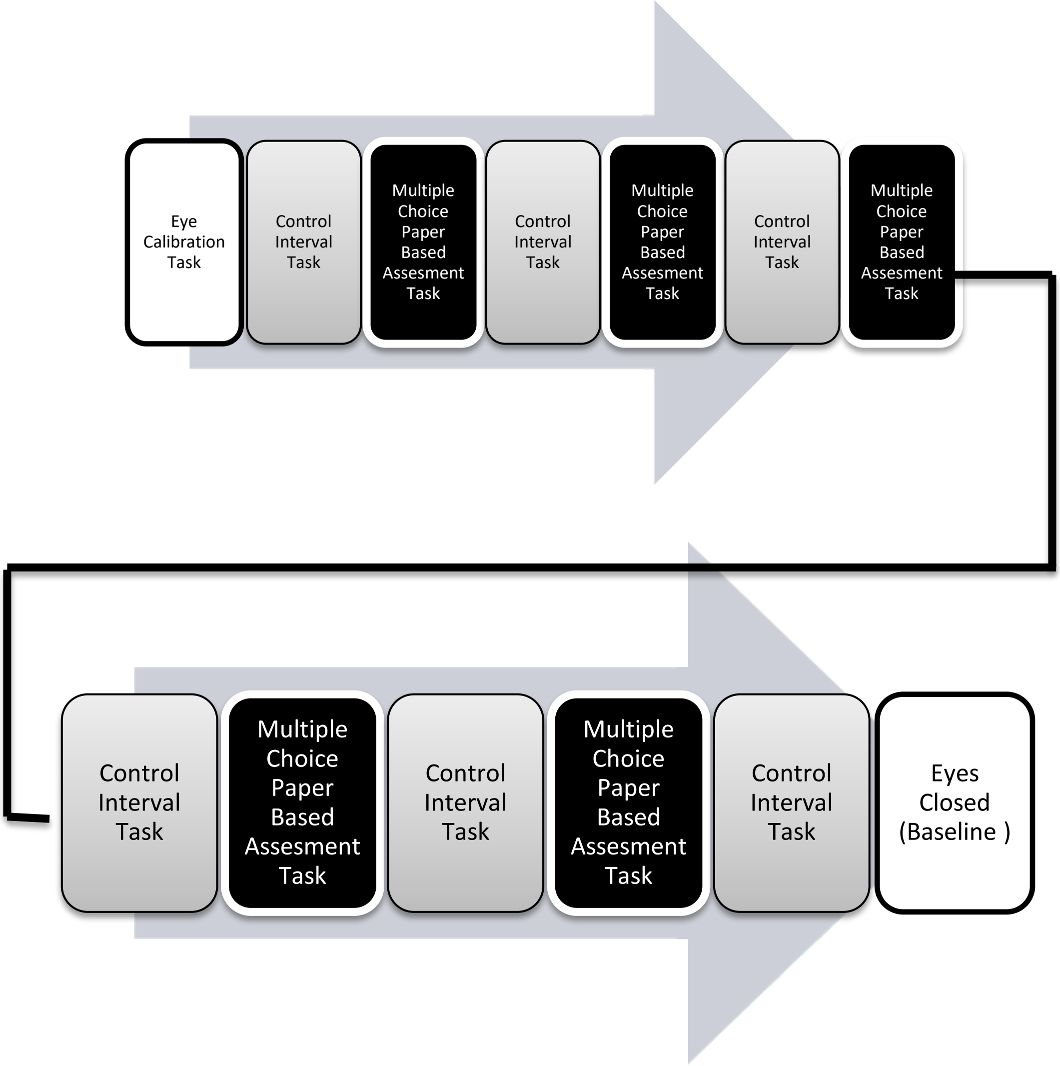


Figure 3-2 Structure of a trial of the EEG recording sessions for Experiment 1 and 2

Low/High Cognitive Demand Transient Information Processing Task & Reverse Assessment Priming Stimuli Experiment Flow – Including Eye Calibration, Eyes Closed & Assessment Completion

3.9 Ethical Considerations

As part of this study a requirement is that it should abide by and meet all ethical guidelines. A human ethics application was lodged and approval received prior to commencing recruitment for the study. There were no foreseeable risks other than a small imposition of time to complete the demographic/prior knowledge questionnaire and the electroencephalography procedure. All participants who would be involved, did so, on a voluntary basis and could withdraw at any time. All participants were over the age of 18 and provided written consent prior to completing the questionnaire and taking part in the EEG experiments.

This chapter detailed the research questions that the study aims to answer, the philosophy of the study, the methodological approach and technique, providing an insight into the logistics and supporting background of the study and the ethical and political considerations.

Chapter 4 The tasks required for the experiment

The previous chapter detailed the research questions that the study aimed to answer, the philosophy of the study, the methodological approach and the technique, in order to provide an insight into the logistics and supporting background of the study.

This chapter leads the reader through each component of the study from the types of stimuli used, how the stimuli are applied, the tasks and assessment tools and the metrics and data acquisition processes. The reader is provided with an insight into the researcher's pre-screening of subjects and a detailed description of the experiment flow.

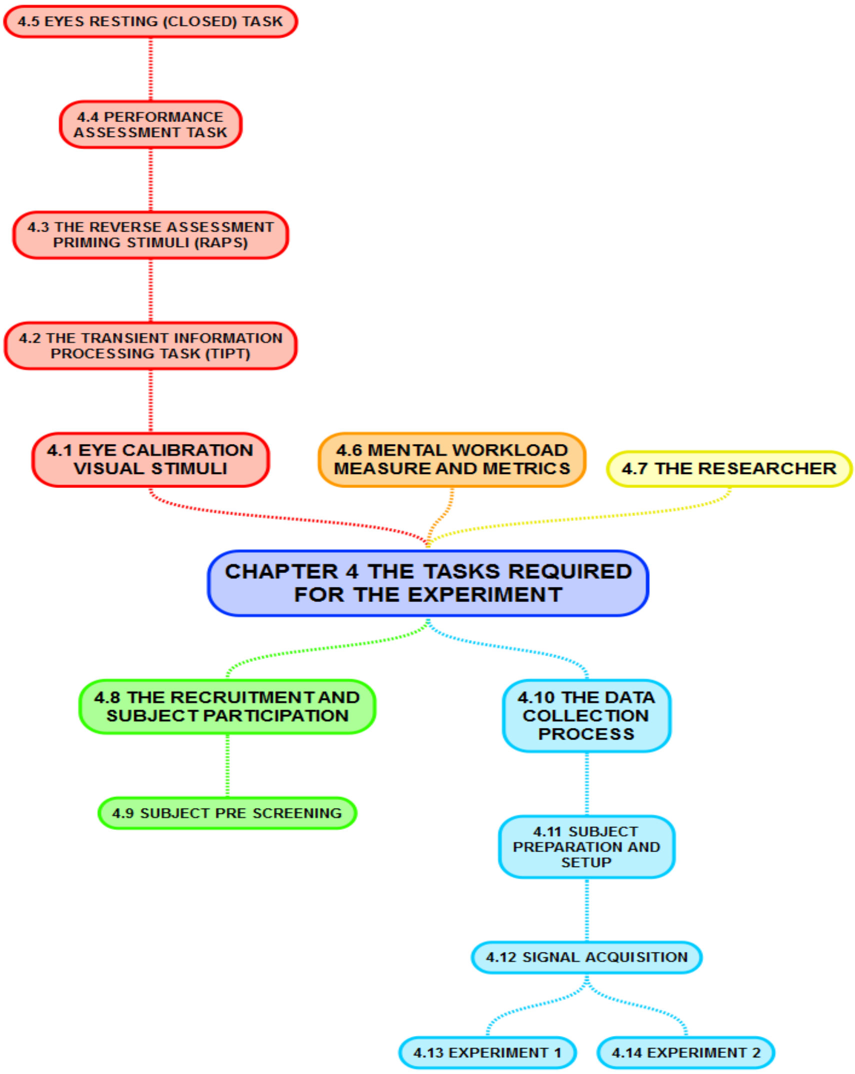


Figure 4-1 Tasks required for the experiment Chapter 4 flowchart

4.1 Eye calibration visual stimuli

A visual stimulus was designed to promote eye blinks and movements in order to carry out eye calibration, allowing eye related artifacts to be removed during the pre-processing of the data. In order to ensure that all subjects were aware of what to expect and what was required of them, the following instructions were read to each subject:

"In the following task you will see a red cross go from left to right across the screen. Please do your best to follow the square with your eyes as it moves from side to side across the screen [see Figure 4-2). Try not to move your head, using only your eyes to follow its movement. After approximately 10 seconds, the red cross will stop moving from side to side and will instead move from the top of the screen to the bottom of the screen. You are required to do the same thing; simply follow the movement. After another 10 seconds, the cross will change colour: each time it does, please blink".

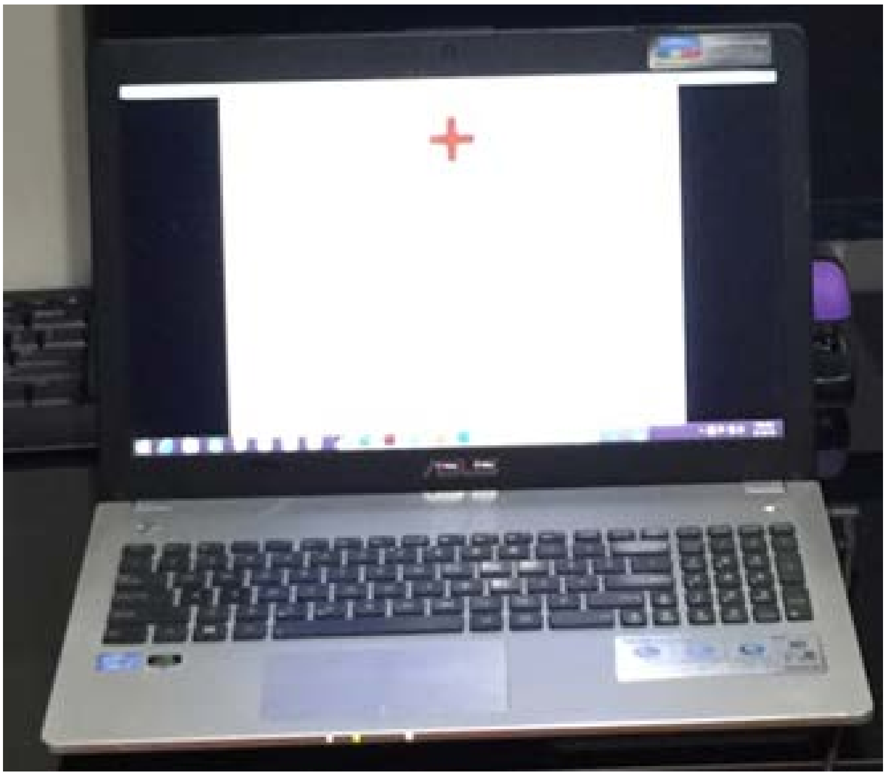


***Figure 4-2** Eye calibration stimuli*

A red cross was presented on the laptop screen, moving from left to right and right to left, followed by top to bottom and bottom to top, and finally the cross remained in the centre of the screen and changed from blue to red and from red to blue.

4.2 The Transient Information Processing Task (TIPT)

Control intervals consisted of the TIPT task being presented with the reverse assessment priming stimuli (RAPS). To ensure a clear picture of the cognitive load that was to be experienced in engaging with the transient information, all information was presented in auditory format to avoid any misinterpretation between transient causal load and multimodal causal cognitive load. Subjects were asked to close their eyes during the TIPT.

All subjects completed six low TIPTs during Experiment 1 and six high TIPTs during Experiment 2. The TIPT varied in the cognitive load demanded, and the level of cognitive demand was determined by the length of the audio stimuli presented. There were 20 different tasks developed for this study (see Table 4-1). Ten scripts were written for low TIPTs, five with a country topic and five with an animal topic, while ten were written for TIPTs, five with a country topic and five with an animal topic. This was to ensure that all subjects would be presented with a topic about which they had either no or very minimal prior knowledge.

Name	Topic	Name	Topic
TIPT_Low_01	Iceland	TIPT_High_01	Japan
TIPT_Low_02	Bhutan	TIPT_ High _02	Liechtenstein
TIPT_Low_03	Mongolia	TIPT_ High _03	Croatia
TIPT_Low_04	Morocco	TIPT_ High _04	Uzbekistan
TIPT_Low_05	Malta	TIPT_ High _05	Ireland
TIPT_Low_06	Sea Urchin	TIPT_ High _06	Sea Eagle
TIPT_Low_07	Dragon Fly	TIPT_ High _07	Fox
TIPT_Low_08	Dugong	TIPT_ High _08	Giraffe
TIPT_Low_09	Goanna	TIPT_ High _09	Chicken
TIPT_Low_10	Penguin	TIPT_ High _10	Pig

Table 4-1 TIPT stimuli pool

All tasks were followed by a one-minute pause prior to completing a written multiple choice assessment. Subjects recorded their answers on the answer sheet provided and had one minute to complete the assessment. The RAPS were presented on A4 pieces of paper and were displayed for one minute. The TIPT was presented in auditory format. This study did not assess the effectiveness of either visual or auditory stimuli, but rather the overall cognitive load experienced when processing a task that included a range of transient stimuli. The low and high tasks were differentiated according to the amount of information presented for processing. Low cognitive tasks were two minutes in length and high cognitive tasks were four minutes in length. The TIPT was presented in audio format in an attempt to avoid any visually provoked suppression of the band waves, as “when the eyes are opened, a suppression (or desynchronisation) of alpha activity occurs indicating alert attention” (Antonenko et al., 2010, p. 430). The subjects were asked to keep their eyes closed during the TIPT with the intention of avoiding any unrelated visual attention and neural activity. Therefore any noise in the data would be easily identified and removed without the concern of losing any important data.

Each subject received the following instructions prior to the TIPT:

“During the following task and subsequent tasks (there are 12 in total), you will listen to an audio file; please refrain from moving around. To avoid any recording noise as a result of eye movement, we request that you close your eyes to assist in listening to the audio. Immediately after each audio file, you may open your eyes as you will be required to complete a series of questions to gauge your memory/knowledge of information you listened to. During the first six tasks you will have one minute to complete five multiple choice questions. During the second six tasks you will have two minutes to complete 10 multiple choice questions”.

4.3 The Reverse Assessment Priming Stimuli (RAPS)

The priming process is a technique that utilises an individual’s prior knowledge stores, whereby pieces of information have been stored in long term memory as a result of successful previous learning experiences. Priming can be dissected into three succinct phases.

Firstly, there needs to be a stored component, a portion of information that is relevant to that of the current stimuli; it should be fresh or accessible.

Secondly, there needs to be the priming stimuli or the trigger that was used to activate the previously stored information. This was a matching process and the working memory was prompted to go in search of relevant material on the presentation of the priming stimuli (Hwang et al., 2007). Further, this was an automated and innate process by which no restraints were placed on the search parameters other than those that were present within the priming trigger. Had the priming stimuli been intentionally presented, typically it would have been done so with an active objective in mind. The use of priming has a primary purpose of initiating and promoting the location, drawing down and recall of specific information. It was hoped that priming would allow the learner to activate these previous knowledge structures with ease and with less of a cognitive demand than would have been the case had a priming stimuli prompt or trigger not been present. These three stages of priming have been labelled as the "availability" of relevant schema or information, the "accessibility" of such information and the "usability" – the opportunity or event that uses or benefits from the outcome of the judgement of priming and process (Hwang et al., 2007, p. 42).

For the purpose of this study, the priming was defined as follows: "'Priming' implies that prior experience ofan object changes its representation in the brain" (Gauthier, 2000, p. 1). There are many modes in which priming can be delivered: the format can be in text (words), graphics, sound, videos or multi modal (Dennis, Minas, & Bhagwatwar, 2013).

The way in which a priming message was delivered impacted on how the new information was received and processed, which was an outcome that was dependent on the level of relevance (Hwang et al., 2007). Thus the priming message influences the subsequent judgments of information and the ways in which an individual carries out the encoding process.

The structure and format of the RAPS were intentionally explicit and aimed at evoking identical information. The assessment questions that were presented to the subject were used directly to develop the priming stimuli. For example, if the subject were presented with a question as part of the assessment as follows:

- Are pelicans known to live in Africa, Australia and the Middle East?

The priming stimuli would likely be as such:

- Are pelicans known to live in Africa, Australia and the Middle East?

Four multiple choice options would be presented for the answer.

The RAPS consisted of a sheet of A4 paper that presented the identical matching assessment questions in text only format without any graphics or narration for each TIPT. The exact matching of the priming ‘triggering’ stimuli and the event ‘recalling’ stimuli as part of the assessment was intentional. It was thought that in being very explicit in the approach a stronger case could result in establishing the impact of a priming approach. It could be seen that prior knowledge was actually gained from the priming stimuli, as these were the first stimuli presented about the topic. All subjects were selected randomly; however, through the completion of a prior knowledge questionnaire the level of knowledge and experiences within a pool of 20 topics was established.

Topics included 10 countries and 10 animals. All subjects were presented with topics to which they possessed a minimal or no prior exposure. Therefore the RAPS was the initial exposure to the topic ahead of the learning opportunity and the presentation of the TIPT and assessment. The presentation of the audio stimuli may not be an exact match word for word; however, it was very close and posed high relevance for the purpose of cognitive matching. It was during the learning task that the subject would be matching the previously stored knowledge gained through priming in order to highlight the relevant information being presented in audio format. This was aimed at encouraging the ‘tagging’ of relevant information during the continuously flowing audio stimuli to be easily accessed in the later assessment stage.

It was not an aim of the study to test the effect of subliminal priming; an effort was made to ensure that all subjects were made aware of the priming stimulus. Neither was it an aim of the study to hide the content of the RAPS or the TIPT in any way. It should be noted that the purpose of the RAPS was not explicitly expressed; however, it was presumed that, as subjects were presented with a combination of both control TIPT and RAPS, the subjects were likely, after the second presentation of the RAPS TIPT and assessment, to become aware of the relationship. Henceforth, the subjects would begin to make their own assumptions about the potential benefit and purpose of the RAPS. As a result of this realization, there would be no benefit to be gained from mixing up the presentation of the stimuli, and therefore for both the low category and the high category tasks, each subject was presented with three controlled TIPT + assessments, then with three RAPS, TIPT + assessments.

There was a gap of a few seconds between presenting the priming stimulus and the presentation of the transient stimuli followed immediately by the assessment. This is a method of priming to which Bargh and Chartrand (2000, p. 7) refer as “supraliminal priming” (p. 7) whereby the participant was aware of the priming material although not aware of the purpose of being given the material. Priming can be a trigger to elaborate, emphasise and reactivate prior knowledge. In this study, none of the subjects had prior knowledge of the task; therefore priming was regarded as a stimulus that would provide an initial exposure to information and measure the effect that this had during the learning task. The information recalled with a decreased level of cognitive resource investment what had impacted on the level of success of the task completion. It may be expected that subjects who did not pick up on the relevance or importance of the RAPS would demonstrate little positive impact during the performance stage; it may also be evident in the cognitive load experienced. As a result of the connection being made by a subject, a further unintentional and subconscious possibility may also exist whereby subjects would indicate a more positive impact of the use of RAPS in the subsequent TIPTs 2 and 3 in comparison with the first TIPT.

The following instructions were read to each subject prior to the EEG recording session: “During some of the tasks you will be presented with a sheet of paper before the audio file (during the first six tasks it will remain visible for 30 seconds, while during the second six tasks it will remain visible for one minute). The paper will have a series of dot points on it. No questions can be asked during the presentation of this stimulus.”

4.4 Performance assessment task

Subjects completed an assessment immediately following the presentation of the TIPT. The assessment consisted of several questions in a multiple choice format. The low cognitive load TIPT assessment had five questions and the high cognitive level TIPT assessment had 10 questions. These were displayed on the screen for two minutes. The subjects were required to indicate their answers on an answer sheet provided.

4.5 Eyes resting (closed) task

“The following task requires you to sit still and keep facing forward in a comfortable position with your eyes closed. You will need to relax and keep your eyes closed for a few minutes. We will advise you when the task is complete, at which time you can open your eyes”. The result of this activity can be seen in the neural data recording in Figure 4-3.

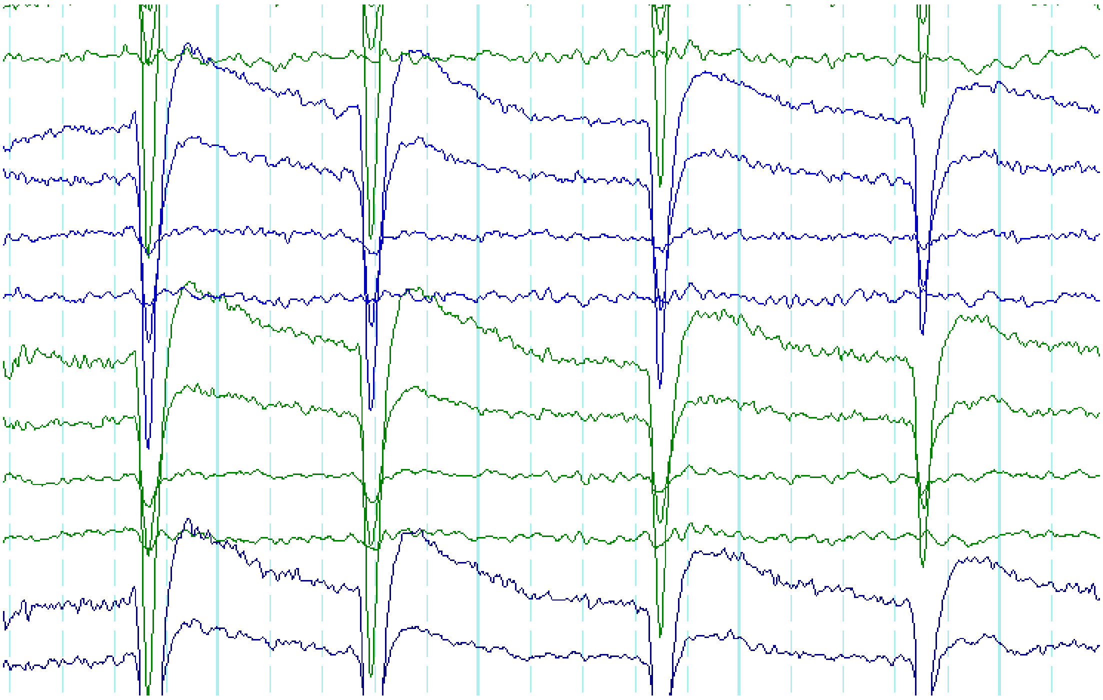


Figure 4-3 ***Eye related artifacts recorded using Compumedics Profusion 4EEG software during the eye calibration stage***

4.6 MWL measure and metrics

Neural activity experienced during the completion of the transient information task was recorded using electroencephalography (EEG), which was chosen owing to its absence of subjective bias and to its ability to avoid subject manipulation of “reliability and accurate metrics” (Sinha et al., 2014, p. 2). All cognitive load analysis was derived from the data collected from the EEG. Artificial, environmental and physiological noise was removed from the raw EEG data collected; during the experiments any factors that had the potential to cause neural artifacts (activity that is unrelated to the stimuli beingtested) were time-stamped on the continuous data recording to enable removal during post processing. At the beginning of each subject’s EEG session, eye calibration stimuli were presented to the subject to capture a recording of the neural activity experienced when the subject blinked and looked up and down and from left to right with her or his eyes in order to allow any noise, as a result of additional eye movement, to be removed.

The literature that exists about which part of the brain is responsible for which function is widely spread, from the posterior parietal cortex to the pre frontal cortex (Berryhill, Chein, & Olson, 2011) to the “prefrontal cortex regions: in particular memory search and controlled retrieval processes” (Cabeza & St Jacques, 2007, p. 219). There are many views; this is still a very active and new field. However, with respect to cognitive functions, there is still much controversy. A safe approach and view is to acknowledge that most of the brain’s regions in some way play a role in cognitive functioning (Taylor, 2004). With this in mind, an approach was used whereby no one particular region was measured and instead an overall picture of neural activity was captured. For this reason, the EEG technique was selected. The EEG brain wave rhythm signals were acquired using EEG 24 gold cap electrode leads. Data were recorded using Compumedics Profusion 4EEG Acquisition Software at a sampling rate of 256Hz with the low pass filter set at 30 and the high pass filter at 0.5. The EEG software allowed separate channel identification and the alpha channel (8-13Hz) was relevant to this study. The electrodes placed on the channels based on the International 10-20 locations were: Fp1, Fp2, Fz, Cz, Pz, F7, F3, F4, F8, A1, T3, C3, C4, T4, A2 P5, P3, P4, P6, O1, O2, Reference, Ground and ECG (see Figure 4-4 and Figure 4-5).

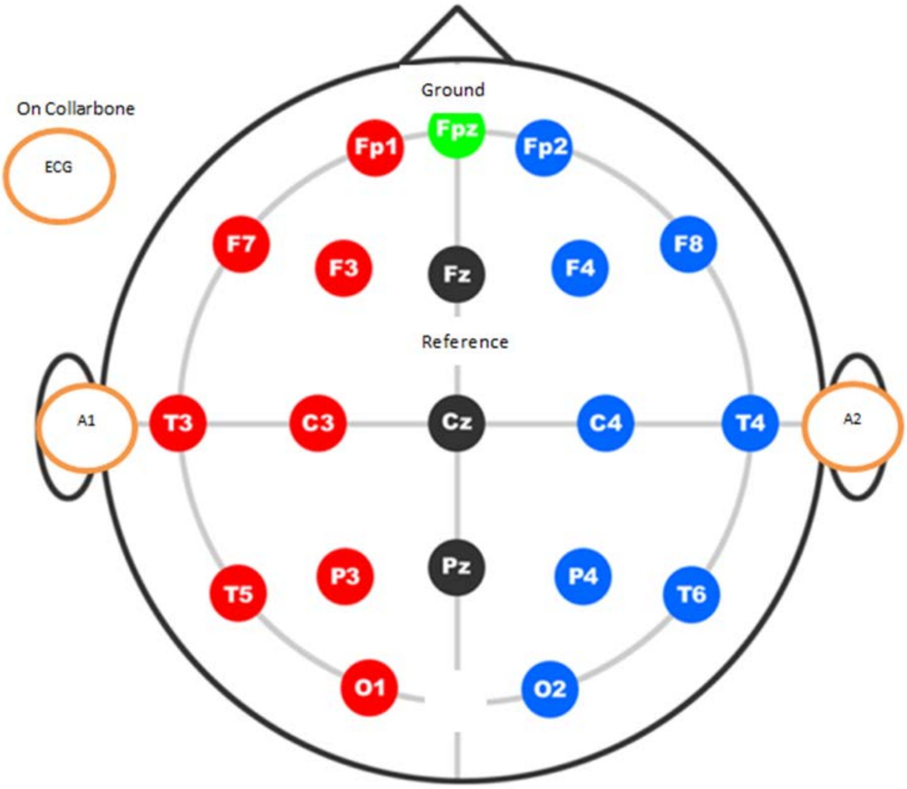


Figure 4-4 ***Topography of electrode placement 10/20 montage***

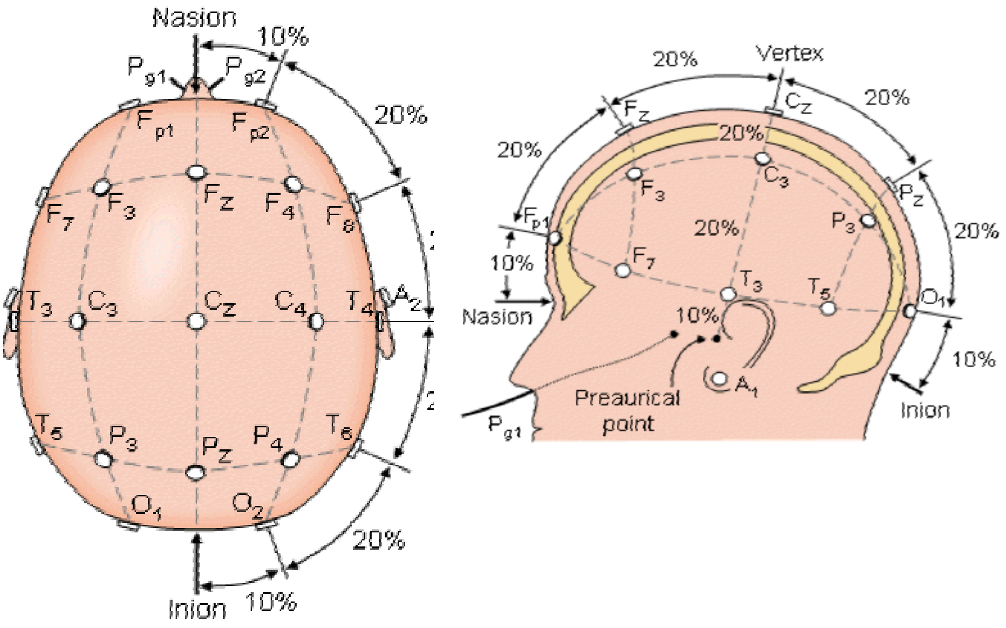


Figure 4-5 ***10/20 Electrode placement demonstrating the even distribution and measurement points from the anion and nasion***

Electrodes were spread over the frontal, central, temporal, parietal and occipital brain regions. All data were decontaminated from eye blinks and other artifacts, using the Compumedics Curry 7 Software.

Each of the subject's band power values for her or his alpha brain waves was used to calculate the levels of Event Related Desynchronisation (ERD) (Klimesch et al., 1997). The ERD values took into account the area under the curve, inclusive of both amplitude and frequency (Antonenko & Niederhauser, 2010, p. 145). The raw EEG data were expressed as a percentage using ERD. "ERD is defined as the percentage of a decrease or increase in band power during a test interval with respect to a reference interval" (Klimesch, 1997, p. 331). This study utilised this calculation method to establish the Unique Human Cognitive Investment (UHCI) as it differentiated the effort required by each subject from an eyes closed and resting baseline, as indicated in Figure 4-6.

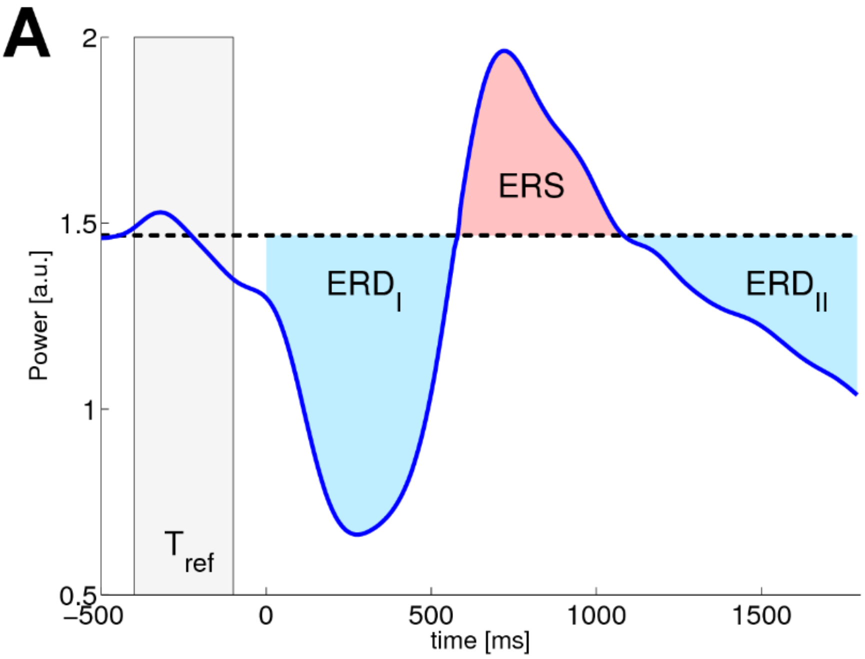


Figure 4-6 ***Event related desynchronisation curve***

As previously stated, a subjective approach is typically taken in order to account for the effort required during a cognitive task, the results of which would be collected post task. This study adopted an objective approach that allowed the researcher to collect and analyse neural data as the task was completed. Using an objective model provided a picture of the actual effort – in this case, the increase in neural activity within the Alpha band (8-12Hz) as the task was being completed.

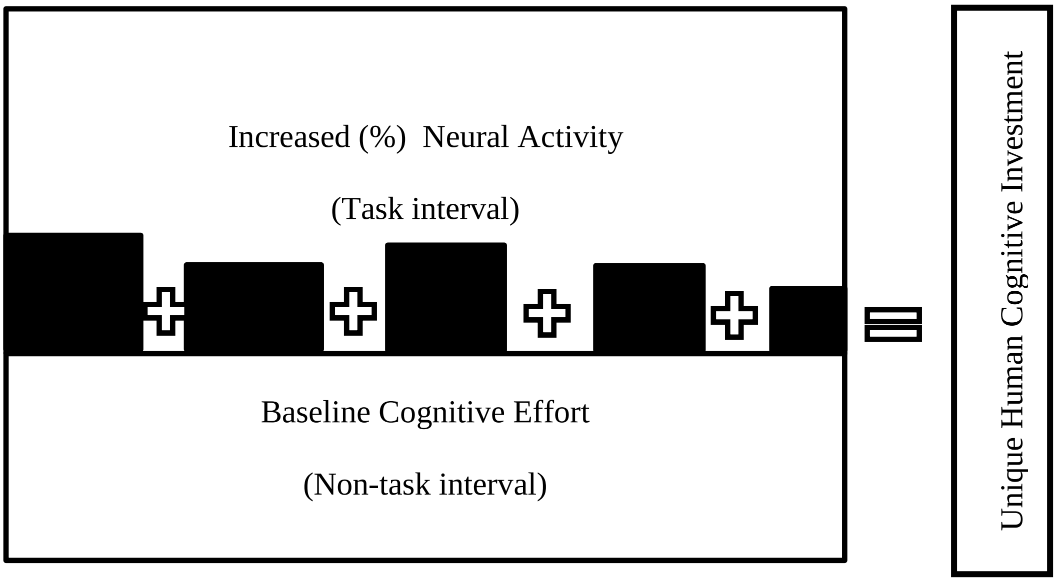


Figure 4-7 ***Objective approach to measuring cognitive effort during a task by capturing the increase in the neural activity from the baseline activity to establish the UHCI.***

The cognitive task being used as the stimuli in this study was a TIPT presented in auditory format. The variable was the complexity of these stimuli: two varying levels of cognitive demand, a high cognitive demand and a low cognitive demand level task. A RAPS allowed the level of impact to be tested against the control TIPT task. Measures included the band power activity recorded via the EEG and the performance results of the paper based, post assessment task. An assortment of metrics was used in the analysis of the assessment of human cognitive efficiency (CE). Self-reporting prior knowledge ratings were used to represent the existing level of knowledge that an individual was believed to hold on a selection of topic areas. Depending on the level, a scale was produced with each subject's allocated score. This was deducted from the performance results to establish the level of consistency to be achieved. The averaging and accumulative band power activity was used to indicate a cohort measure and the individual Event Related Desynchronisation/Event Related Synchronisation (ERD/ERS) was a unique indicating measure together with the individually scaled performance scores. The averaged (see Figure 4-8) neural activity is determined from the raw data before An objective approach to measuring cognitive effort during a task by capturing the increase in the neural activity from the baseline activity to establish the UHCI was used (see Figure 4-7).

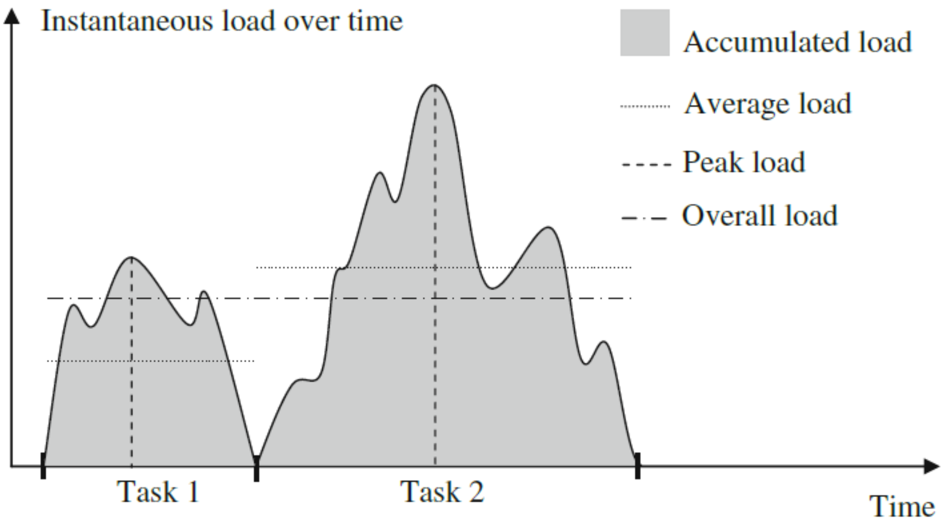


Figure 4-8 ***The accumulative band power and the averaged band power can be differentiated***
Here the accumulated band power indicates the instantaneous load experienced during the entire timed task and the average band power takes an average over the entire time.

4.7 The researcher

The researcher is a human performance technologist specialising in the optimisation of human capital performance, capacity and efficiency. This research has contributed to the tools used in the investigation of human performance and achieving human CE across a range of organisational and communication environments. The researcher received specialist training from experts in EEG data acquisition, analysis and understanding of neural data as a means of measuring cognitive activity.

The researcher received hands-on experience and training within both professional clinic and research contexts using the EEG to record and analyse neurophysiological activity. The research institute was under the guidance of Professor Rodney Croft, Executive Director of the Australian Centre for Radio Frequency Bio-effects Research at the University of Wollongong (UOW), assisted by Dr David Camfield, a post-doctoral research fellow at UOW. The clinical practice was *My Neurologist* located in Toowoomba, Queensland, under the guidance of Dr Grant Kleinschmidt, a neurologist, and Paul Irvine, an experienced EEG technician.

4.8 The recruitment and subject participation

In total, 13 random subjects, two male and 11 female, were recruited to take part in the main study. Interested volunteers completed the pre-screening questionnaire. The 13 eligible subjects who were selected to participate in this study self-reported that they were of general good health, had no neurological disorders diagnosed and were fluent in written and spoken English. Expressions of interest were sought from all students and staff at a regional Australian university. Flyers were placed around the campus on noticeboards. These potential volunteers who showed interest were then emailed the “Letter to interested parties” (see Appendix C), the “Participation Information Sheet” (see Appendix D) and the participant “Consent Form” (see Appendix E). Consent forms were required to be completed and returned if the applicant wished to take part in the study after reading the information provided. Subjects were then advised of their respective appointment times and locations in order to take part. On arrival, subjects were required to complete a “Demographic and Prior Knowledge Questionnaire” (see Appendix G). Prior knowledge of a range of topics was required to allow all subjects to be presented with the most appropriate stimuli. All subjects were presented with topics to and about which they indicated that they had no or very minimal previous exposure and knowledge. It was thought that this process would strengthen the consistency and credibility of the overall study. Data collected during the study and assessment answers were completed using a self-reporting technique.

The actual study was designed to be carried out in three stages, commencing with Stage 1, where all eligible volunteers completed a pre-screening questionnaire before progressing to Stage 2, which consisted of the first of two experiments that involved EEG based processing and a post-task assessment. Working memory and therefore cognitive load were measured by the spectral changes recorded by the EEG (Klimesch, 1999).

These EEG data were collected whilst the subjects were presented with a TIPT and then completed an assessment: Experiment 1 with a low level cognitive load; and Experiment 2 with a high cognitive level task.

- All subjects completed an eye calibration phase, then they were presented with three two-minute low transient information tasks without priming stimuli, and each task was followed by an assessment sheet. The subjects had one minute to complete the questions.

- Subjects were then presented with three four-minute low transient information tasks with RAPS; again each task was followed by an assessment sheet. The subjects had two minutes to complete the questions.
- All subjects were fitted with an EEG headset prior to viewing the stimuli and completing the assessments. Neural activity was recorded only during the TIPT.
- All TIPTs were presented in audio format.
- Assessment sheets and RAPS were presented consecutively. Both were paper-based and the answers to the assessment questions were recorded on the answer sheet provided.

Stage 3 was a repeat of Experiment 1 that used a high transient information processing task stimuli.

4.9 Subject pre screening

All subjects completed a demographic and prior knowledge questionnaire (see Appendix G). The prior knowledge component was used to establish the level of knowledge of the 20 potential topics that were available from the transient information processing stimuli pool.

4.10 The data collection process

Neural activity was recorded using EEG); All subjects attended the clinic according to the appointment times provided. The EEG sessions were scheduled for one and half hours for each participant, allowing approximately 25 minutes for setting up and 65 minutes for testing.

Data were collected from two sources: the EEG and post-task assessment. As was noted above, the EEG channel names based on the International 10-20 locations were: Fp1, Fp2, Fz, Cz, Pz, F7, F3, F4, F8, A1, T3, C3, C4, T4, A2 P5, P3, P4, P6, O1, O2, Reference, Ground and ECG. To capture the oscillations relevant to working memory, this study isolated the alpha rhythms detected from the EEG (Klimesch, 1996, 1999; Maltseva & Masloboev, n.d) and used them as a metric to provide a measure of the cognitive load experienced (Eija, SeungJun, Jodi, & Anind, 2010). The frontal, central, temporal, parietal and occipital brain regions made up the topography for the study. The researcher completed specialist training in conducting the EEG.

Owing to the nature of the EEG process and the effects that they might have on the accuracy of the data, several steps were required to ensure that the data to be analysed were clean and free of any errors. Artifacts that may have been caused by biological responses or environmental stimuli would be identified and removed. This was done by setting filters to eradicate waveforms deemed to be beyond the permitted frequency. According to any specific notations of other external interruptions that may have been experienced during the recording, further event related potentials recorded could be removed. Quantitative data collected from the experiments were analysed using the EEG compatible software.

The software used not only recorded the data but also “allows amplification of the incoming signal, differentiation of the alpha band, streamlined removal of eye blink, movement and amplifier saturation artifacts, tracking of temporal data and automation of spectral power analysis” (Antonenko et al., 2010, p. 436). This process and the data outputs were used to determine the impact of RAPS during transient information processing.

Data for each epoch and each of the 64 channels were digitally filtered and the alpha band was isolated. A procedure called Event Related Desynchronisation (ERD) (Klimesch et al., 1997; Pfurtscheller & Aranibar, 1977; Pfurtscheller & Lopes da Silva, 1999) was used to identify and measure the degree of increase and decrease in the band power during the test interval as opposed to the reference interval. It must be noted that a positive EEG response was a state of desynchronisation and a negative EEG response was a state of synchronization (Klimesch et al., 1997). An equation was used to calculate the ERD.

Steps in presenting the stimuli and capturing, displaying and recording the EEG data included (see Figure 4-9 and Table 4-2):

1. Each subject was fitted out with EEG leads, consisting of 24 electrodes.
2. All electrodes were checked for accuracy prior to the commencement of the data recording.
3. The subjects were advised that they should attempt to remain as still as possible and keep their eyes closed during the TIPT.

4. Recording was commenced.
5. Audio stimuli were started (inclusive of breaks and completion of assessment).
6. EEG recording concluded when all audio files were completed.

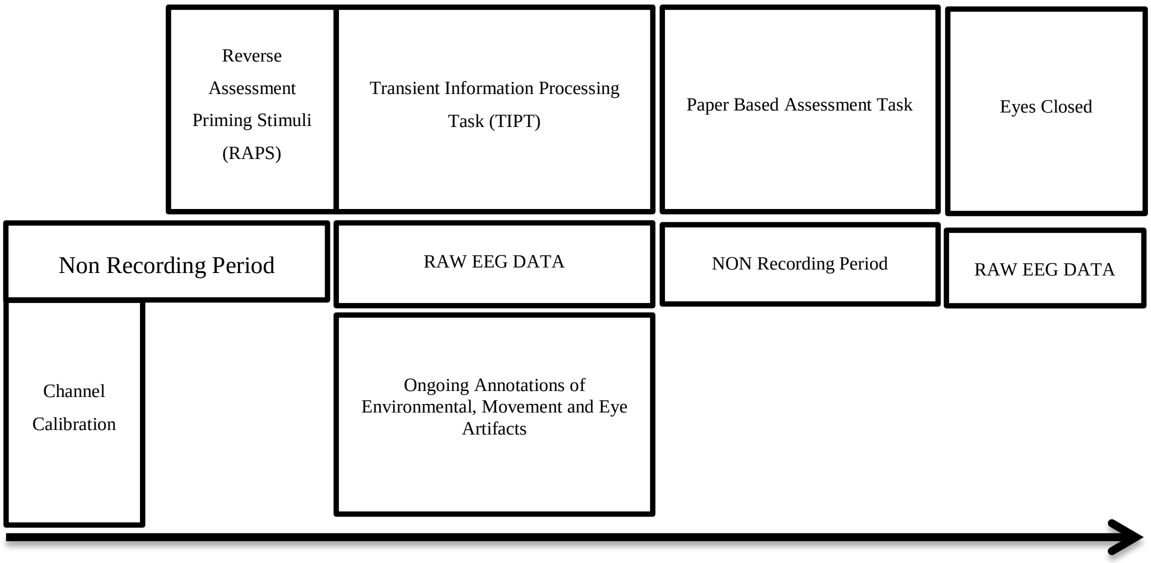


Figure 4-9 ***EEG recording session timeline***

From calibration of electrodes to final task with eyes closed, indicating recording and non recording phases.

Steps	Time	Main Study			
		Experiment 1 – LOW CL (2min)	**T**	**Experiment 2 – HIGH CL (4min)**	**Format/Mode**
1	1	Eye calibration Instructions are read to subject	1	Time to enable the subject to move and get comfortable	
2	3	Eye calibration			
3	1	TIPT instructions are read to participant	1	TIPT instructions are read to participant	
4		Start recording/Save and play audio		Start recording/Save and play audio	
4	2	TIPT_Low_02 (Bhutan)	4	TIPT_High_01_C (Japan)	EEG RECORDING
5		Stop audio and stop recording		Stop audio and stop recording	
6	1	Question sheet	2	Question sheet	A4 paper
7		Start recording and play audio		Start recording/Save and play audio	
8	2	TIPT_Low_03 (Mongolia)	4	TIPT_High_02_C (Liechtenstein)	EEG RECORDING
9		Stop audio and stop recording		Stop audio and stop recording	
10	1	Question sheet	2	Question sheet	A4 paper
11		Start recording and play audio		Start recording/Save and play audio	
12	2	TIPT_Low_05_C (Malta)	4	TIPT_High_04_C (Uzbekistan)	EEG RECORDING
13		Stop audio and stop recording		Stop audio and stop recording	
14	1	Question sheet	2	Question sheet	A4 paper
15	1	TIPT (RAPS) instructions are read to participant	1	TIPT (RAPS) instructions are read to participant	
16	.30	RAPS sheet	1	RAPS sheet	A4 paper
17		Start recording and play audio		Start recording/Save and play audio	
18	2	TIPT_Low_RAPS_07 (Dragon Fly)	4	TIPT_High_RAPS_06 (Sea Eagle)	EEG RECORDING
19		Stop audio and stop recording		Stop audio and stop recording	
20	1	Question sheet	2	Question sheet	A4 paper

Steps	Time	Main Study			
		Experiment 1 – LOW CL (2min)	**T**	**Experiment 2 – HIGH CL (4min)**	**Format/Mode**
21	.30	RAPS sheet	1	RAPS sheet	A4 paper
22		Start recording and play audio		Start recording/Save and play audio	
23	2	TIPT_Low_RAPS_08(Dugong)	4	TIPT_High_RAPS_07 (Fox)	EEG RECORDING
24		Stop audio and stop recording		Stop audio and stop recording	
25	1	Question sheet	2	Question sheet	A4 paper
26	.30	RAPS sheet	1	RAPS sheet	A4 paper
27		Start recording and play audio		Start recording and play audio	
28	2	TIPT_Low_RAPS_09 (Goanna)	4	TIPT_High_RAPS_08 (Giraffe)	EEG RECORDING
29		Stop audio and stop recording		Stop audio and stop recording	
30	1	Question sheet	2	Question sheet	A4 paper
	25.5		1	**Eyes closed**	**EEG RECORDING**
			42		Both 1hr 7.5min

Table 4-2 ***The transient information processing task (TIPT) and RAPS experiment flow, including eye calibration, eyes closed and assessment completion***

4.11 Subject preparation and setup

Setting up each subject for the attachment of electrode leads required the measurement (see Figure 4-10) of their heads. This enabled the marking of electrode positions with a red pencil to ensuring consistency across subjects.

Figure 4-10 ***How the subjects were measured***

Subjects were measured using the 10/20 placement system, with each electrode position being marked using a red pencil.

The scalp surface was prepared by rubbing cotton tips with skin preparation exfoliate, then electrode caps were fitted to the scalp with conductive gel (see Figure4-11).

Figure 4-11 ***EEG consumables***

Cotton tips, ten 20 conductive electrode paste, Nu Prep skin preparation gel, measuring equipment, red china pencil and tape measure and cleaning wipes

4.12 Signal acquisition

The EEG signal was captured from the leads attached to the subjects' scalps. The metal leads had a 10mm gold cap at one end; this was the end that was fitted to the subjects' scalps with conductive gel.

Figure 4-12 Subject with 10mm gold capped electrodes fitted to the scalp

The other end was plugged into the amplifier where each was labelled with a number that indicated the individual scalp placement according to the standard 10/20 placement method (see Figure 4-12).

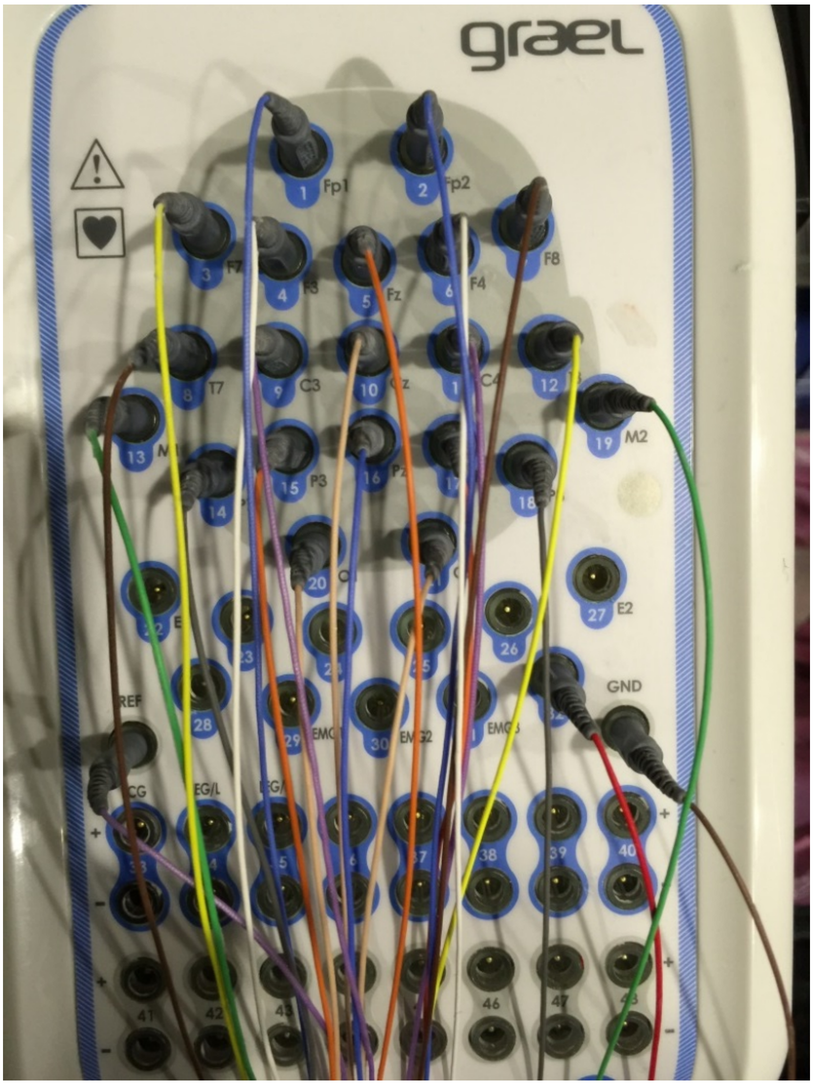


Figure 4-13 Amplifier illustrating the lead labels

Prior to commencing the recording of neural activity, all electrodes were checked for impedances to ensure that sufficient connectivity was achieved (see Figure 4-13). As a standard procedure, all electrodes impedances were checked and adjusted until all were below five and within a range of 3.7Ohms from the lowest to the highest (see Figure 4-14 and 4-15).

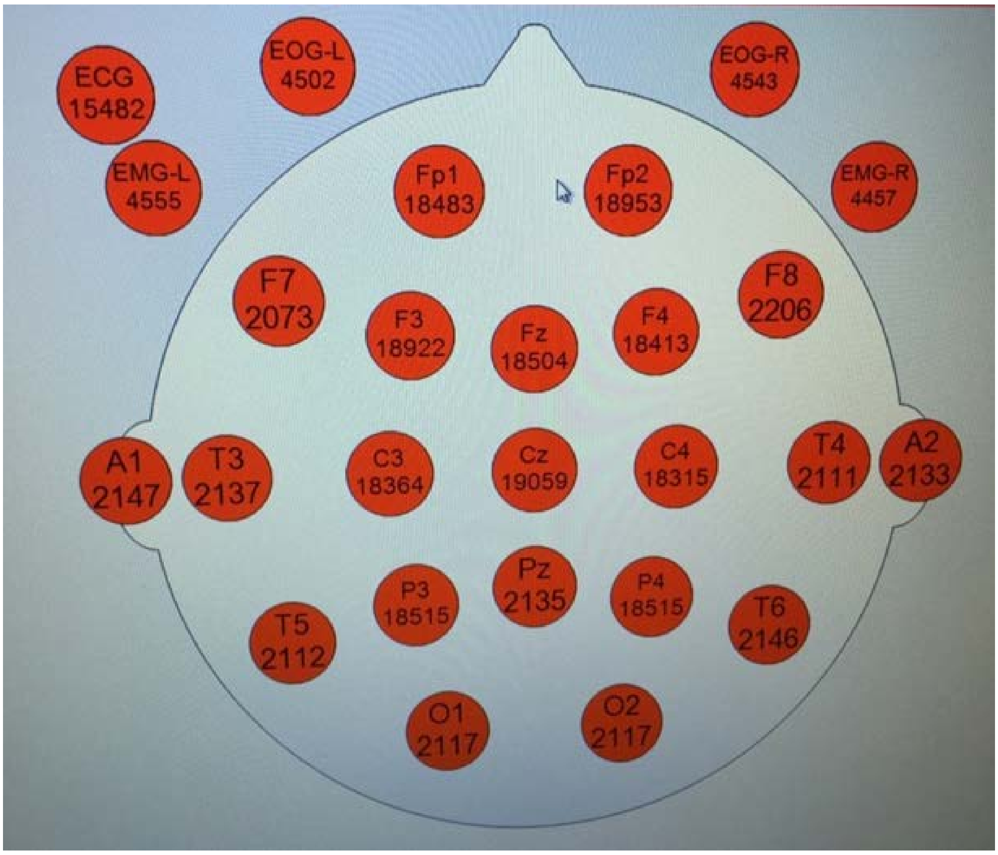


Figure 4-14 Impedance checker montage - prior to electrode placement

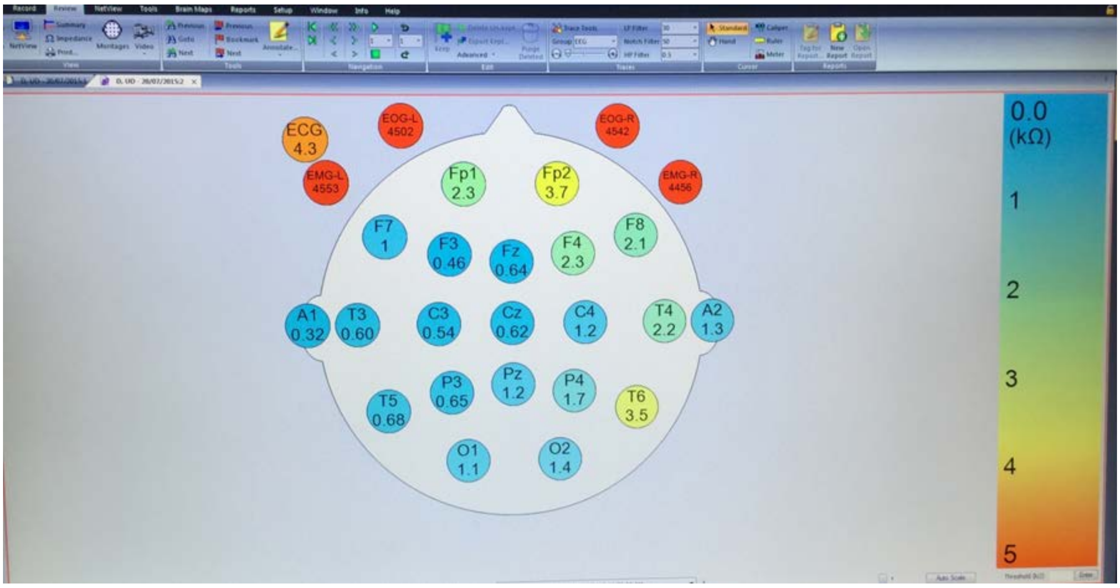


Figure 4-15 Impedance checker function after the electrodes had been attached to the subject's scalp, with a range of 3.7 between the highest and the lowest readings.

The quality of the signals being received was then calibrated using the built in calibration functions of the Profusion 4 EEG software.

4.13 Experiment 1

The purpose of Experiment 1 was to capture the neural activity that took place during a low TIPT. Each subject was fitted out with 24 10mm gold cap electrodes. They were placed over the scalp according to the 10/20 method as illustrated in Figure 4 -5 and Figure 4-6. The subject was then presented with a stimulus that encouraged the subject to look from the left to the right and back to the left, then up and down repeatedly and finally she or he was required to blink several seconds apart, thus providing suitable data that were used to establish the eye's activity during the experiment. Eye muscles and movement involved in blinking caused noise artifacts in the raw data and were removed prior to any post processing.

All subjects who participated in Experiment 1 were presented with three low control intervals TIPTs and three low test intervals TIPTs, all of which were followed immediately by an assessment sheet, which included five multiple choice questions. No neural data were recorded during the assessment period. This also acted as a period when subjects were permitted to look around and relax whilst neural data were recorded. The low TIPT was two minutes in duration and presented to the participant in audio format and the subjects wore head phones to avoid any external and environmental interference. The EEG recorded the neural data during this task. These data were used to establish the accumulative and average cognitive demand from a neurophysiological perspective, and they enabled the comparison between the low TIPT and the high TIPT. Whilst the subjects were listening to the low TIPT audio, they were requested to remain still and avoid fidgeting.

After the TIPT phase was completed, all subjects were asked to close their eyes and relax. This "eyes closed" period was captured via the EEG, and acted as a baseline cognitive demand reference. An additional neurophysiological metric was applied using the base line and the band power during the test phase Experiment 1.

The typical steps involved in setting up subjects for the EEG were as follows:

1. Subjects were shown the equipment to be used and a short briefing about the EEG process was given.
2. 24 electrodes, including two reference leads and one heart rate lead, were attached to the head of the participant.

3. The scalp was prepared using skin prep gel, with the hair parted, and each electrode was filled with 10/20 conductive gel.
4. Electrodes were checked for connectivity using the impedance checker.
5. Subjects were asked a few questions and received task instructions.
6. EEG recording was commenced.
7. Subjects were presented with the eye calibration stimuli and the TIPT stimuli.
8. Recording ceased and the subjects were asked to complete an assessment.
9. On the completion of the assessment, a new stimulus was presented and the recording commenced.
10. This process was repeated until all of the tasks had been completed.
11. The leads were removed from the subjects' heads and they were free to leave.

Name	**Topic**	**Control X 3**	**Test RAPS X 3**
TIPT_Low_01	Iceland	N	N
TIPT_Low_02	Bhutan	**Y**	N
TIPT_Low_03	Mongolia	N	N
TIPT_Low_04	Morocco	**Y**	N
TIPT_Low_05	Malta	**Y**	N
TIPT_Low_06	Sea Urchin	N	N
TIPT_Low_07	Dragon Fly	N	**Y**
TIPT_Low_08	Dugong	N	**Y**
TIPT_Low_09	Goanna	N	**Y**
TIPT_Low_10	Penguin	N	N

Table 4-3 Stimuli selection for experiment 1 – Low TIPT

In Experiment 1, each participant was presented with six TIPT_Low Files excluding any subjects about which there were high levels of prior knowledge (see Table 4-3). Three control tasks were presented, followed by an assessment without any priming stimuli. Then three test tasks were presented, preceded by the RAPS, followed by an assessment.

4.14 Experiment 2

Owing to the logistical requirements of the study, it was necessary to conduct Experiment 1 and Experiment 2 back to back as detailed in Figure 4-12. The subjects were identical for both experiments.

The purpose of Experiment 2 was to capture the neural activity experienced by individuals and collectively whilst listening to and processing transient information for the duration of four minutes on a topic about which the subjects had minimal prior knowledge. These data were used to establish the accumulative and average cognitive demand from a neurophysiological perspective and to compare the demand between the low TIPT and the high TIPT. An additional neurophysiological metric was applied using the base line and the band power during the test phase Experiment 2.

Experiment 2 was identical to Experiment 1 other than that the subjects were presented with high cognitive level tasks.

Name	**Topic**	**Control X 3**	**Test RAPS X 3**
TIPT_High_01	Japan	**Y**	N
TIPT_ High _02	Liechtenstein	**Y**	N
TIPT_ High _03	Croatia	N	N
TIPT_ High _04	Uzbekistan	**Y**	N
TIPT_ High _05	Ireland	N	N
TIPT_ High _06	Sea Eagle	N	**Y**
TIPT_ High _07	Fox	N	**Y**
TIPT_ High _08	Giraffe	N	**Y**
TIPT_ High _09	Chicken	N	N
TIPT_ High _10	Pig	N	N

Table 4-4 Stimuli selection for experiment 2 – High TIPT

In Experiment 2, each participant was presented with six TIPT_High Files excluding any subjects about which there was prior knowledge (see Table 4-4). Three control tasks were presented, followed by an assessment without any priming stimuli. Then three test tasks were presented, preceded by the RAPS, followed by an assessment.

Neural data is recorded as each subject progresses though the experiment process (see Figure 4-16 and 4-17).

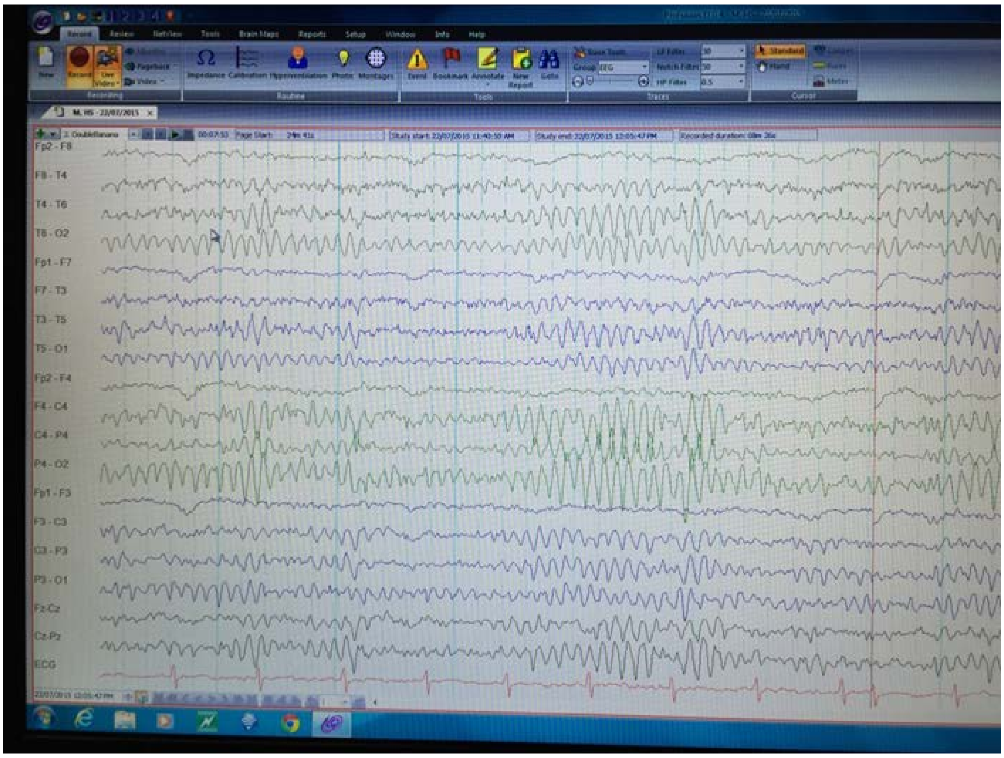


Figure 4-16 Neural data being recorded and displayed in the Profusion 4 EEG interface at a sampling rate of 256 amps

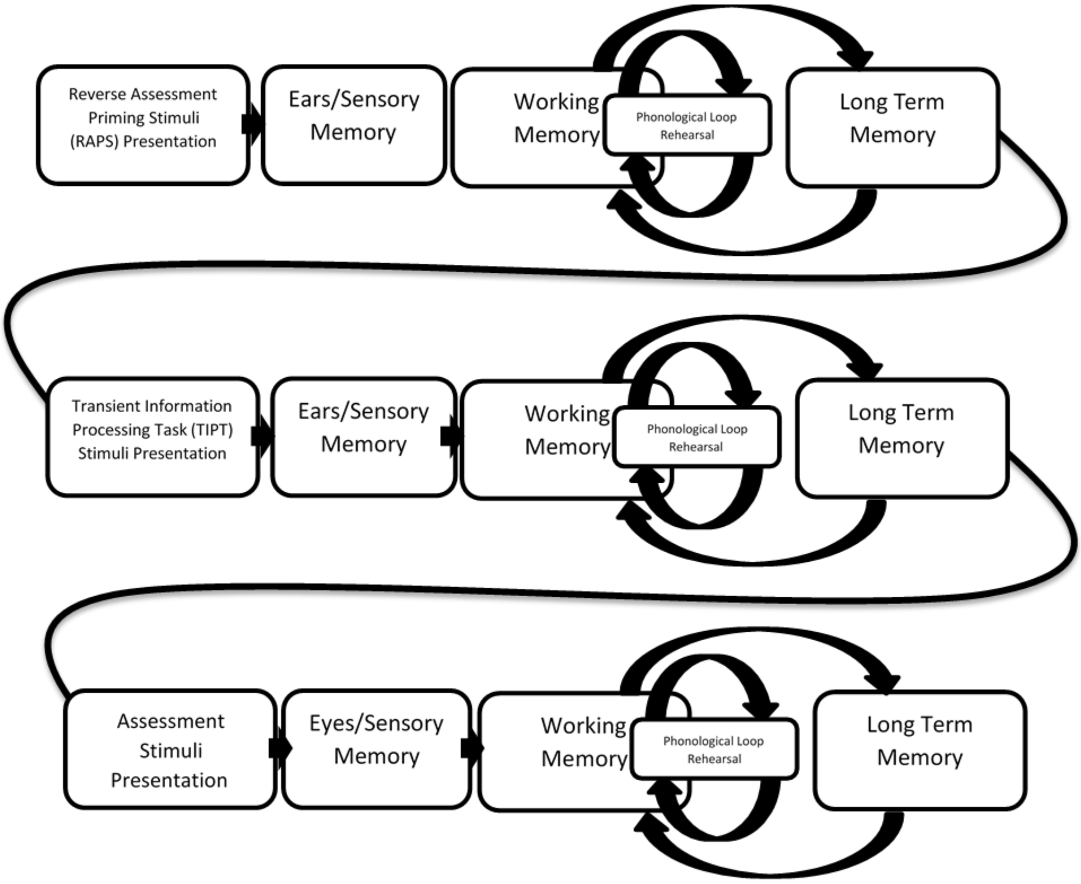


Figure 4-17 The cognitive processing model for a single TIPT and RAPS single trial

This chapter has guided the reader though each component of the study from the types of stimuli used, how the stimuli were applied, the tasks and assessment tools and the metrics and data acquisition processes. The reader has been provided with an insight into the researcher, the pre-screening of subjects and a detailed description of the experiment flow.

Chapter 5 Data Collection

The previous chapter guided the reader though each component of the study from the types of stimuli used to how the stimuli are applied, tasks and assessment tools, the metrics and data acquisition processes. The reader was provided with an insight into the researcher's pre-screening of subjects and a detailed description of the experiment flow.

This chapter launches into the data collection phase by first describing in more detail the subjects, the pre-processing and the steps in the data collection. It proceeds through each phase and illustrates the raw data collected: the prior knowledge questionnaire, the transient information processing assessment task performance scores raw data, the raw neural data, the unique human cognitive investment data and finally the cognitive efficiency (CE) measures.

Figure 5-1 Data collection Chapter 5 flowchart

5.1 The participants

I studied 13 neurologically normal and healthy controls: 2 males and 11 females. Volunteers were recruited from the Toowoomba campus of the University of Southern Queensland, Queensland, Australia, including undergraduate and postgraduate students and staff members. The age ranges of the participants was between 27 and 55, with a mean age of 41. Subjects were 1 left handed and 12 right handed.

All participants were required to meet the criteria of the study: no neurological diagnosis; generally healthy; over the age of 18; and fluent in both written and spoken English. All subjects gave written informed consent prior to their participation.

The data from one participant were excluded from the data analysis owing to the discovery of unidentifiable impedance readings that were out of the acceptable range.

5.2 The raw data results

Raw data as a result of the data collection processes have been set out in this chapter. There were several areas where raw data were sourced: the demographic and prior knowledge questionnaire (see Appendix G); the EEG data recordings; and the transient information processing assessment task audio scripts (see Appendix H). The raw data have been arranged according to the source.

5.3 Pre-processing of raw EEG data

After the recording of the EEG (see Figure 5-2), all data were inspected to identify any obvious artifacts that required removal. This included any significant subject movements and eye blinks noted throughout the recording session. Preprocessing and processing steps were carried out using the Compumedics CURRY 7 Software. These steps included:

1. Import the data and ensure that all channels are references correctly.
2. Set low and high pass filter parameters.
3. Visually select any bad blocks of data to be excluded (see Figure 5-3).

4. Identify and remove any other noise intervals (environmental or biological as indicated by the annotations and eye blink intervals collected).
5. Save cleaned data.

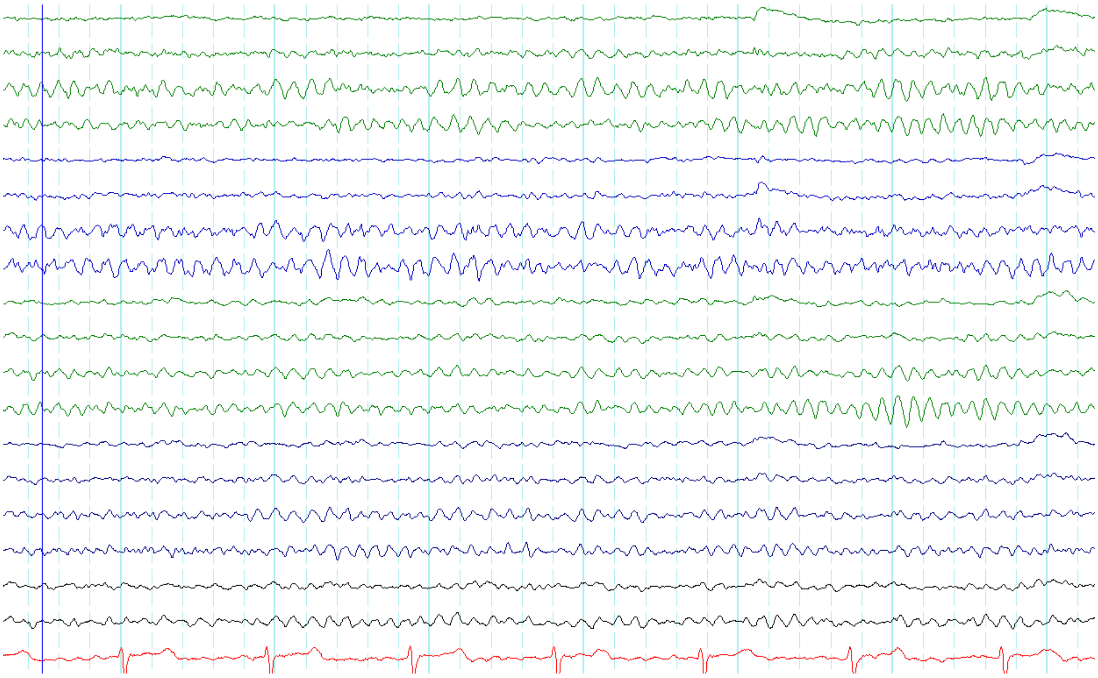


Figure 5-2 *EEG recording in the original sourced format as it appears in the Profusion4EEG interface*

5.4 The processing and extraction of EEG data

Processing of the data was completed using the Compumedics CURRY version 7 software. The following steps were carried out:

1. Clean data sets were selected for each subject.
2. Individual events for each stimulus were selected and epoched (selected time frame sections of neural data) as separate datasets (see Figure 5-4).
3. Each subject's baseline averages were also epoched using the same method.
4. The band power values (Alpha 8-12) and the individual band power averages were calculated using the Compumendics CURRY 7 software
5. Data tables were populated with the raw data.
6. The variance of individual mental workload (MWL) power values was calculated using raw EEG.

7. Comparisons were made between data.
8. Data and performance scores were used to establish the CE achieved.
9. The data from tables were plotted and presented into a graphical format.

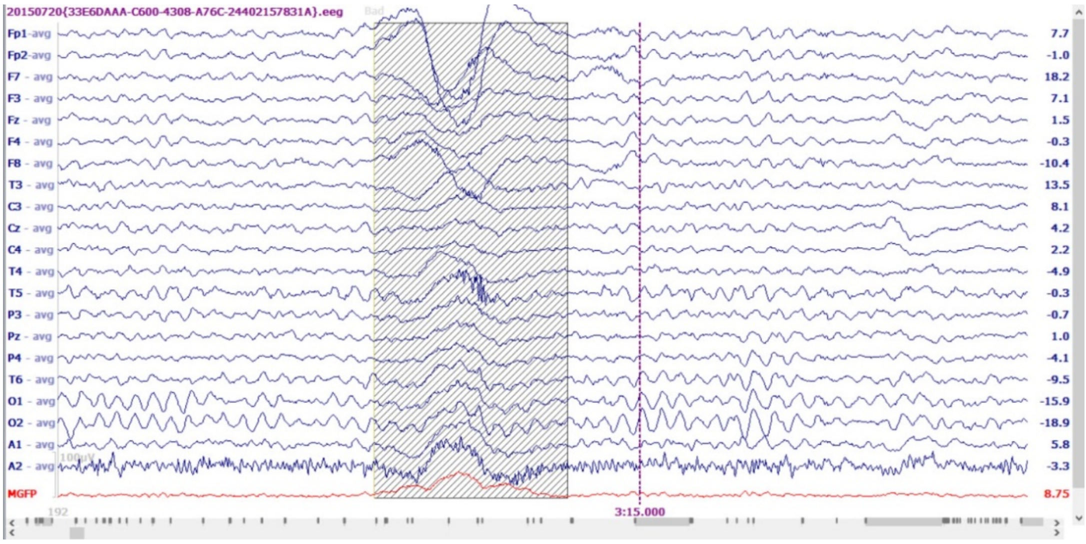


Figure 5-3 *Visual identification of bad blocks of data*

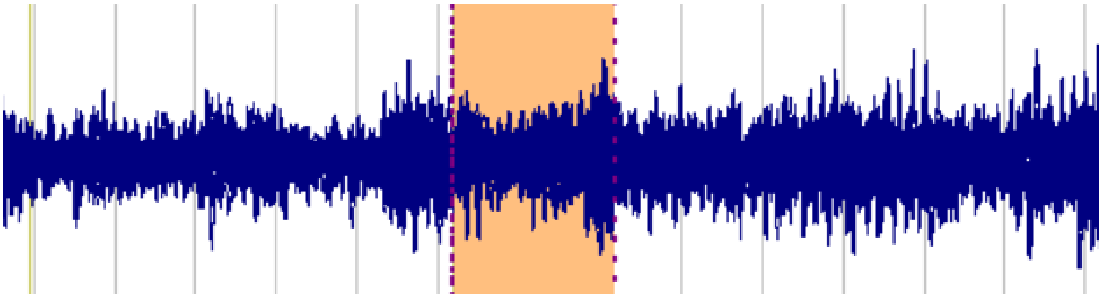


Figure 5-4 ***Compumedics CURRY 7 software***

Using two Epoch data sets, these ere were extracted from each subject using randomly assigned 6 x 15000ms events across the entire timeline per subject and per event type.

The electrical neural activity was averaged using the Compemedics CURRY software. Activity from all the electrodes are measured, summed together and averaged (see Figure 5-5) (EBME, 2016, p. 2) .

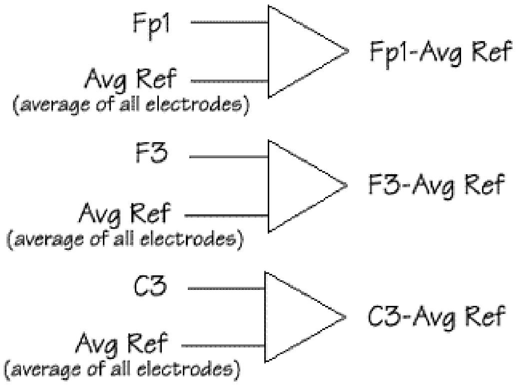


Figure 5-5 Electrodes averaged referenced deviation (EBME, 2016, p. 2)

5.5 The demographic and prior knowledge questionnaire data

Data collected from the demographic and prior knowledge questionnaire were used to determine the stimuli that would be selected for each participant in order to ensure that all subjects were presented with topics about which they had minimal or no prior knowledge. The results for all topics are listed in Appendix J.

5.6 The transient information processing assessment task performance scores raw data

The variability in the low performance scores for the low transient information processing task (TIPT) assessment task performance scores was as follows: the minimum variance was an increase of 7% and there was a maximum increase of 40% (see Table 5-1), with an average of a 25% increase across all subjects (see Table 5-1).

	Low TIPT (Control) Intervals			Low TIPT (Control) Score Value	Low TIPT Control Score %	Low TIPT RAPS (Test) Intervals			Low RAPS (Test) Score Value	Low RAPS (Test) Score %	Score Difference between Low TIPT (Control) & Low TIPT RAPS (Test) Values	Score Difference between Low TIPT (Control) & Low TIPT RAPS (Test)%	Total Low TIPT Scores
Subject	#02	#03	#05			#07	#08	#09					
J	4	2	3	9	60	5	5	5	15	100	6	40	24
K	5	3	4	12	80	4	4	5	13	87	1	7	25

Table 5-1 ***Low TIPT assessment task performance scores***

The variability in the high performance scores for the high TIPT was as follows: the minimum variance was a decrease of 3% and there was a maximum increase of 80% (see Table 5-2), with an average of a 26% increase across all subjects.

	High TIPT (Control) Intervals			High TIPT (Control) Score Value	High TIPT (Control) %	High TIPT RAPS (Test) Intervals			High TIPT RAPS (Test) Score Value	High TIPT RAPS (Test) %	Score Difference between High TIPT (Control) & High TIPT RAPS (Test) Values	Score Difference between High TIPT (Control) & High TIPT RAPS (Test) %	Total High TIPT Scores
Subject	#01	#02	#04			#06	#07	#08					
B	10	10	10	30	100	10	10	9	29	97	-1	-3	59
C	1	4	1	6	20	10	10	10	30	100	24	80	36

Table 5-2 High TIPT assessment task performance scores

5.7 The raw EEG Data

A single subject's dataset was removed from the study owing to excessive noise; EEG data for 12 subjects remained in the study. Full data for all subjects appear in Appendix L.

5.7.1 MWL raw neural data

Data averaging was carried out using the Compumedics CURRY & software. For all EEG data, therefore, the numerical values used to indicate and measure MWL for all bands Theta (3-8Hz), Alpha (8-12Hz) and Beta (12-30Hz) are shown as the sum of the average band power and are measured in microvolts. The symbols used to illustrate bands and power are as follows: ϴ = Theta (3-8Hz), α = Alpha (8-12Hz), β = Beta (12-30Hz) and µV = Microvolts. Detailed raw neural data for subjects A, B, C, D, E, G, H, I, J, K, L, M and N provide an opportunity to review activity across both low and high TIPT control and RAPS test intervals (see Table 5-3, 5-4, 5-5, 5-6, 5-7, 5-8, 5-9, 5-10, 5-11, 5-12, 5-13, 5-14).

SUBJECT	Sum of the Average Band Power µV		
A	ϴ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	0.667	1.73	0.39
Low TIPT (Control)	4.06	8.42	2.46
Low TIPT RAPS (Test)	4.07	7.21	2.56
High TIPT (Control)	4.16	9.81	2.46
High TIPT RAPS (Test)	4.53	8.4	2.68

Table 5-3 Raw neural data across all tasks, ϴ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject A

SUBJECT	Sum of the Average Band Power µV		
B	ϴ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	8.96	14.55	3.7
Low TIPT (Control)	9.06	14.81	4.31
Low TIPT RAPS (Test)	9.29	15.01	4.39
High TIPT (Control)	9.41	15.48	4.41
High TIPT RAPS (Test)	8.669	15.18	4.29

Table 5-4 Raw neural data across all tasks, ϴ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject B

SUBJECT	Sum of the Average Band Power µV		
C	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	9.72	15	3.5
Low TIPT (Control)	10.92	15.52	4.11
Low TIPT RAPS (Test)	10.92	16.42	4.02
High TIPT (Control)	12.64	19.13	4.25
High TIPT RAPS (Test)	10.69	17.1	3.94

Table 5-5 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject C

SUBJECT	Sum of the Average Band Power µV		
D	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	8.99	23.93	7.5
Low TIPT (Control)	8.4	24.03	6.33
Low TIPT RAPS (Test)	9.47	25.15	7.3
High TIPT (Control)	9.57	22.5	6.39
High TIPT RAPS (Test)	10.59	14.72	4.99

Table 5-6 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject D

SUBJECT	Sum of the Average Band Power µV		
G	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	7.64	4.95	4.51
Low TIPT (Control)	9.61	6.034	5.44
Low TIPT RAPS (Test)	9.94	6.189	5.51
High TIPT (Control)	9.56	6.85	6.6
High TIPT RAPS (Test)	8	6.73	6.05

Table 5-7 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject G

SUBJECT	Sum of the Average Band Power µV		
H	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	4.99	9.19	3.52
Low TIPT (Control)	5.54	10.48	3.55
Low TIPT RAPS (Test)	5.47	9.83	3.72
High TIPT (Control)	5.54	11.67	3.76
High TIPT RAPS (Test)	5.24	9.46	3.72

Table 5-8 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject H

SUBJECT	Sum of the Average Band Power µV		
I	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	20.46	6.45	4.04
Low TIPT (Control)	4.9	9.01	4.4
Low TIPT RAPS (Test)	4.76	1.49	4.7
High TIPT (Control)	5.25	11.61	5.37
High TIPT RAPS (Test)	4.88	10.83	4.89

Table 5-9 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject I

SUBJECT	Sum of the Average Band Power μV		
J	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	14.56	5.26	2.95
Low TIPT (Control)	5.37	6.63	3.35
Low TIPT RAPS (Test)	5.16	6.66	3.61
High TIPT (Control)	6.11	8.01	4.25
High TIPT RAPS (Test)	5.46	8.224	4.11

Table 5-10 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject J

SUBJECT	Sum of the Average Band Power μV		
K	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	15.77	8.58	3.14
Low TIPT (Control)	11.9	24.65	4.198
Low TIPT RAPS (Test)	12.4	25.65	4.6
High TIPT (Control)	12.14	27.89	4.8
High TIPT RAPS (Test)	12.24	29.39	4.91

Table 5-11 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject K

SUBJECT	Sum of the Average Band Power μV		
L	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	13.51	7.13	3.03
Low TIPT (Control)	11.77	17.49	4.44
Low TIPT RAPS (Test)	11.36	21.2	5.01
High TIPT (Control)	12.99	19.2	5.04
High TIPT RAPS (Test)	12.63	22.05	5.03

Table 5-12 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject L

SUBJECT	Sum of the Average Band Power μV		
M	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	9.53	5.72	3.4
Low TIPT (Control)	7.1	15.79	4.17
Low TIPT RAPS (Test)	7.38	16.27	4.34
High TIPT (Control)	10.24	21.32	5.54
High TIPT RAPS (Test)	7.99	16.41	4.18

Table 5-13 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject M

SUBJECT	Sum of the Average Band Power μV		
N	Θ (3-8Hz)	α (8-12Hz)	β (12-30Hz)
Baseline	6.16	20.26	4.62
Low TIPT (Control)	7.08	21.06	4.45
Low TIPT RAPS (Test)	6.61	22.04	4.72
High TIPT (Control)	7.89	25.9	5.84
High TIPT RAPS (Test)	6.81	20.8	4.43

Table 5-14 Raw neural data across all tasks, Θ = theta (3-8Hz), α = alpha (8-12Hz), β = beta (12-30Hz) - Subject N

The sum of the average band power (value) α (8-12Hz) for subjects A, B, C, D, E, G, H, I, J, K, L, M and N provides an opportunity to review the activity recorded between the MWL low TIPT task (control) and the high TIPT (control), highlighting the mean low TIPT (control) of 14.48 µV, a mean high TIPT RAPS (control) 16.62 µV and an average difference µV in MWL of 16.51 µV (see Table 5-15).

MWL Low TIPT Task (Control) vs High TIPT (Control) – Sum of the average band power (value) α (8-12Hz)				
Subject	Low TIPT (Control) µV	High TIPT (Control) µV	Difference µV	Difference %
A	8.42	9.81	1.39	16.51
B	14.18	15.48	1.3	9.17
C	15.52	19.13	3.61	23.26
D	24.03	22.49	-1.54	-6.41
G	6.03	6.85	0.82	13.60
H	10.48	11.67	1.19	11.35
I	9.01	11.61	2.6	28.86
J	6.63	8.01	1.38	20.81
K	24.65	27.88	3.23	13.10
L	17.48	19.19	1.71	9.78
M	15.78	21.32	5.54	35.11
N	21.05	25.89	4.84	22.99
Mean Low TIPT (Control)				**14.48**
Mean High TIPT RAPS (Control)				**16.62**
Average Difference µV				**16.51**

Table 5-15 ***MWL low TIPT task (Control) task vs high TIPT (control) task - sum of the average band power (value) α (8-12Hz)***

The sum of the average band power (value) α (8-12Hz) for subjects A, B, C, D, E, G, H, I, J, K, L, M and N provides an opportunity to review the activity recorded between the MWL low TIPT RAPS (test) task and the high TIPT RAPS (test), highlighting the mean low TIPT RAPS (test) of 15.18 µV, a mean high TIPT RAPS (test) 14.90 µV and an average difference µV in MWL of 1.87 µV (see Table 5-16).

MWL Low TIPT RAPS (test) Task vs High TIPT RAPS (test) - Sum of the average Alpha (8-12Hz) band power value µV				
Subject	Low TIPT RAPS (test)	High TIPT RAPS (test)	Difference - µV	Difference %
A	7.21	8.4	1.19	16.50
B	15.08	15.1	0.02	0.13
C	16.41	17.1	0.69	4.20
D	25.14	14.7	-10.44	-41.53
G	6.18	6.7	0.52	8.41
H	9.83	9.4	-0.43	-4.37
I	10.49	10.8	0.31	2.96
J	6.66	8.2	1.54	23.12
K	25.64	29.3	3.66	14.27
L	21.2	22.04	0.84	3.96
M	16.27	16.4	0.13	0.80
N	22.04	20.7	-1.34	-6.08
Mean Low TIPT RAPS (test)				**15.18**
Mean High TIPT RAPS (test)				**14.90**
Average Difference µV				**1.87**

Table 5-16 ***MWL low TIPT RAPS (test) task vs high TIPT RAPS (test)task - sum of the average band power (value) α(8-12Hz)***

The sum of the average band power (value) α (8-12Hz) for subjects A, B, C, D, E, G, H, I, J, K, L, M and N provides an opportunity to review the activity recorded between the MWL low TIPT (control) task and the low TIPT RAPS (test), highlighting the mean low TIPT (control) of 14.43 μV, a mean low TIPT (test) of 15.17 μV and an average difference in MWL of 4.05 μV (see Table 5-17).

<table>
<tr><th colspan="5">MWL
Low TIPT (Control) vs Low RAPS TIPT (Test) - Sum of the average band power (value) α (8-12Hz)</th></tr>
<tr><th>Subject</th><th>Low TIPT (Control) μV</th><th>Low TIPT Test μV</th><th>Difference μV</th><th>Difference %</th></tr>
<tr><td>A</td><td>8.42</td><td>7.21</td><td>-1.21</td><td>-14.37</td></tr>
<tr><td>B</td><td>14.18</td><td>15.08</td><td>0.9</td><td>6.35</td></tr>
<tr><td>C</td><td>15.52</td><td>16.41</td><td>0.89</td><td>5.73</td></tr>
<tr><td>D</td><td>24.03</td><td>25.14</td><td>1.11</td><td>4.62</td></tr>
<tr><td>G</td><td>6.03</td><td>6.18</td><td>0.15</td><td>2.49</td></tr>
<tr><td>H</td><td>10.48</td><td>9.83</td><td>-0.65</td><td>-6.20</td></tr>
<tr><td>I</td><td>9.01</td><td>10.49</td><td>1.48</td><td>16.43</td></tr>
<tr><td>J</td><td>6.63</td><td>6.66</td><td>0.03</td><td>0.45</td></tr>
<tr><td>K</td><td>24.65</td><td>25.64</td><td>0.99</td><td>4.02</td></tr>
<tr><td>L</td><td>17.48</td><td>21.2</td><td>3.72</td><td>21.28</td></tr>
<tr><td>M</td><td>15.78</td><td>16.27</td><td>0.49</td><td>3.11</td></tr>
<tr><td>N</td><td>21.05</td><td>22.04</td><td>0.99</td><td>4.70</td></tr>
<tr><td colspan="4">Mean Low (Control) μV</td><td>14.43</td></tr>
<tr><td colspan="4">Mean Low (Test) μV</td><td>15.17</td></tr>
<tr><td colspan="4">Average Difference μV</td><td>4.05</td></tr>
</table>

Table 5-17 MWL low TIPT (control) vs low RAPS TIPT (test) - sum of the average band power (value) α (8-12Hz)

The sum of the average band power (value) α (8-12Hz) for subjects A, B, C, D, E, G, H, I, J, K, L, M and N provides an opportunity to review the activity recorded between the MWL high TIPT (control) task and the high TIPT RAPS (test), highlighting the mean high TIPT (control) of 16.61 µV, a mean high TIPT RAPS (test) of 14.09 µV and an average difference in MWL of -9.29 µV (see Table 5-18).

MWL High TIPT (Control) vs High RAPS TIPT (Test) - Sum of the average band power (value) α (8-12Hz)				
Subject	High TIPT (Control) µV	High TIPT RAPS (Test) µV	Difference µV	Difference %
A	9.81	8.4	-1.41	-14.37
B	15.48	15.1	-0.38	-2.45
C	19.13	17.1	-2.03	-10.61
D	22.49	14.7	-7.79	-34.64
G	6.85	6.7	-0.15	-2.19
H	11.67	9.4	-2.27	-19.45
I	11.61	10.8	-0.81	-6.98
J	8.01	8.2	0.19	2.37
K	27.88	29.3	1.42	5.09
L	19.19	22.04	2.85	14.85
M	21.32	16.4	-4.92	-23.08
N	25.89	20.7	-5.19	-20.05
Mean High TIPT (Control) µV				**16.61**
Mean High TIPT RAPS (Test) µV				**14.09**
Average Difference µV				**-9.29**

Table 5-18 MWL high TIPT (control) vs high TIPT RAPS (test) - sum of the average band power (value) α (8-12Hz)

5.7.2 Unique human cognitive investment (UHCI)

The UHCI (value) α (8-12Hz) for subjects A, B, C, D, E, G, H, I, J, K, L, M and N has been calculated (see Appendix N) for the low TIPT (control) and low TIPT RAPS (test) allowing for a side by side comparison between the neural investment using the RAPS strategy (see Table 5-19).

UHCI - Low TIPT (Control) & Low TIPT RAPS (Test)		
Subject	**Low TIPT (Control) µV**	**Low TIPT RAPS (Test) µV**
A	0.20	-14.20
B	-2.54	3.64
C	3.54	9.47
D	0.46	5.10
G	21.82	24.85
H	14.04	6.96
I	39.69	62.64
J	26.05	26.62
K	187.30	198.83
L	145.02	197.17
M	175.63	184.19
N	3.90	8.79

Table 5-19 UHCI- low TIPT (control) & low TIPT RAPS (test)

The UHCI (value) α (8-12Hz) for subjects A, B, C, D, E, G, H, I, J, K, L, M and N has been calculated (see Appendix N) for the high TIPT (control) and high TIPT RAPS (test) allowing for a side by side comparison between the neural investment using the RAPS strategy (see Table 5-20).

UHCI - High TIPT (Control) & High TIPT RAPS (Test)		
Subject	High TIPT (Control) µV	High TIPT RAPS (Test) µV
A	16.74	-0.04
B	6.39	3.78
C	27.62	14.08
D	-5.98	-38.55
G	38.38	35.35
H	26.99	2.29
I	80.00	67.44
J	52.28	55.89
K	224.94	241.49
L	168.99	208.94
M	272.40	186.46
N	27.79	2.17

Table 5-20 UHCI- high TIPT (control) & high TIPT RAPS (test)

5.7.3 CE

The CE scores for subjects A, B, C, D, E, G, H, I, J, K, L, M and N has been calculated (see Appendix N) for the low TIPT (Control) and low TIPT RAPS (test) displaying the overall CE between tasks when applying the RAPS strategy (see Table 5-21).

CE Scores - Low TIPT			
Subject	Low TIPT (Control)	Low TIPT RAPS (Test)	Difference In Overall CE
A	1.00	1.07	0.07
B	1.50	0.92	-0.58
C	0.50	0.87	0.37
D	0.53	-0.15	-0.68
G	0.79	0.74	-0.06
H	-0.07	0.89	0.96
I	1.09	0.41	-0.68
J	-0.66	0.72	1.38
K	-0.81	-2.86	-2.05
L	-1.81	-1.79	0.02
M	-2.11	-1.68	0.43
N	0.03	0.87	0.84

Table 5-21 CE scores - low TIPT (control) & low TIPT RAPS (test)

The CE scores for subjects A, B, C, D, E, G, H, I, J, K, L, M and N has been calculated for the high TIPT (Control) and high TIPT RAPS (test) displaying the overall CE between tasks when applying the RAPS strategy (see Table 5-22).

CE Scores - High TIPT			
Subject	High TIPT (Control)	High TIPT RAPS (Test)	Difference In Overall CE
A	0.40	0.77	0.38
B	1.43	0.75	-0.68
C	-1.02	1.24	2.26
D	0.19	0.50	0.30
G	1.19	1.08	-0.11
H	0.61	0.76	0.15
I	0.87	0.84	-0.03
J	0.32	-0.79	-1.10
K	-1.48	-2.76	-1.27
L	-0.86	-1.37	-0.51
M	-1.75	-1.20	0.55
N	-0.35	0.19	0.54

Table 5-22 CE scores - high TIPT (control) & high TIPT RAPS (test)

This chapter has outlined the data collection phase by first describing the subjects, the pre-processing and the steps in the data collection. It proceeded through each phase and illustrated the raw data collected: the prior knowledge questionnaire, the transient information processing assessment task performance scores raw data, the raw neural data, the unique human cognitive investment data and finally the CE measures. The raw data was tabled to enable clear comparisons to be made between low and high TIPT and control and RAPS test tasks, along with the calculation of UNHI and CE for all subjects.

Part III Analysis and Discussion of Data

Chapter 6 Data Analysis

The previous chapter provided a linear diplay into the data collection phase by describing the subjects, the pre-processing and the steps in the data collection. It proceeded through each phase illustrating the raw data collected: the prior knowledge questionnaire, the transient information processing assessment task performance scores, raw data, the raw neural data, the unique human cognitive investment data and finally the cognitive efficiency (CE) measures.

This chapter takes the data collected and analyses it with reference to the study's research questions, first looking at the mental workload (MWL) variance between the low and high level tasks, then evaluating the impact that RAPS had on MWL, human performance and CE.

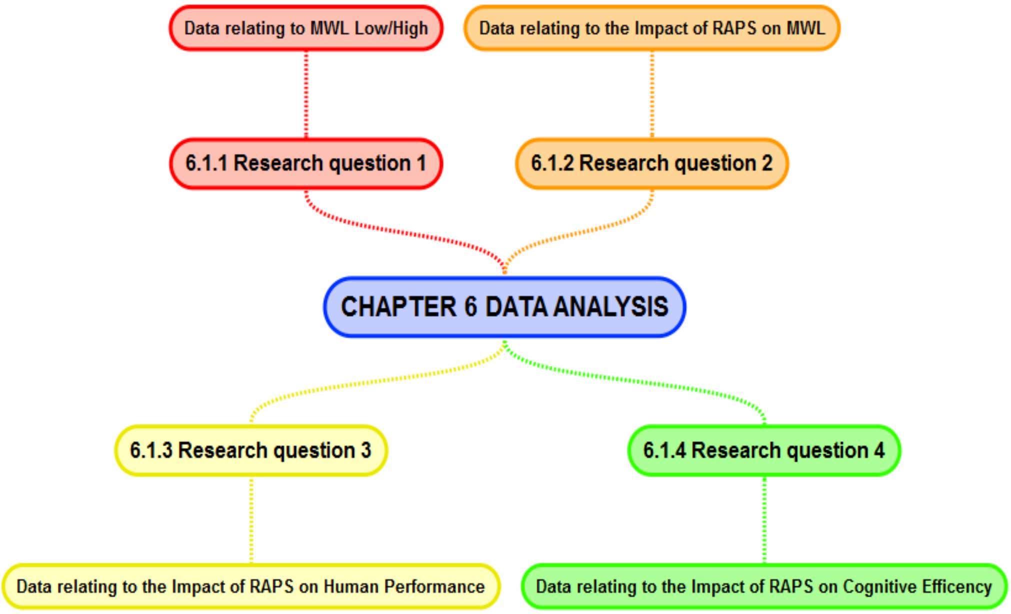


Figure 6-1 Data analysis Chapter 6 flowchart

This chapter consists of a more detailed discussion on: How does the MWL differ between a low cognitive demanding TIPT and a high cognitive demanding TIPT. Provides graphical representations of the data collected: the sum of the average band power μV of all band frequencies, ϴ (3-8Hz), α (8-12Hz) & β (8-30Hz) and across all tasks for each subject, a collective sum of the average band power μV - ϴ (3-8Hz), α (8-12Hz) & β (8-30Hz) across all tasks, MWL low (control)/ high (control) & low (test)/high (test) tasks per subject, low μV low TIPT RAPS (test) task vs high RAPS TIPT (test) task - sum of the average alpha (8-12Hz) band power value μV of all subjects.

The focus then shifts to research question 2: What impact does the use of reverse assessment priming stimuli (RAPS) have on the MWL imposed during a low cognitive demanding and a high cognitive demanding TIPT? The MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/ high TIPT RAPS (test) results are displayed for each subject.

This is followed by research question 3: What impact does the use of RAPS have on the performance results achieved across both low and high level TIPT? The individual performance score analysis - Performance scores low TIPT (control)/ (test) & high TIPT (control)/(test) are demonstrated for each subject.

Finally the data results are shown addressing research question 4: What impact does the use of RAPS have on the overall CE achieved across both low and high level TIPT? Illustrating the UHCI /PS analysis and the corresponding CE analysis.

EEG Signal Processing/offline signal processing was performed using the Compumedics CURRY 7 Software. The filter parameters were set as follows: high pass filter at 1.0Hz low pass filter at 70.0Hz notch filter at 50Hz. Bad blocks of data were removed from the continuous data, as was seen in Figure 5.4. Each individual data file was divided into 12 events according to the stimuli presented as is seen in Figure 6.2. The 12 events for each subject are made up of epochs (time blocks of data recording), 3 epochs for each stimulus type presented. Therefore there were 3 each for the low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test).

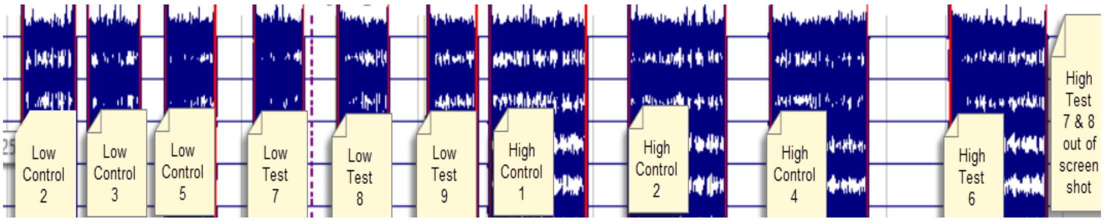


Figure 6-2 *Recording of all events as shown in CURRY 7 interface*

Three forms of data output were available for analysis in this study, as follows:

1. MWL or the sum of the average band power value for theta (3-8Hz), alpha (8-12Hz) and beta (8-30Hz) band waves. This was calculated using the Compumedics CURRY 7 software.
2. A UHCI measure was established as the difference in MWL (average band power value for the alpha 8-12Hz frequency band) from a baseline task to a targeted task. This was calculated using the Event Related Desynchronisation (ERD)% (Antonenko & Niederhauser, 2010; Klimesch et al., 1997) equation to express this difference as a percentage of individual cognitive investment as opposed to MWL across the cohort.
3. Performance scores were collected through the use of a post task assessment; the scores indicated the level of accuracy, the level of information processed and the knowledge retained. This was also expressed as a percentage.

The "Basic principles of reporting EEG studies in NeuroIS research" (Müller-Putz, Riedl, & Wriessnegger, 2015, p. 929) were used as a guide for the collection, experimental protocol, data processing, analysis and reporting of the data for this study. The data were sourced from each of the experiments for each subject; equations were used to conduct statistical and descriptive analysis to answer the research questions.

6.1.1 Research question 1

How does the MWL differ between a low cognitive demanding transient information processing task (TIPT) and a high cognitive demanding TIPT?

Firstly, with respect to the many variations on EEG data interpretations found in the literature and the range of methods used in the analysis, the data was filtered to capture the sum of the average band power across the theta (3-8Hz), alpha

(8-12Hz) and beta (8-30Hz) band waves. Figure 6-3—displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for Subject A and Figure 6-4 allows the relationship to be viewed in task clusters.

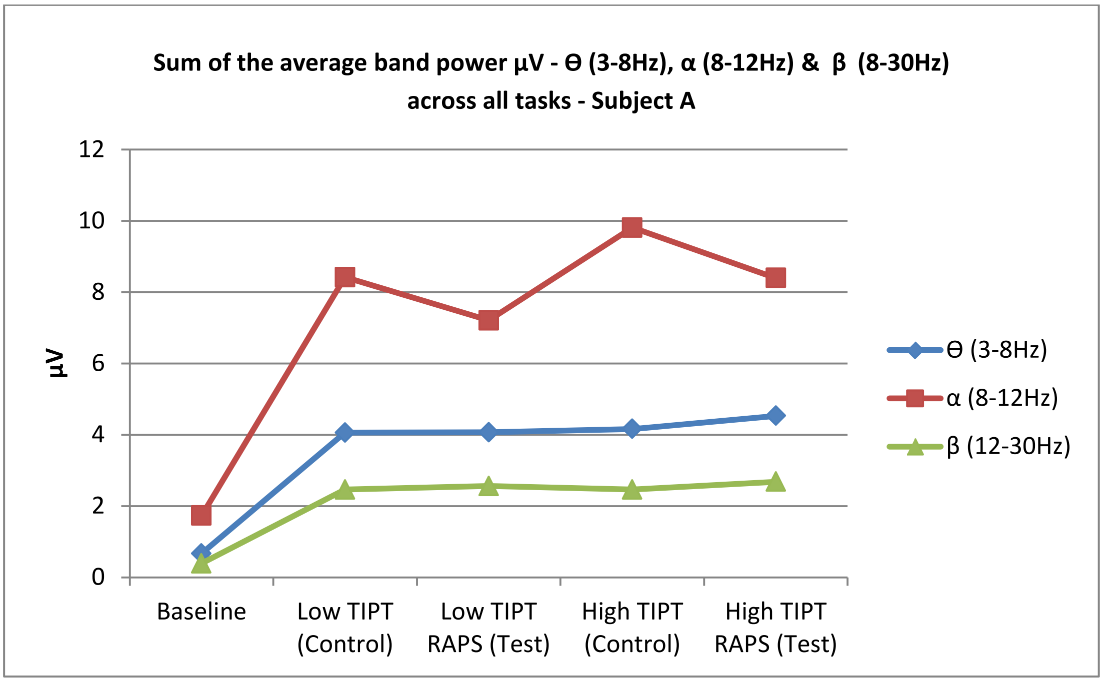


Figure 6-3 ***Line graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject A***

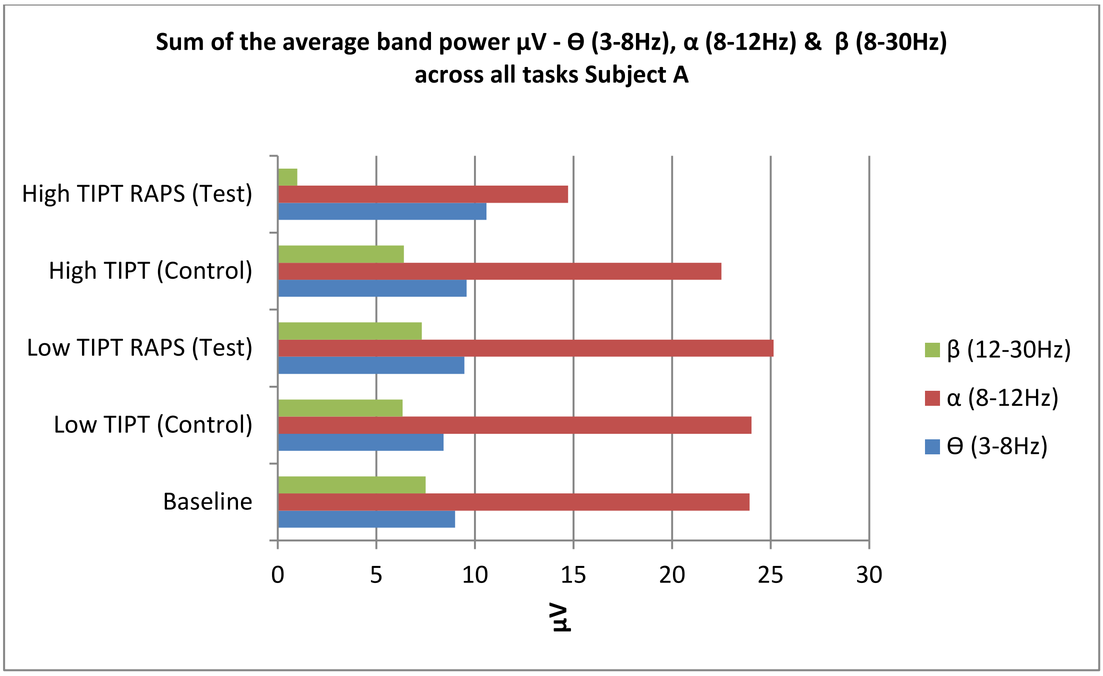


Figure 6-4 ***Bar graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject A***

Figure 6-3 and 6-4 display the sum of the band power average values in μV for each band - theta (3-8Hz) alpha (8-12) and beta (8-30Hz) for subject A. As expected the alpha (8-12Hz) band increased from a baseline level of 1.73μV to 8.42 μV with the low TIPT (control), then showed a decrease in power when presented with the low TIPT RAPS (test) stimuli of 7.21μV. The neural activity - specifically the alpha (8-12Hz) band - further increased on the presentation of the high TIPT (control) stimuli to 9.81μV and continues to follow the pattern of decreasing when the RAPS (test) stimuli were presented, decreasing to 8.4μV. Other than an increase from the baseline level of 1.73μV, both the beta (12-30Hz) band and the theta (3-8Hz) band resulted in parallel results through all events.

Figure 6-5 displays the flow and the relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject B Figure 6-6 allows the relationship to be viewed in task clusters.

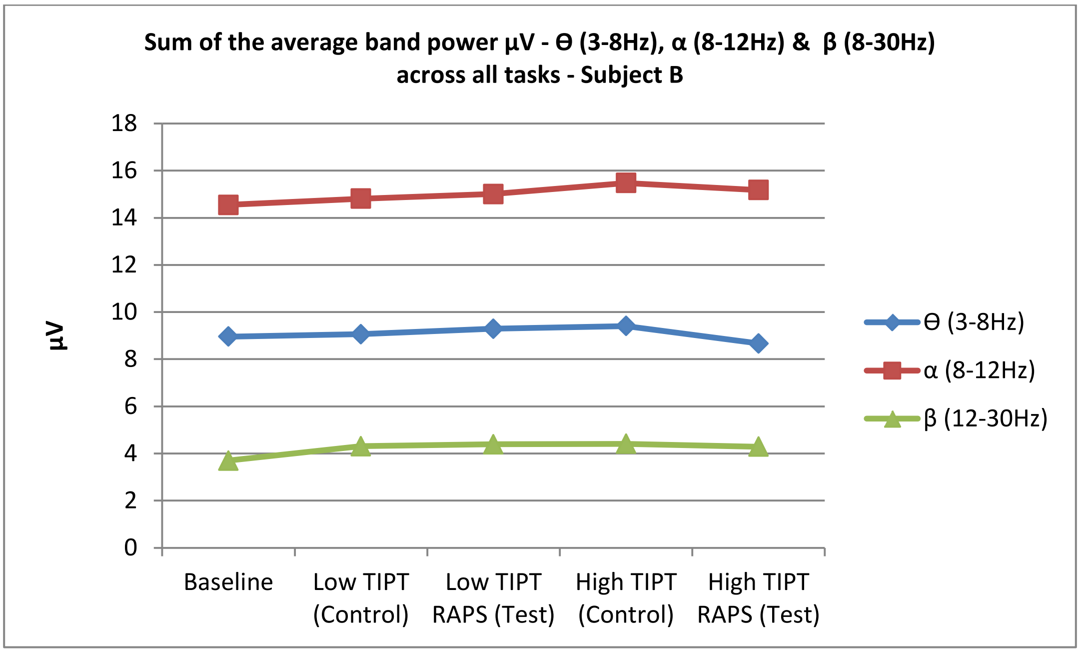


Figure 6-5 ***Line graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject B***

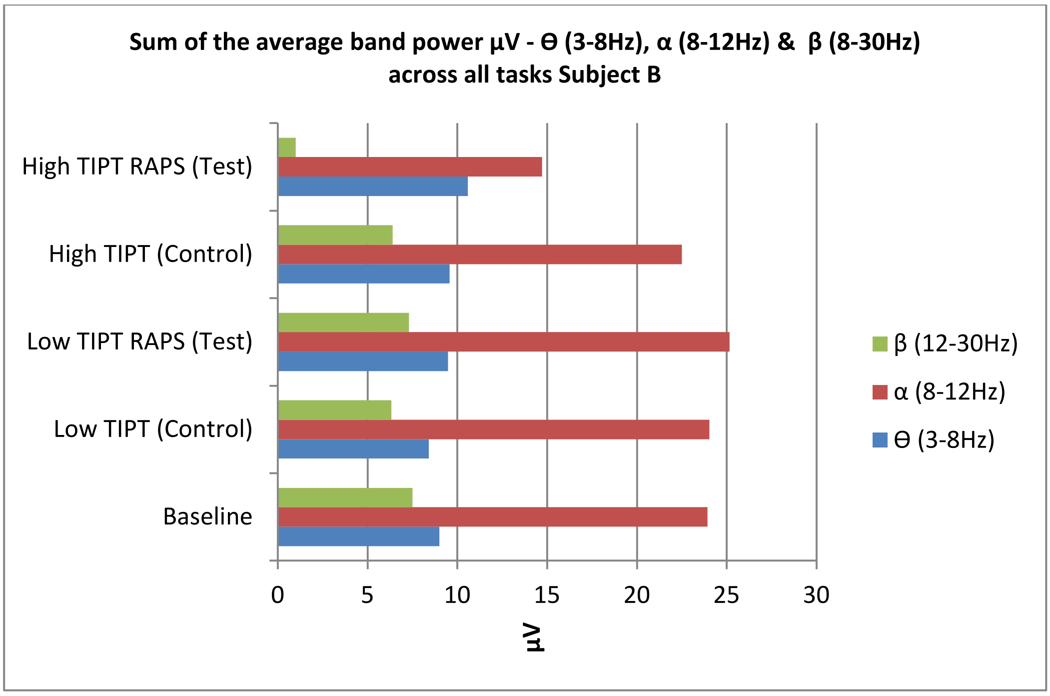


Figure 6-6 *Bar graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject B*

Figures 6-4 and 6-5 illustrate the sum of the band power average values in µV for each band - theta (3-8Hz) alpha (8-12) and beta (8-30Hz) - for subject B. All bands resulted in steady increases and remained on similar trends. Again in the alpha (8-12Hz) band a slight increase can be seen from the baseline 14.55µV to 14.51µV with the low TIPT (control) event. No decrease resulted from low TIPT (control) to low TIPT (test). However, as with subject A, there was a decrease in the neural activity with the alpha (8-12Hz) band from the 15.48µV with the high TIPT (control) to the 15.18 when presented with the high TIPT RAPS (test) event. Already for both Subject A and B patterns have been indicated between the theta (3-8Hz) alpha (8-12) and beta (8-30Hz) bands. The alpha (8-12Hz) band was indicative of the activity changing from a low cognitive demanding task to a more complex task. This result supported the literature on cognitive theories whereby strategies designed to assist in reducing the MWL are typically more effective with more complex tasks.

Figure 6-7 displays the flow and the relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject C. Figure 6-8 allows the relationship to be viewed in task clusters.

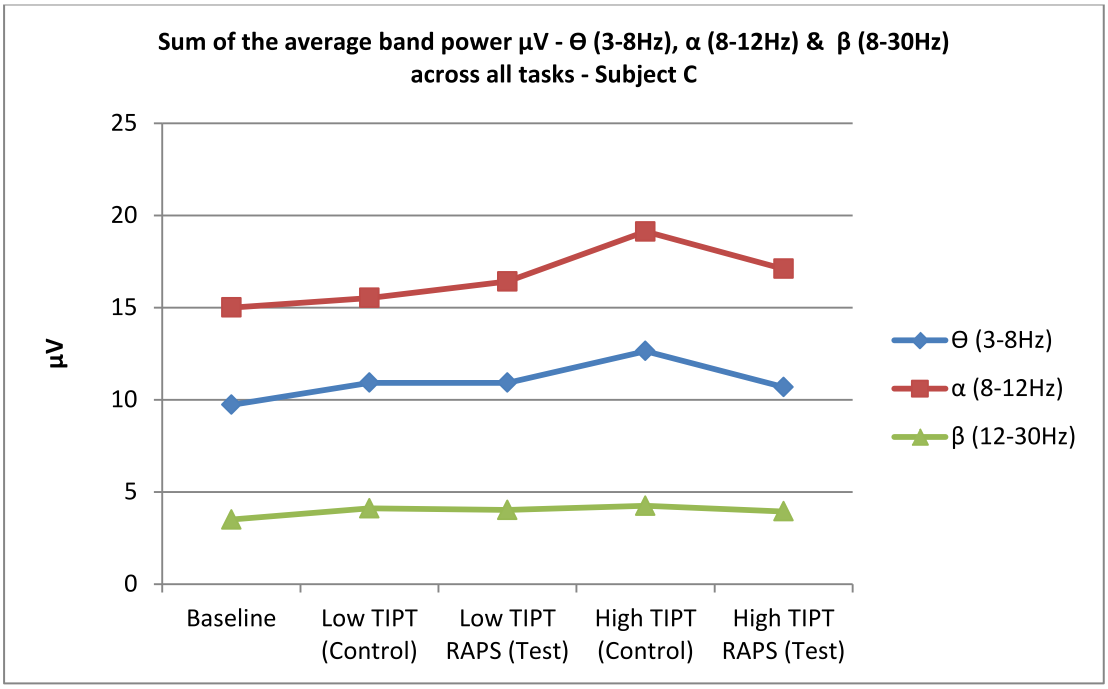


Figure 6-7 ***Line graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject C***

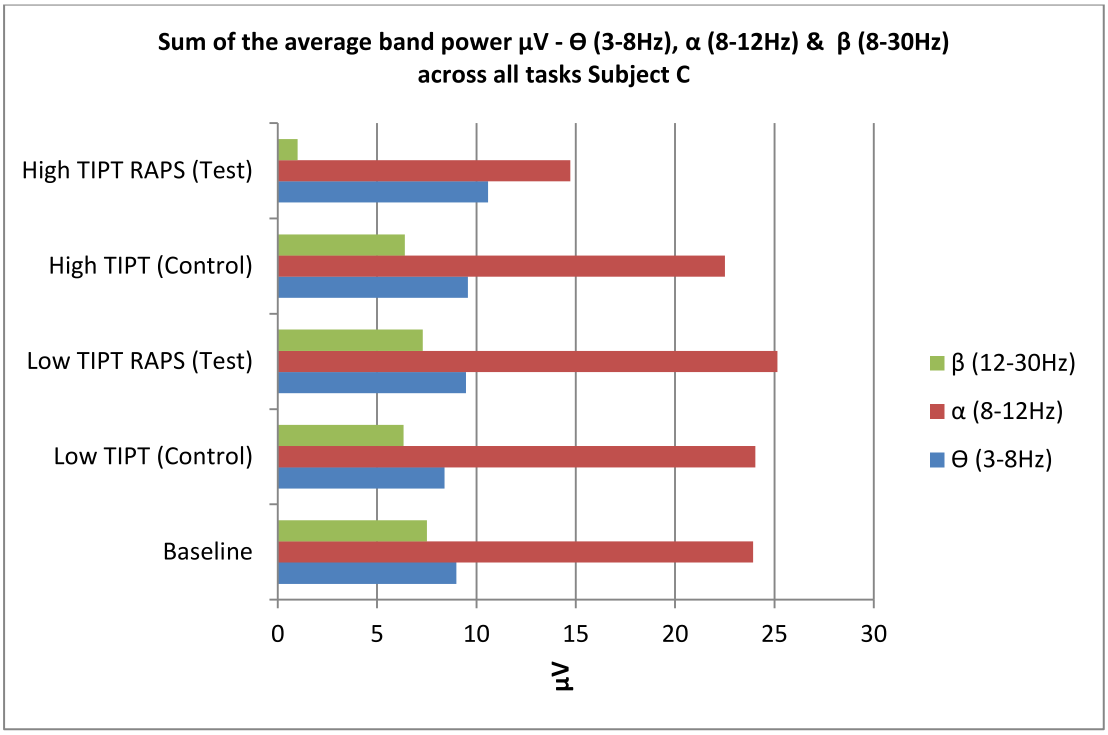


Figure 6-8 ***Bar graph patterning of band power theta (3-8Hz, alpha (8-12) and beta (8-30Hz) across all tasks — Subject C***

Figures 6-6 and 6-7 show the sum of the band power average values in µV for each band - theta (3-8Hz) alpha (8-12) and beta (8-30Hz) - for subject C. As with the results for subjects A and B, both beta (8-30Hz) and theta (3-8Hz) bands were steady. Theta (3-8Hz) had a small increase with the high TIPT (control) although when looking at the pattern beginning to emerge with the previous subjects it aappeared that subject C also continued this pattern. The alpha (8-12Hz) band power at the baseline event for subject C was 15µV increasing to 15.52µV, for the low TIPT (control) event. A further increase to 16.42 was indicated, with the low TIPT RAPS (test) event continuing to increase when presented with the high TIPT (control) event. At this point the results reflected similar pathways and an increase in the alpha (8-12Hz) band power was evident, with the high TIPT (control) event at 19.13µV, decreasing to 17.1µV with the high TIPT RAPS (test) event.

Figure 6-9 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject D. Figure 6-10 allows the relationship to be viewed in task clusters.

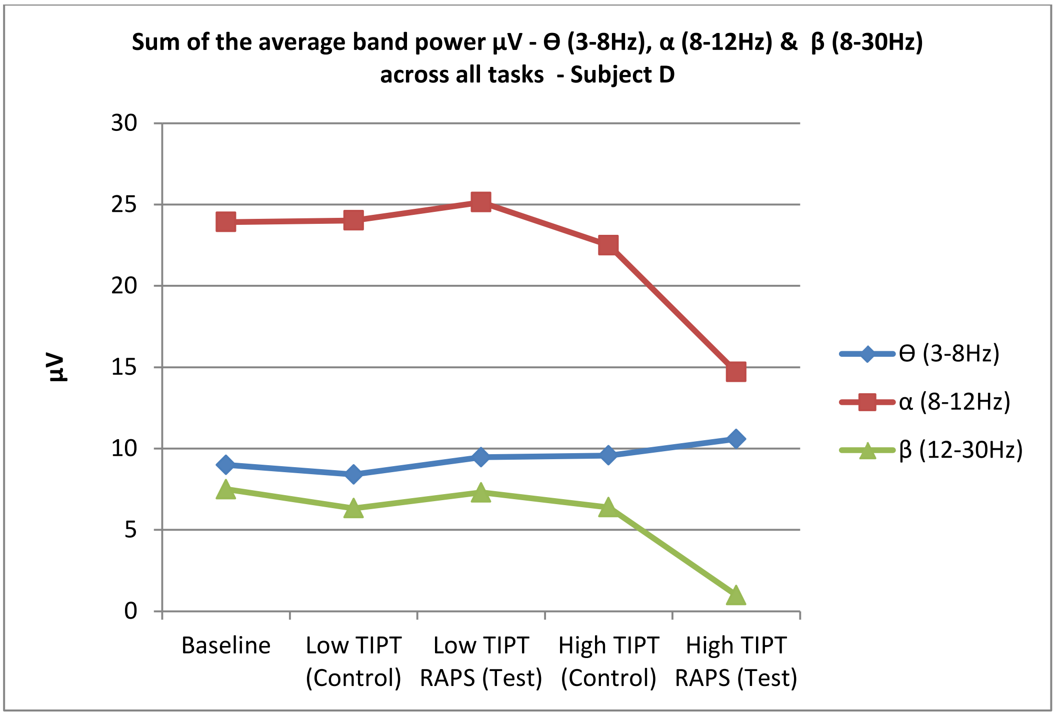


Figure 6-9 *Line graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject D*

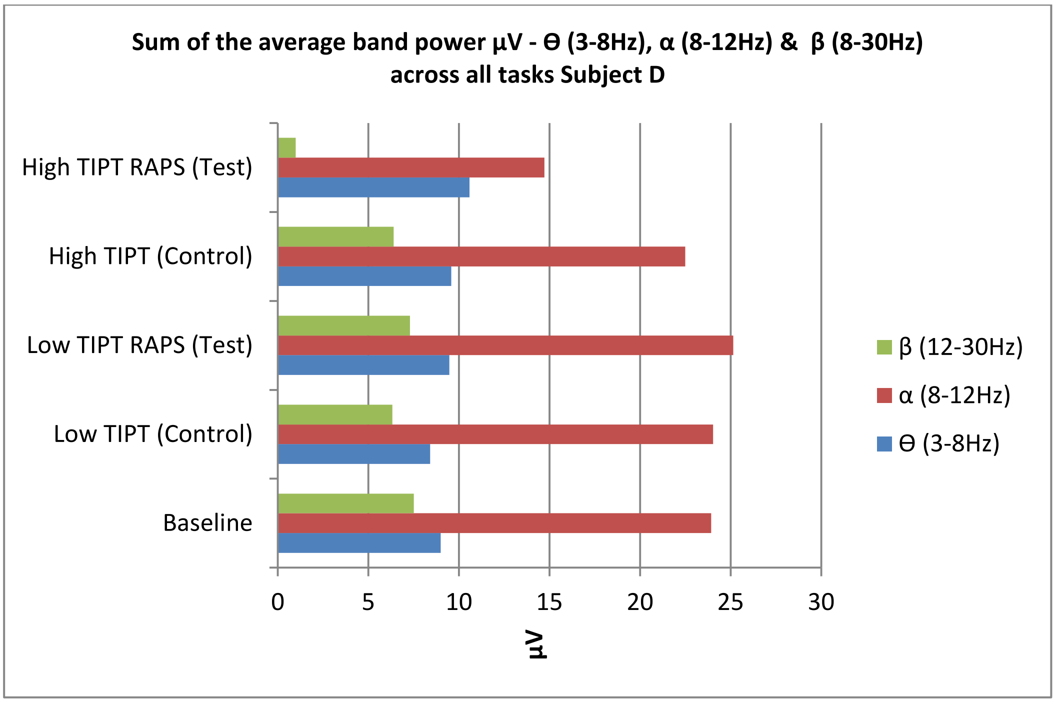


Figure 6-10 *Bar graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject D*

Figures 6-9 and 6-10 display the sum of the band power average values in μV for each band - theta (3-8Hz), alpha (8-12) and beta (8-30Hz) - for subject D. The results shown here were similar to previous subjects, with the beta and theta (3-8Hz) bands remaining steady, as was seen for subjects A, B and C. Interestingly, subject D experienced the highest alpha (8-12Hz) band power with the low TIPT RAPS (test) event of 25.15μV. The alpha (8-12Hz) band power results then decreased to 22.50 μV and then, keeping to the pattern of results from subjects A, B and C, the alpha (8-12Hz) band power decreased from 22.50 μV with the high TIPT (control) event down to 14.72 μ,V with the high TIPT RAPS (test) event. This finding demonstrated RAPS as a possibly effective strategy in reducing the alpha (8-12Hz) band power during a complex cognitive task.

Figure 6-11 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject G. Figure 6-12 allows the relationship to be viewed in task clusters.

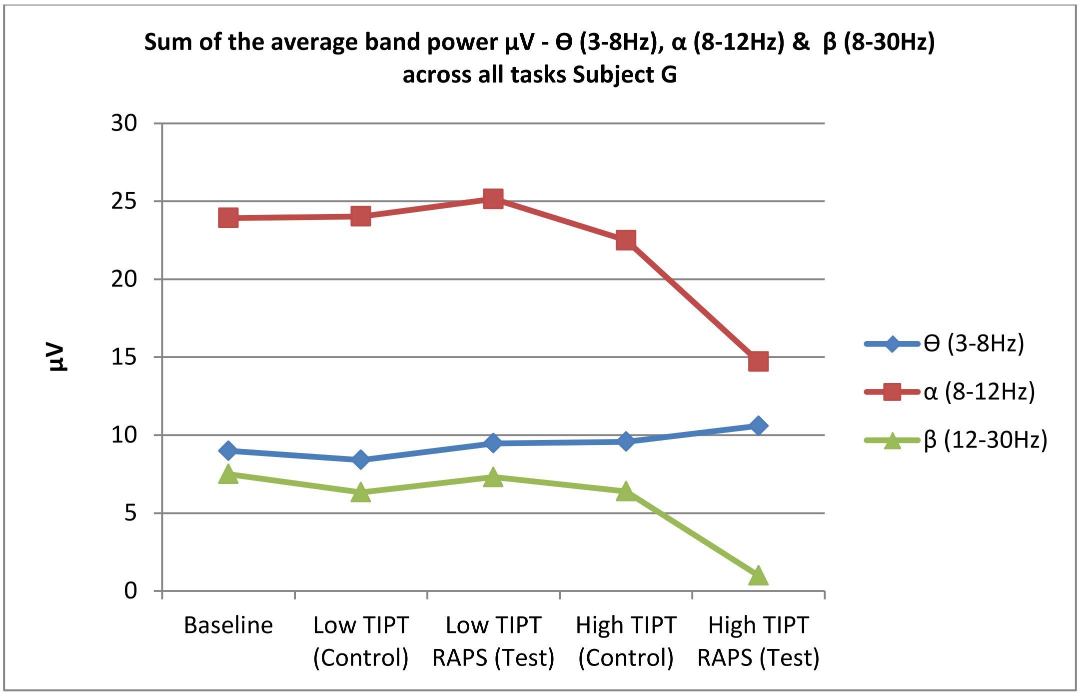


Figure 6-11 ***Line graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject G***

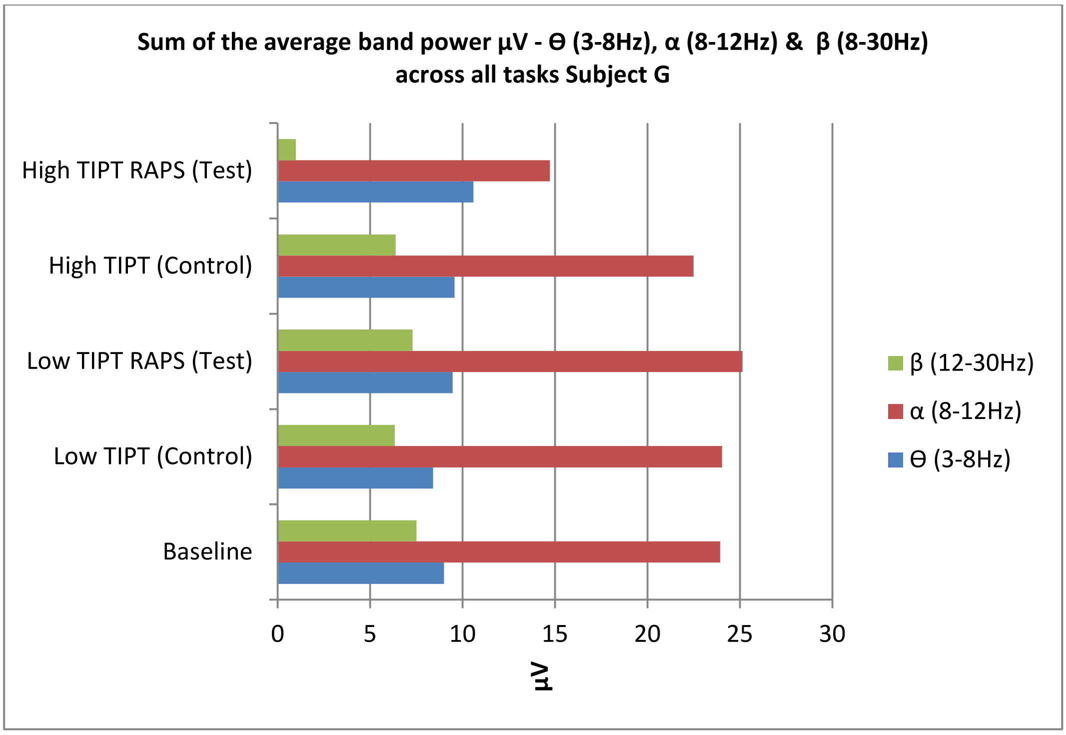


Figure 6-12 ***Bar graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject G***

Figures 6-10 and 6-11 illustrate the sum of the band power average values in µV for each band - theta (3-8Hz) alpha (8-12) and beta (8-30Hz) - for subject G. The alpha (8-12Hz) and theta (3-8Hz) band power in this case mirrored the trend across all events. The theta (3-8Hz) band power was recorded at a high baseline of 7.64µV. It then increased from the low TIPT (control) and further with he low TIPT RAPS (test) event, then it decreased with the high TIPT (control) and even more down to 8µV with the high TIPT RAPS (test) events, a similar level to the subject G baseline**.** Subject G continued the pattern with the alpha (8-12Hz) band of decreasing from 6.85µV with the high TIPT (control) event down to 6.73µV with the high TIPT RAPS (test) event.

Figure 6-13 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject H. Figure 6-14 allows the relationship to be viewed in task clusters.

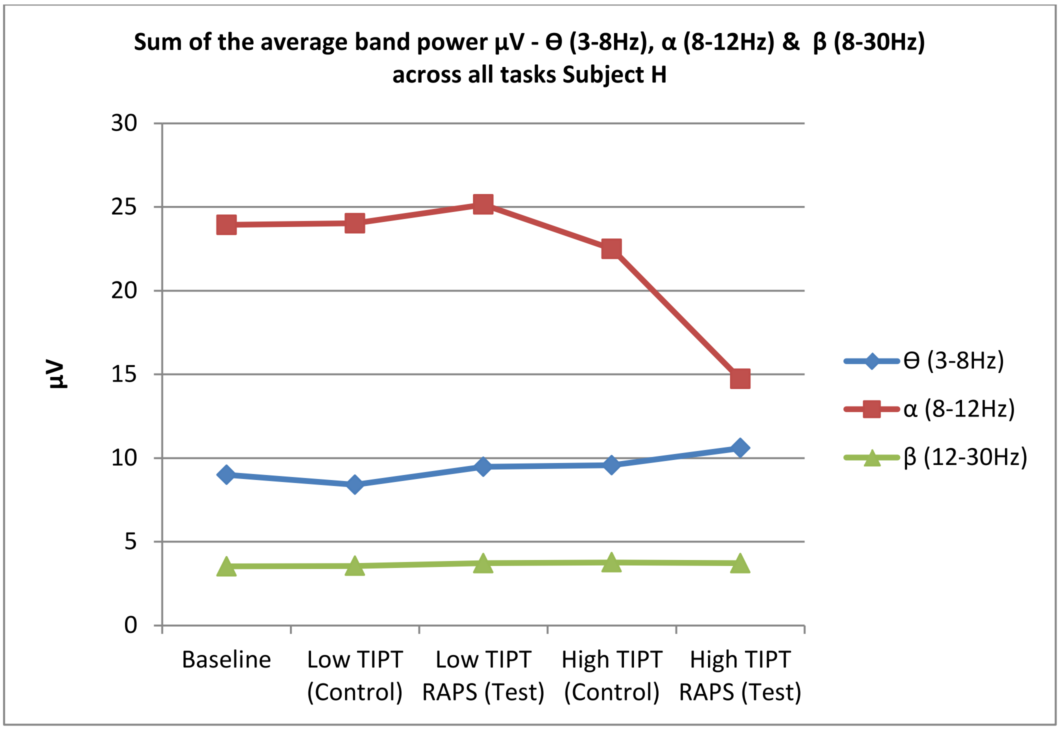


Figure 6-13 ***Line graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject H***

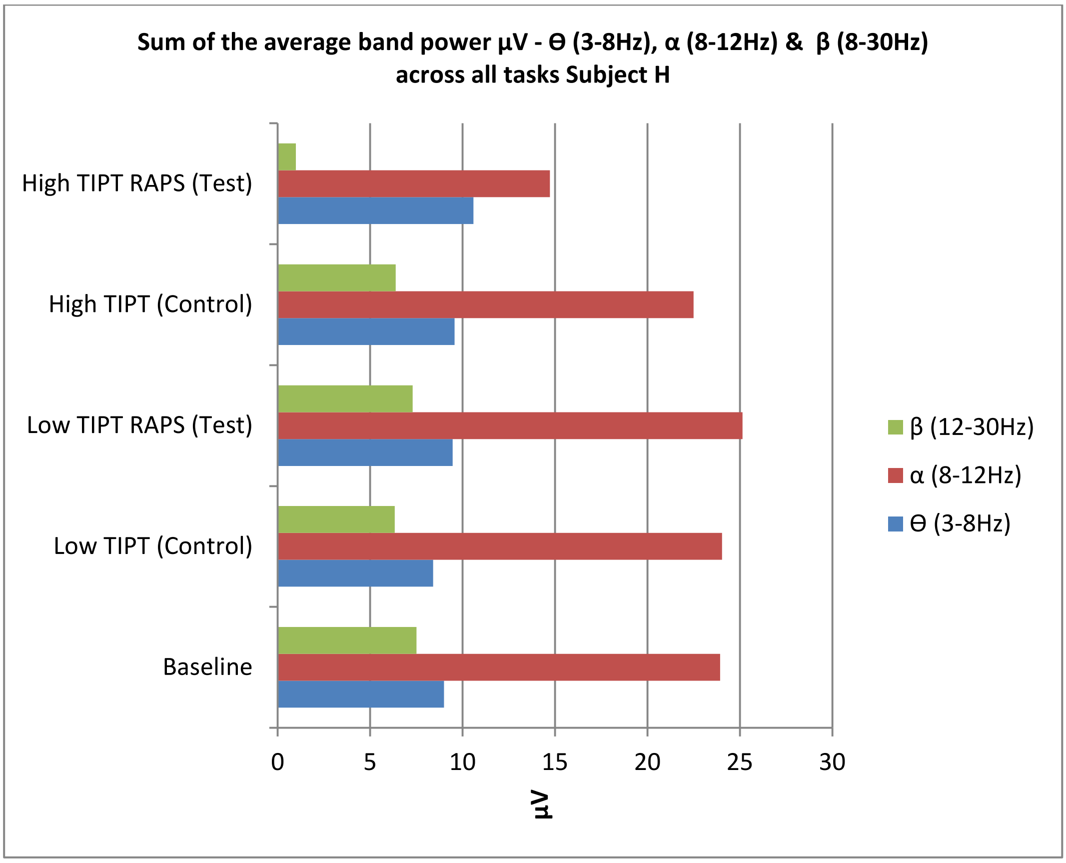


Figure 6-14 ***Bar graph patterning of band power theta (3-8Hz) alpha (8-12) and beta (8-30Hz) across all tasks – Subject H***

Figures 6-13 and 6-14 demonstrates the sum of the band power average values in µV for each band - theta (3-8Hz) alpha (8-12) and beta (8-30Hz) - for subject H. The beta (8-30Hz) and theta (3-8Hz) bands followed the same pattern by replicating a similar trending path, and the absence of obvious movement reflected a change in stimuli events. For subject H, the alpha (8-12Hz) band power returned to the identical results pattern of subjects A, B, C and D, whereby the alpha (8-12Hz) band power decreased from the high TIPT (control) event of 11.67µV to 9.46µV with the high TIPT RAPS (test) event. Subject H's alpha (8-12Hz) band power also illustrated the same pattern as subject A of decreasing between the low cognitive demand (control) and the (test) tasks.

Figure 6-15 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject I and Figure 6-16 allows the relationship to be viewed in task clusters.

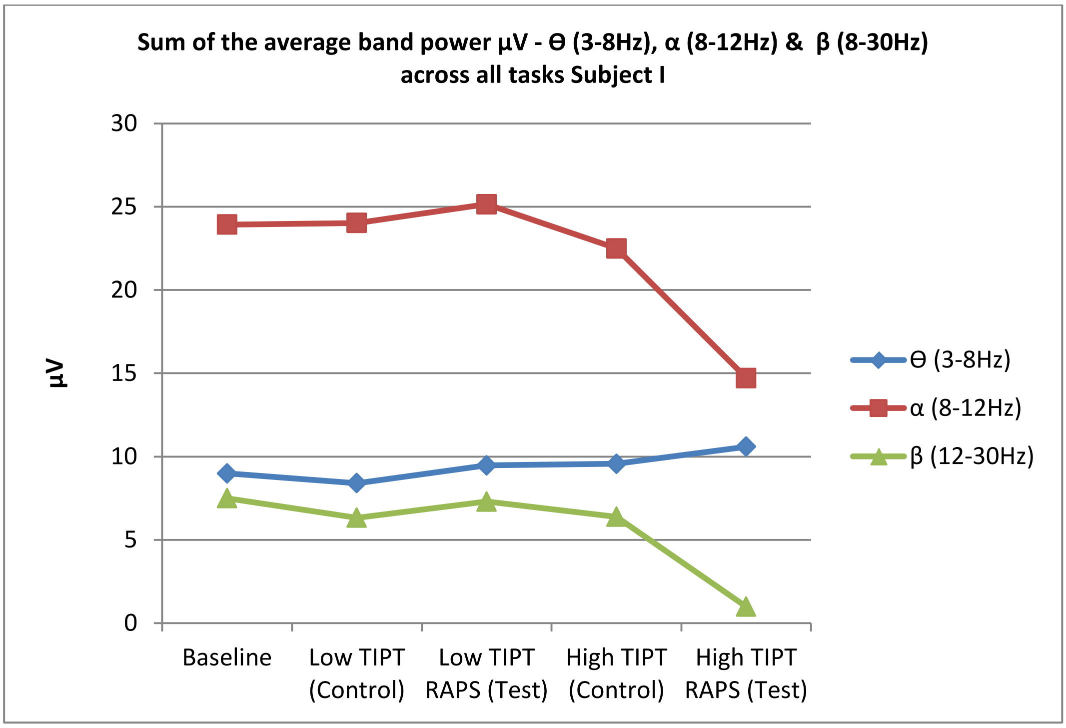


Figure 6-15 ***Line graph patterning of band power theta (3-8Hz,) alpha (8-12) and beta (8-30Hz) across all tasks – Subject I***

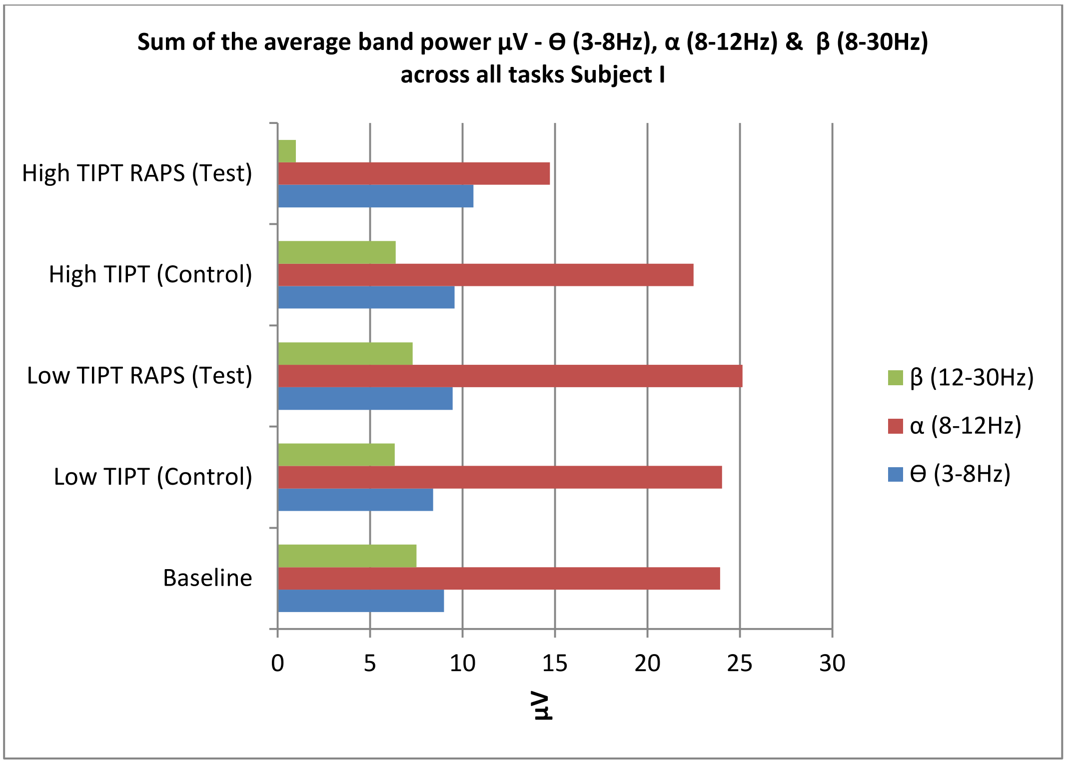


Figure 6-16 ***Bar graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject I***

Figures 6-15 and 6-16 show the sum of the band power average values in µV for each band - theta (3-8Hz) alpha (8-12) and beta (8-30Hz) - for subject I. The theta (3-8Hz) band resulted in an unusually high baseline of 20.46µV before returning to a similar pattern, as was seen to date with all subjects. No changes were evident with the beta (8-30Hz) band and, as with the other subjects, the pattern continued in a steady trend, following the theta (3-8Hz) band and showing no variation when the stimuli changed. For subject I, the alpha (8-12Hz) band continued the pattern of an increase from a baseline 6.45µV to 9.01µV with low TIPT (control) event, a decrease down to 1.49µV when presented with the low TIPT RAPS (test) event. There was a continuing trend of a higher alpha (8-12Hz) band power of 11.61µV with the high TIPT (control) event and a decreased alpha (8-12Hz) band power of 10.83µV when presented with the high TIPT RAPS (test) event.

Figure 6-17—displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject J. Figure 6-18 allows the relationship to be viewed in task clusters.

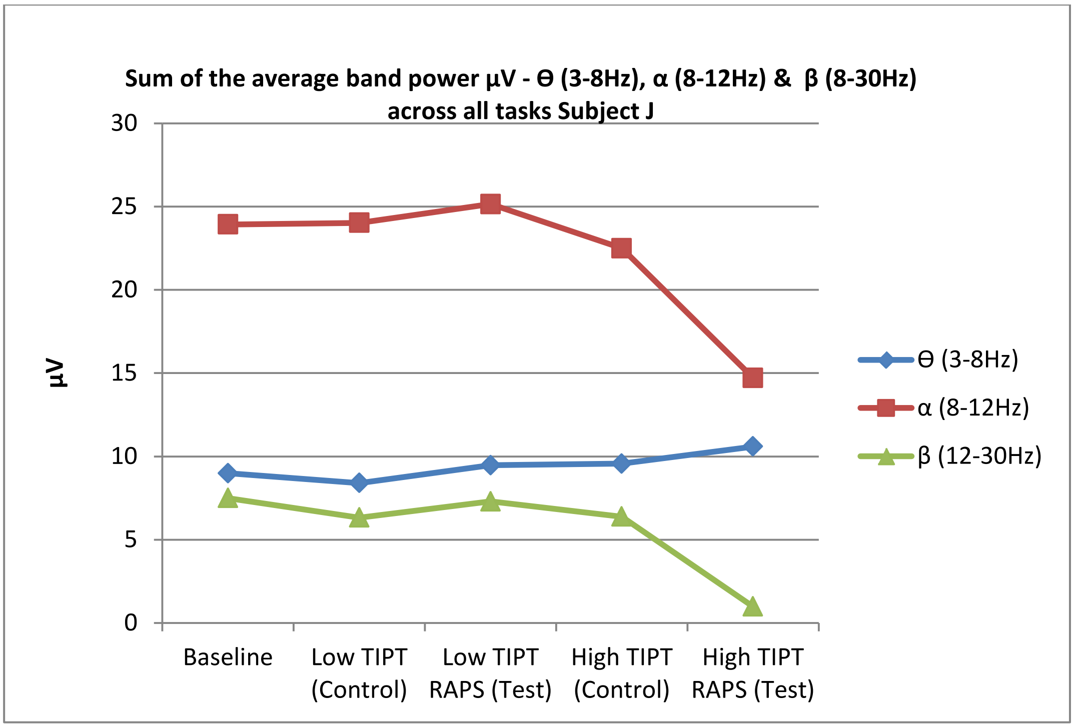


Figure 6-17 ***Line graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject J***

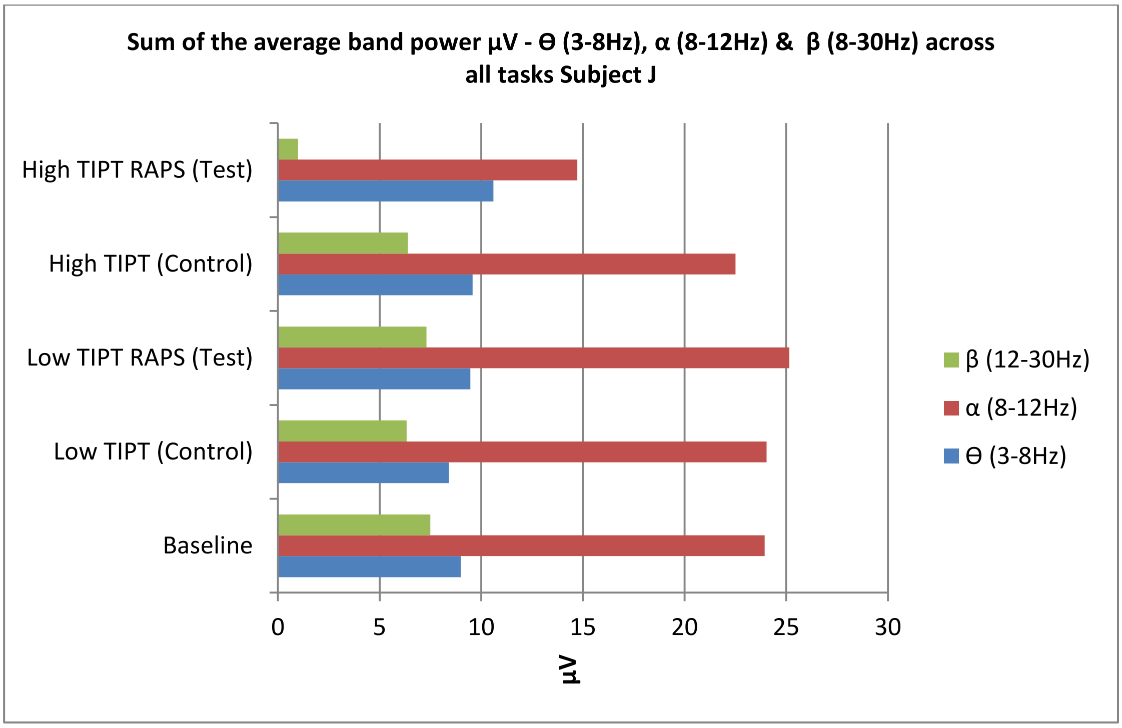


Figure 6-18 ***Bar graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject J***

Figures 6-17 and 6-18 represent the sum of the band power average values in µV for each band - theta (3-8Hz) alpha (8-12) and beta (8-30Hz) - for subject J. Other than the high baseline theta (3-98Hz) band power of 14.56 subject, J started with a baseline of 5.26µV and experienced an increase to 6.63µV with the low TIPT (control) event. The subject continued with a steady increase through the low TIPT RAPS (test) event with 6.66µV, 8.01µV with high TIPT control and finally 8.22µV with the high TIPT RAPS (test) events.

Figure 6-19 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject K. Figure 6-20 allows the relationship to be viewed in task clusters.

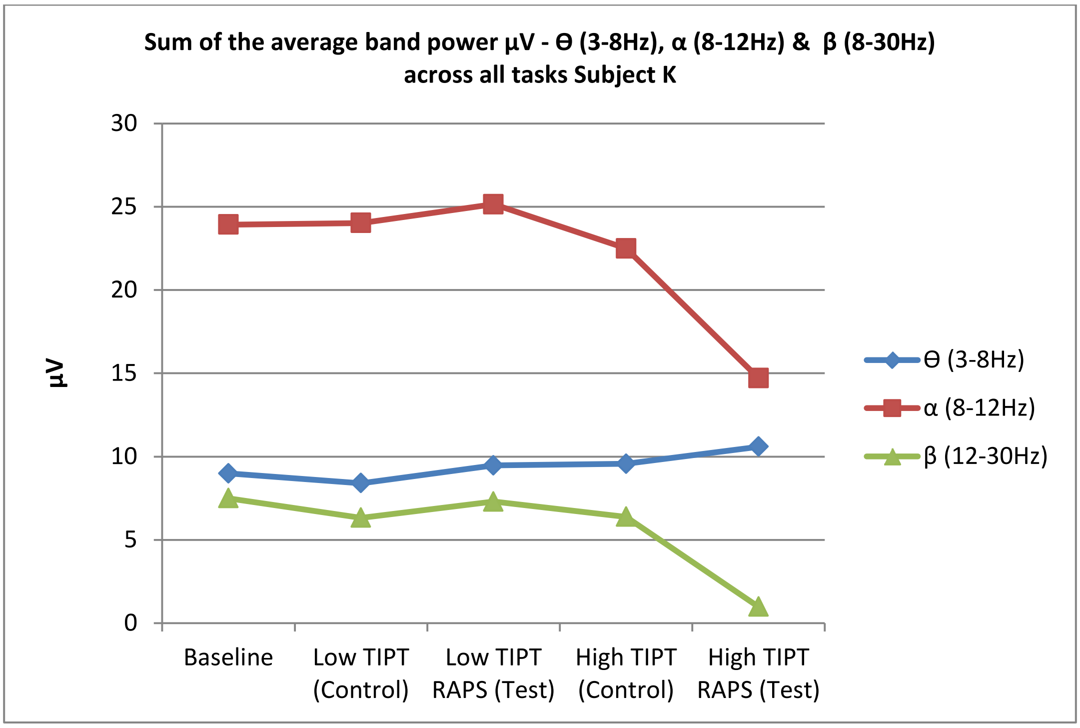


Figure 6-19 ***Line graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject K***

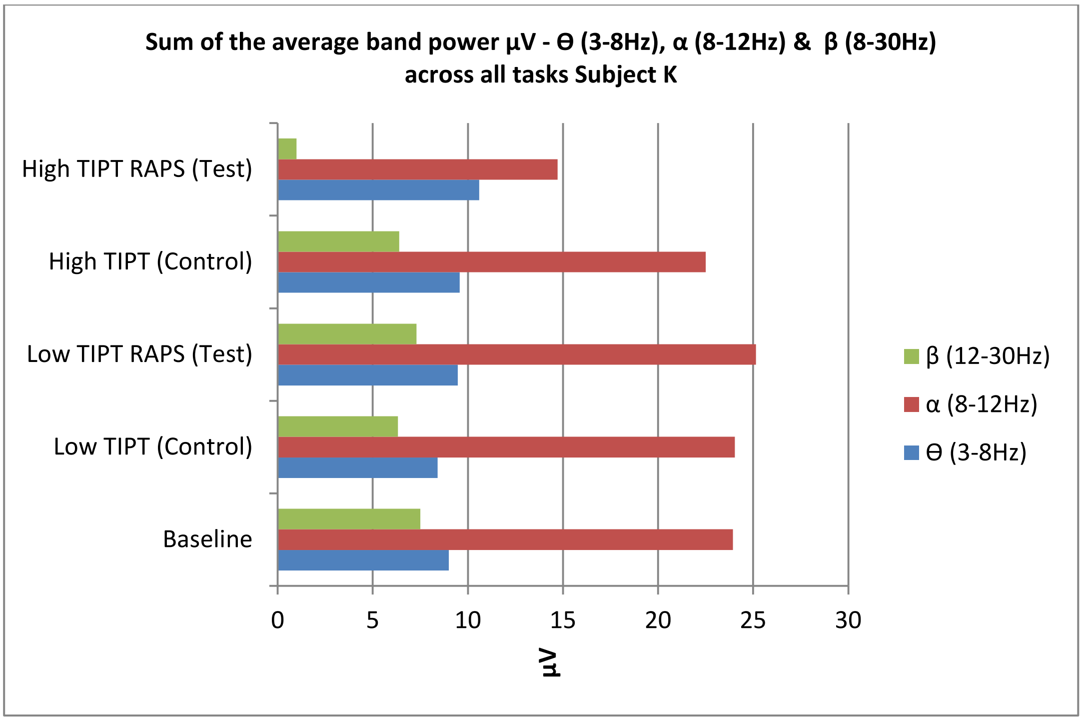


Figure 6-20 ***Bar graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject K***

Figures 6-19 and 6-20 demonstrated the sum of the band power average values in µV for each band - theta (3-8Hz), alpha (8-12) and beta (8-30Hz) - for subject K, other than the high baseline theta (3-8Hz) band power of 15.77µV. All the bands of theta (3-8Hz), alpha (8-12) and beta (8-30Hz) followed a similar trend, although there was no decrease in the alpha (8-12Hz) band power for subject K, as was seen with the subjects A, B, C, D, H and I. Subject K started with a baseline of 8.58µV and experienced a sharp increase to 24.65µV with the low TIPT (control) event. The subject continued with a not so steep but steady increase through the low TIPT RAPS (test) event with 25.65µV, 27.89µV with high TIPT (control) and finally 29.39µV with the high TIPT RAPS (test) events.

Figure 6-21 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject L. Figure 6-22 allows the relationship to be viewed in task clusters.

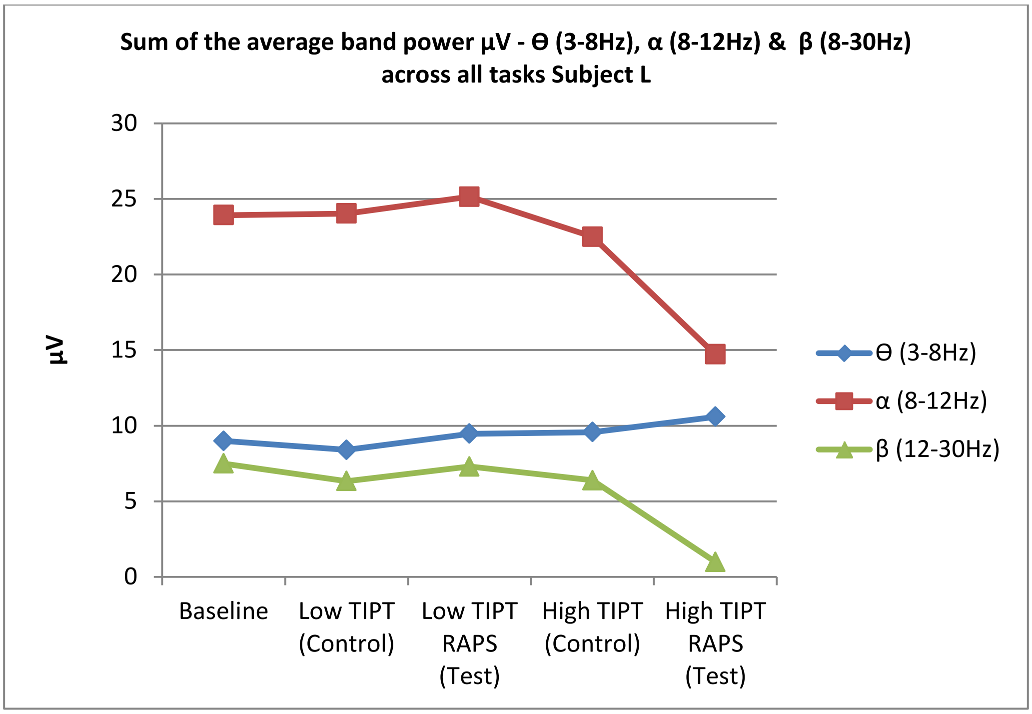


Figure 6-21 ***Line graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject L***

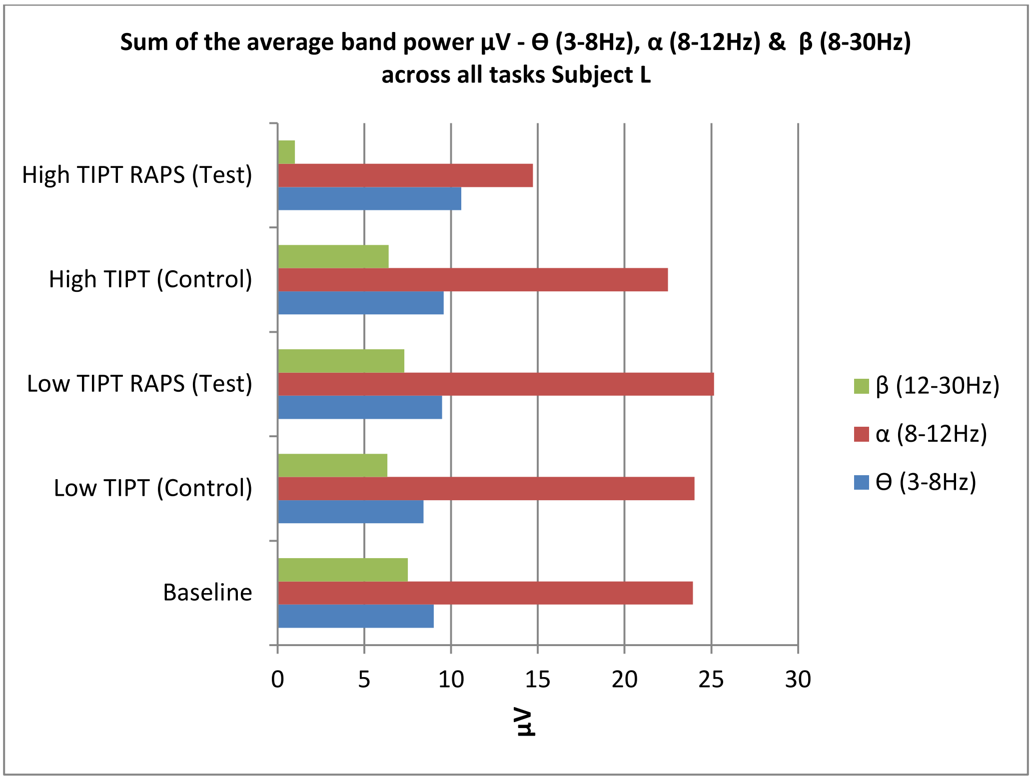


Figure 6-22 ***Bar graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject L***

Figures 6-21 and 6-22 reveal the sum of the band power average values in µV for each band - theta (3-8Hz), alpha (8-12) and beta (8-30Hz) - for subject L. The beta (8-30Hz) and theta (3-8Hz) band power remained in line with all other subjects with constant steady levels in a parallel fashion**.** There was no indication of when the stimuli events changed. The alpha (8-12Hz) band power continued the pattern of indicating when the stimuli changed and increased between a low cognitive demanding task, low TIPT (control) of 17.49µV to a high cognitive demanding task of 19.20µV with high TIPT (control) and again with 21.2µV with the low TIPT RAPS (test) event and 22.05µV with the high TIPT RAPS (test) event. Subject L failed to demonstrate the pattern of where the alpha (8-12Hz) band power decreased between the high TIPT (control) event and the high TIPT RAPS (test) event.

Figure 6-23 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject M. Figure 6-24 allows the relationship to be viewed in task clusters.

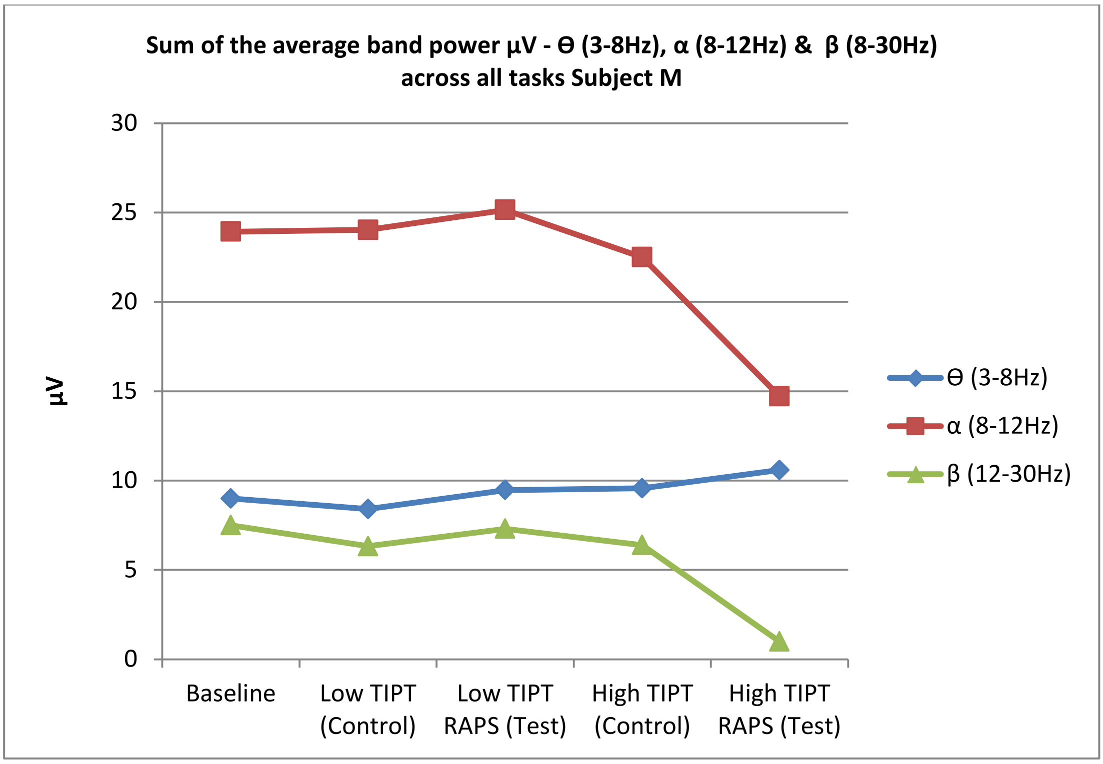


Figure 6-23 ***Line graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject M***

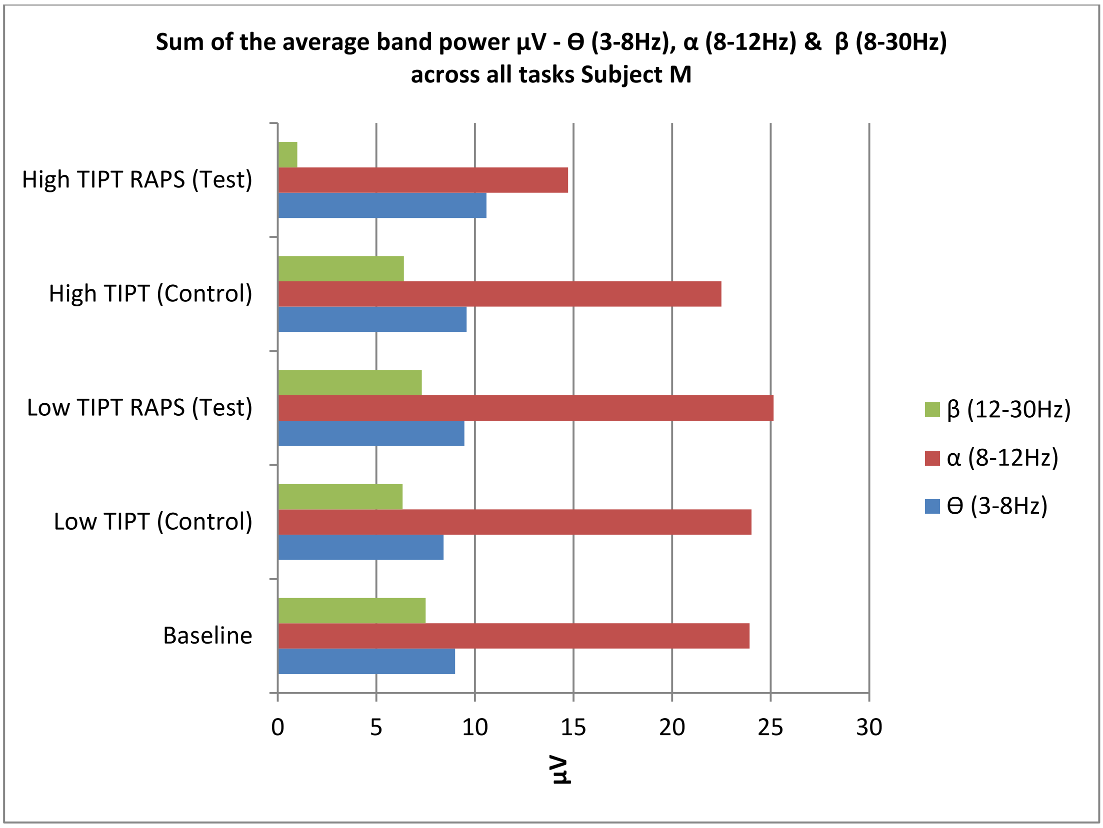


Figure 6-24 ***Bar graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject M***

Figure 6-23 and 6-24 represent the sum of the band power average values in µV for each band - theta (3-8Hz), alpha (8-12) and beta (8-30Hz) - for subject M. The theta (3-8Hz) band did not show any unusual conclusions or results that differ in a significant way from all the subjects thus far.

It was reassuring to see that the alpha (8-12Hz) band power for subject M followed the clear pattern of a low baseline of 5.72µV, with an increase in the alpha (8-12Hz) band power to 15.79, 16.27 and 21.32µV, across the low TIPT (control) event, low TIPT RAPS (test) event and high TIPT (control) event respectively. Subject M's results demonstrated a further continuation of the pattern; this was apparent with the alpha (8-12Hz) band power then decreasing to 16.41µV with the presentation of the high TIPT RAPS (test) event.

Figure 6-25 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for subject N. Figure 6-26 allows the relationship to be viewed in task clusters.

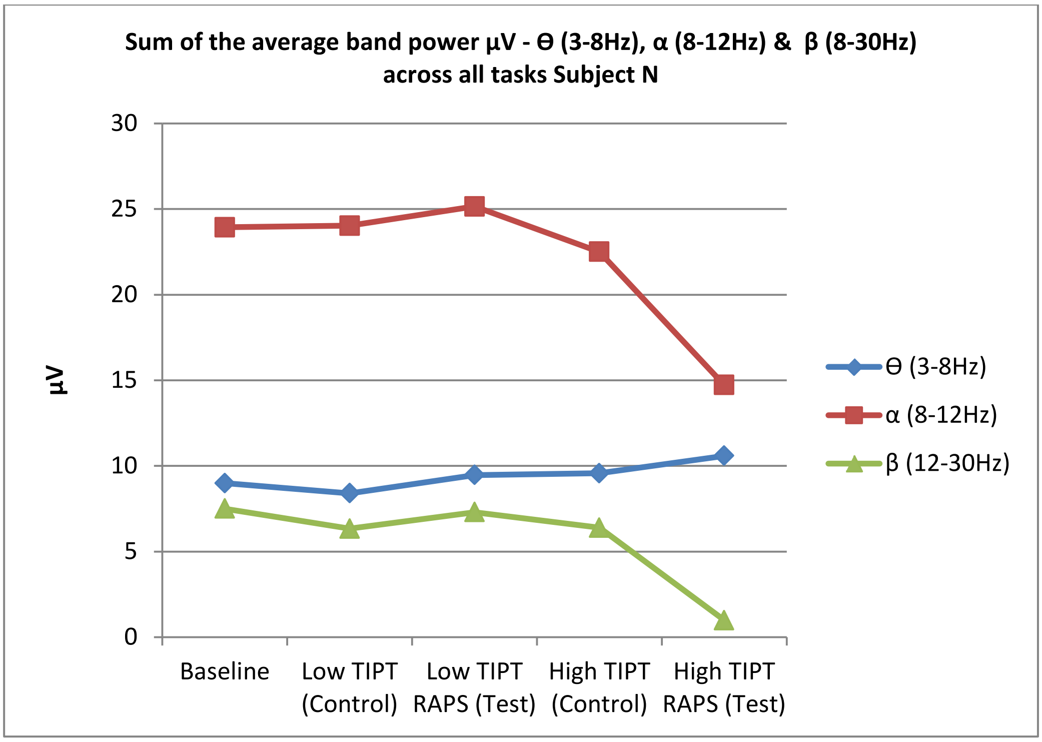


Figure 6-25 ***Line graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject N***

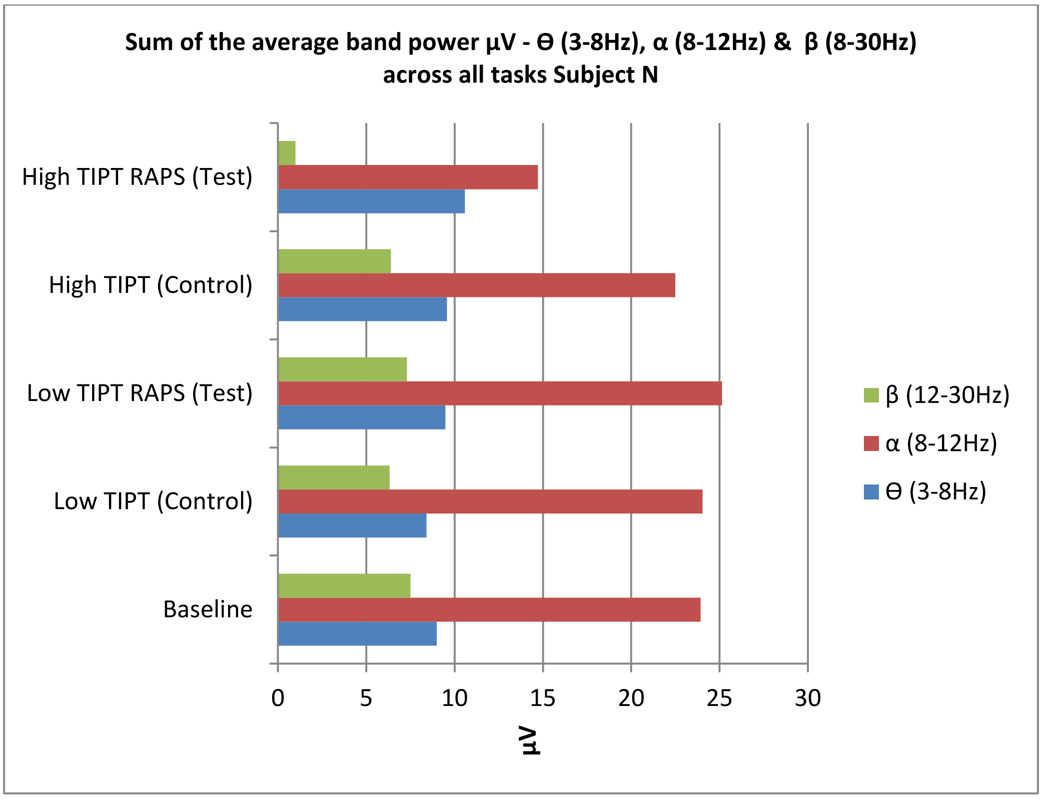
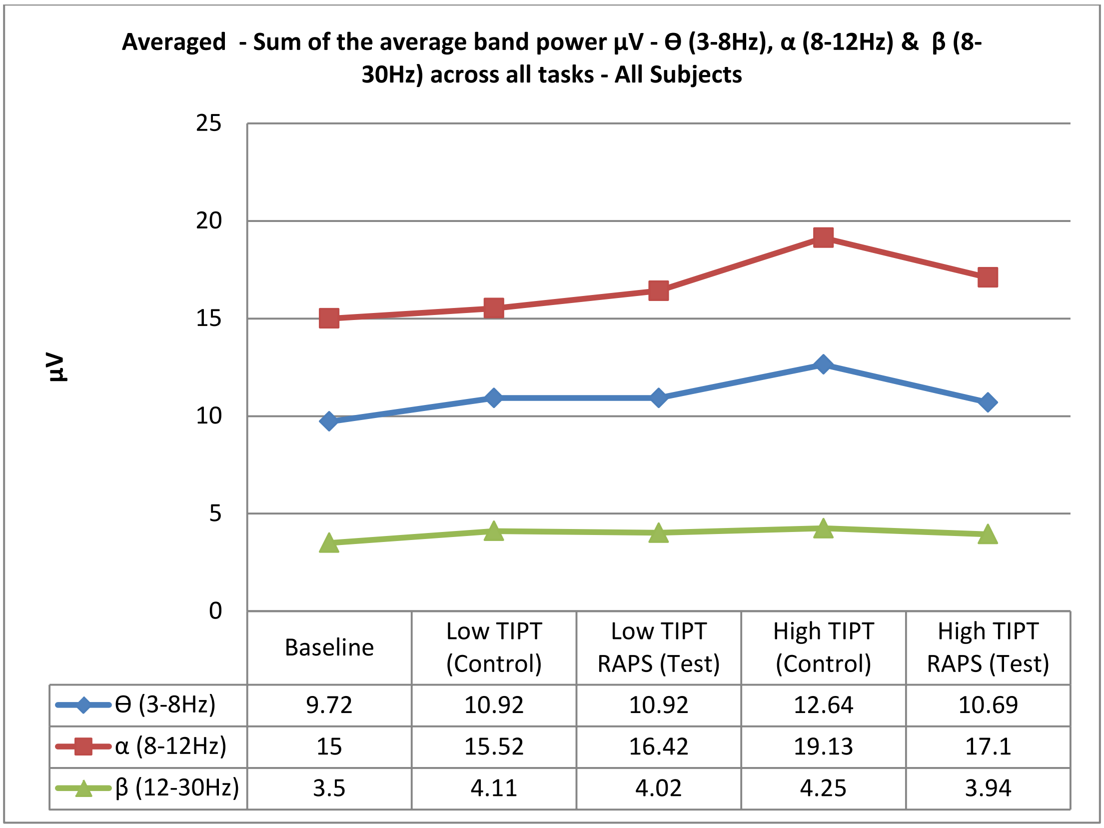


Figure 6-26 ***Bar graph patterning of band power theta (3-8Hz), alpha (8-12) and beta (8-30Hz) across all tasks – Subject N***

Figures 6-25 and 6-26 show the sum of the band power average values in µV for each band - theta (3-8Hz), alpha (8-12) and beta (8-30Hz) - for subject N. The findings for Subject N resulted in highly characteristic graph in that both the theta (3-8Hz) and the beta (8-30Hz) band power results were again in parallel and remained non indicative of the varying levels of cognitive tasks that were presented to each subject. The alpha (8-12Hz) band power demonstrated the low baseline 20.26µV with an increase to 21.06, 22.04 and 25.9µV through the low TIPT (control) event, the low TIPT RAPS (test) event and the high TIPT (control) event respectively, which reflected identical patterning to those of the previous subjects. Again subject M mirrored a decrease in the alpha (8-12Hz) band power from the high TIPT (control) event to the high TIPT RAPS (test) event of 25.9µV to 20.8µV.

Figure 6-27 displays the flow and relative change of MWL during the baseline, low TIPT (control), low TIPT RAPS (test), high TIPT (control) and high TIPT RAPS (test) intervals for all subjects. Figure 6-28 allows the relationship to be viewed in task clusters.



	Baseline	Low TIPT (Control)	Low TIPT RAPS (Test)	High TIPT (Control)	High TIPT RAPS (Test)
◆ ϴ (3-8Hz)	9.72	10.92	10.92	12.64	10.69
■ α (8-12Hz)	15	15.52	16.42	19.13	17.1
▲ β (12-30Hz)	3.5	4.11	4.02	4.25	3.94

Figure 6-27 **Averaged - Sum of the average band power** μV **- ϴ (3-8Hz), α (8-12Hz) and β (8-30Hz) across all tasks – All Subjects**

Figure 6-27 represents a collective summation of the sum of the band power average values in µV across all task s and all subjects. As a result of the alpha (8-12Hz) band wave patterning and the evidence in this research played by the alpha (8-12Hz) band wave in MWL and cognitive processing, the alpha (8-12Hz) band has been used for all future calculations and analysis through the study. These results have shown a pattern indicating and supporting the theory that the alpha (8-12Hz) band power is responsive to when a subject is presented with varying stimuli. This result therefore is also supportive as a measure of the neural activity and in this study acts as the measure of MWL when presented with TIPT and the RAPS.

All individual MWL's as discussed below, were a result of the EEG recordings and the data are expressed as the sum of the average alpha (8-12Hz) band in microvolts.

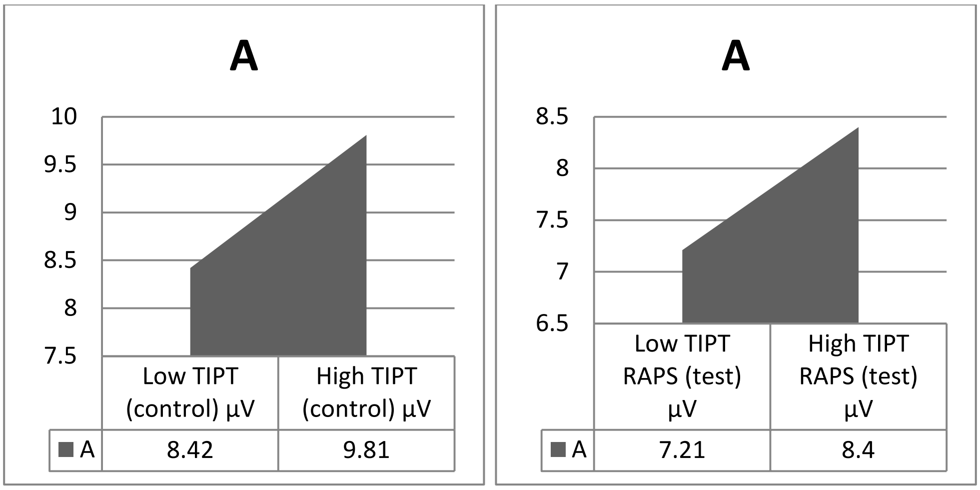


Figure 6-28 MWL low (control)/high (control) and low (test)/high (test) tasks – Subject A

Figure 6-28 illustrates that subject A - recorded an increase in MWL in both pairs of compared tasks, an increase of 1.39µV between the low TIPT (control) and the high TIPT (control) task and an increase of 1.19µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject A experienced a 16.51% and a 16.50% increase respectively.

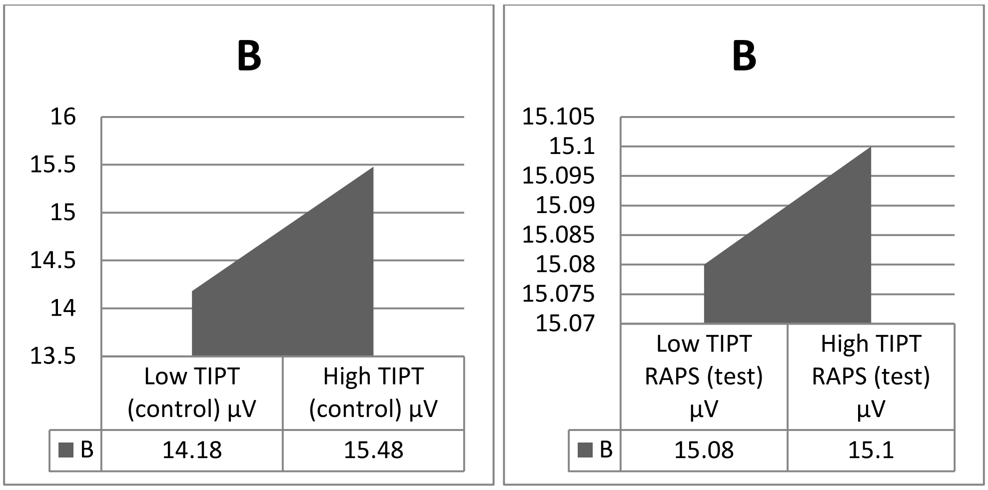


Figure 6-29 MWL low (control)/high (control) and low (test)/high (test) tasks – Subject B

Figure 6-29 shows that subject B - recorded an increase in MWL in both pairs of compared tasks: an increase of 1.30µV between the low TIPT (control) and the high TIPT (control) task; and an increase of 0.02µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject B experienced a 9.17% and a 0.13% increase respectively.

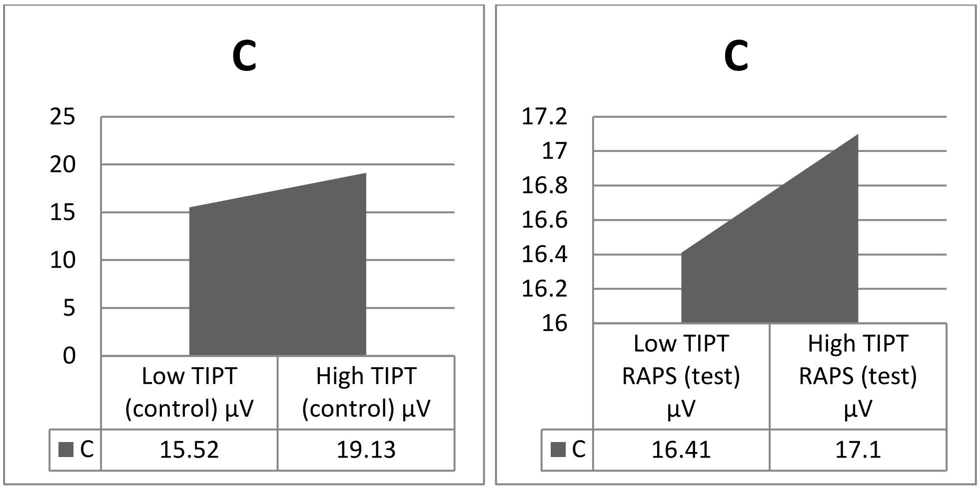


Figure 6-30 MWL low (control)/high (control) and low (test)/high (test) tasks – Subject C

Figure 6-30 demonstrates that subject C, recorded an increase in MWL in both pairs of compared tasks: an increase of 3.61µV between the low TIPT (control) and the high TIPT (control) task; and an increase of 0.69µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject C experienced a 23.26% and a 4.20% increase respectively.

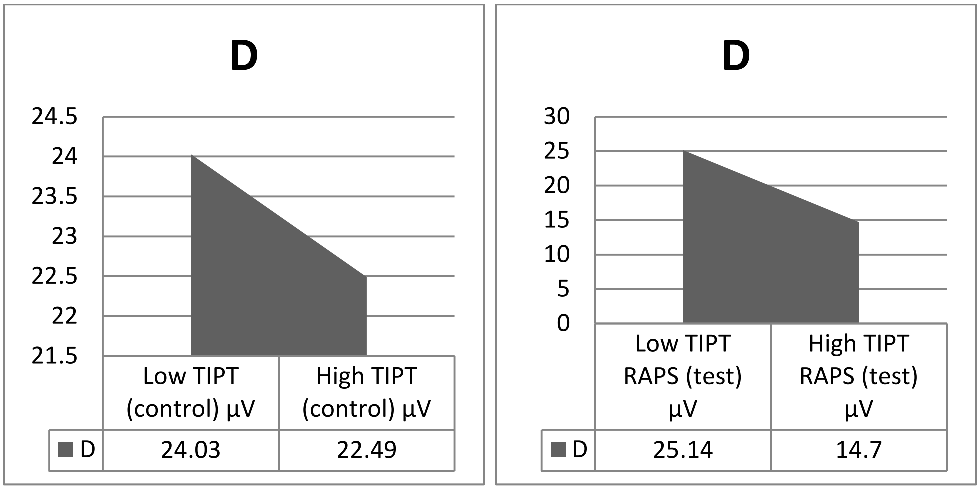


Figure 6-31 *MWL low (control)/high (control) and low (test)/high (test) tasks –Subject D*

Figure 6-31 shows that subject D, unlike any of the other subjects, recorded a decrease in MWL in both pairs of compared tasks: a decrease of 1.54µV between the low TIPT (control) task and the high TIPT (control) task; and an increase of 10.44µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject D experienced a 6.41% and a 41.53% decrease respectively.

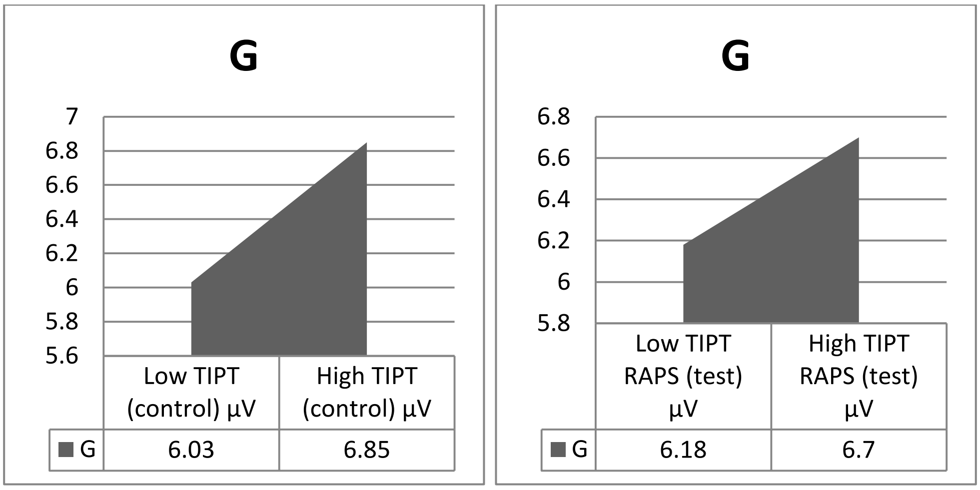


Figure 6-32 *MWL low (control)/high (control) and low (test)/high (test) tasks – Subject G*

Figure 6-32 shows that subject G, as was the case with subjects A, B, and C, recorded an increase in MWL in both pairs of compared tasks: an increase of 0.82µV between the low TIPT (control) task and the high TIPT (control) task and an increase of 0.52µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject G experienced a 13.60% and an 8.41% increase respectively.

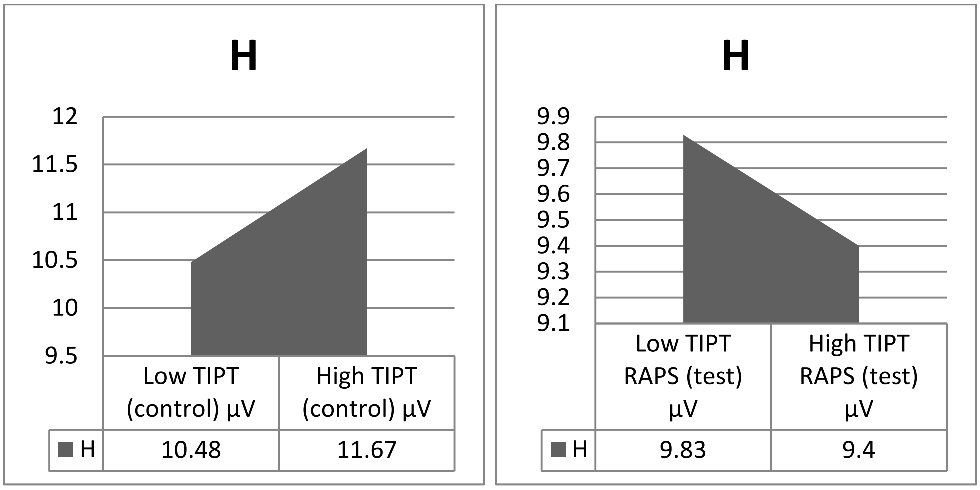


Figure 6-33 MWL low (control)/high (control) and low (test)/high (test) tasks – Subject H

Figure 6-33 shows that subject H, recorded an increase in MWL in one of the compared tasks and a decrease in the other: an increase of 1.19µV between the low TIPT (control) task and the high TIPT (control) task and a decrease of 0.43µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject H experienced an increase of 11.35% and a decrease of 4.37% respectively.

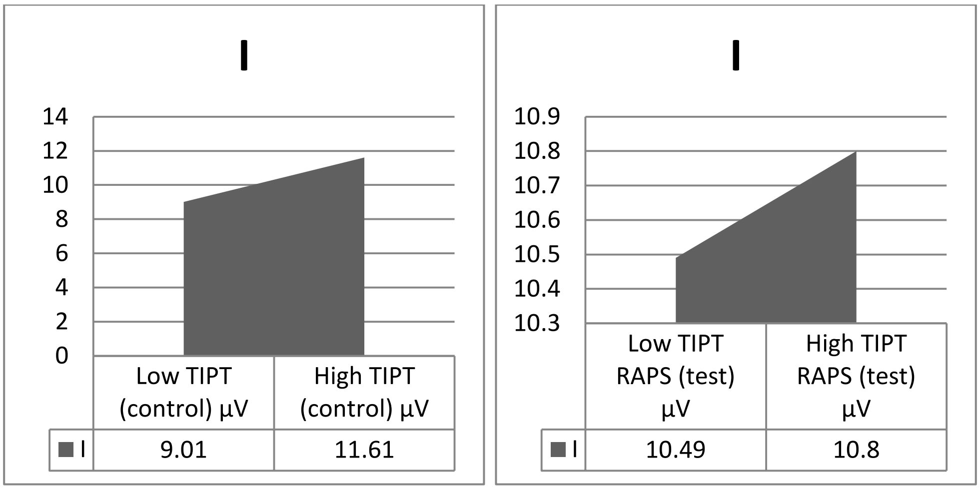


Figure 6-34 MWL low (control)/high (control) and low (test) high (test) tasks – Subject I

Figure 6-34 reveals that subject I, recorded an increase in MWL in both pairs of compared tasks: an increase of 2.60µV between the low TIPT (control) task and the high TIPT (control) task and an increase of 0.31µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task**.** Subject I experienced a 28.86% and a 2.96% increase respectively.

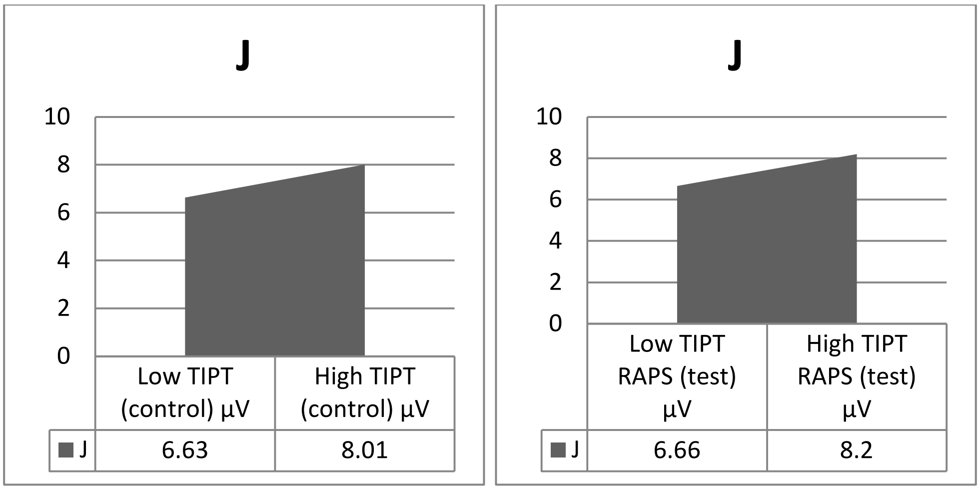


Figure 6-35 MWL low (control)/high (control) and low (test)/high (test) tasks – Subject J

Figure 6-35 shows that subject J, also recorded an increase in MWL in both pairs of compared tasks: an increase of 1.38µV between the low TIPT (control) task and the high TIPT (control) task; and an increase of 1.54µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject J experienced a 20.81% and a 23.12% increase respectively.

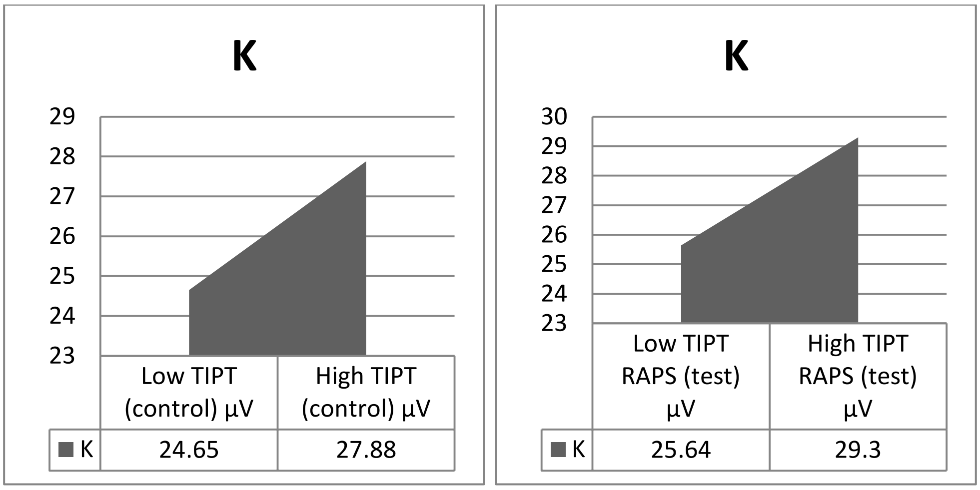


Figure 6-36 MWL low (control)/high (control) and low (test) high (test) tasks – Subject K

Figure 6-36 shows that subject K, recorded an increase in MWL in both pairs of compared tasks: an increase of 3.23µV between the low TIPT (control) task and the high TIPT (control) task; and an increase of 3.66µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject K experienced a 13.10% and a 14.27% increase respectively.

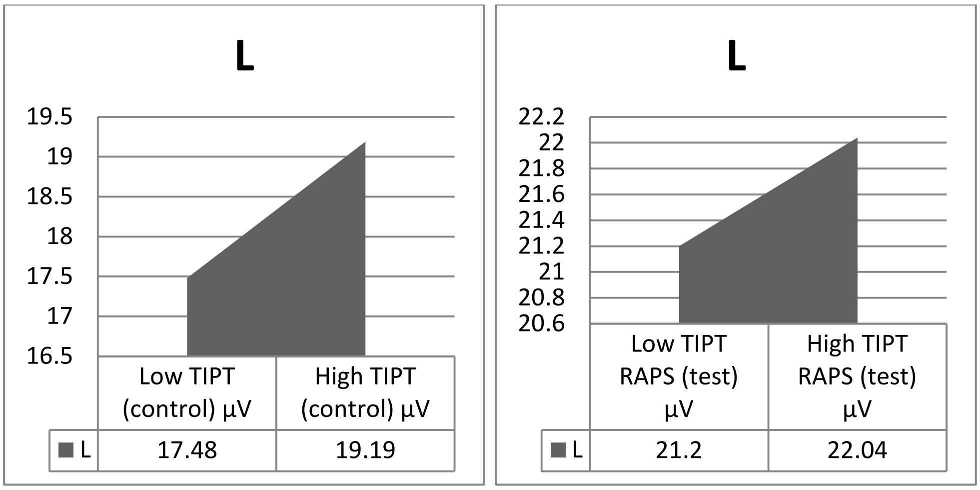


Figure 6-37 MWL low (control)/high (control) and low (test/ high (test) tasks – Subject L

Figure 6-37 details that subject L - also recorded an increase in MWL in both pairs of compared tasks: an increase of 1.71µV between the low TIPT (control) task and the high TIPT (control) task and an increase of 0.84µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject L experienced a 9.78% and a 3.96% increase respectively.

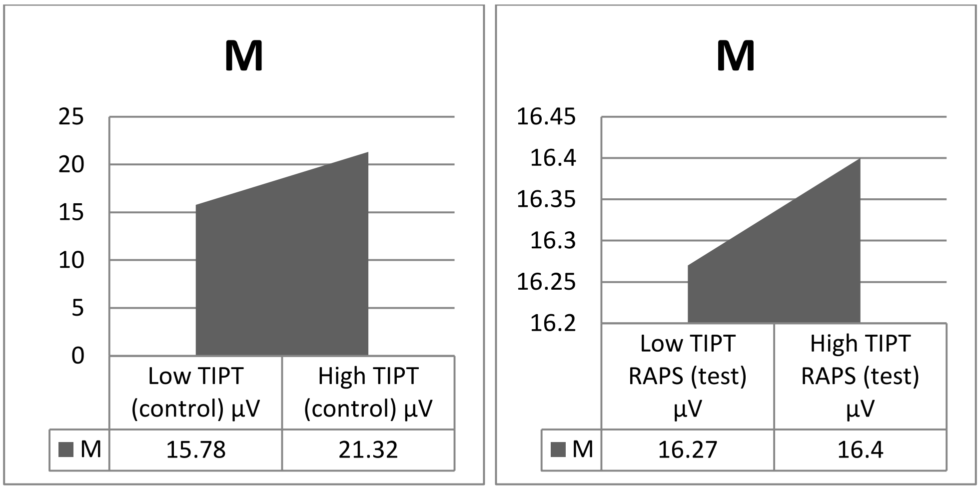


Figure 6-38 MWL low (control)/high (control) and low (test)/high (test) tasks – Subject M

Figure 6-38 confirms that subject M, recorded an increase in MWL in both pairs of compared tasks: an increase of 5.54µV between the low TIPT (control) task and the high TIPT (control) task; and an increase of 0.13µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject M experienced a 35.11% and an 0.80% increase respectively.

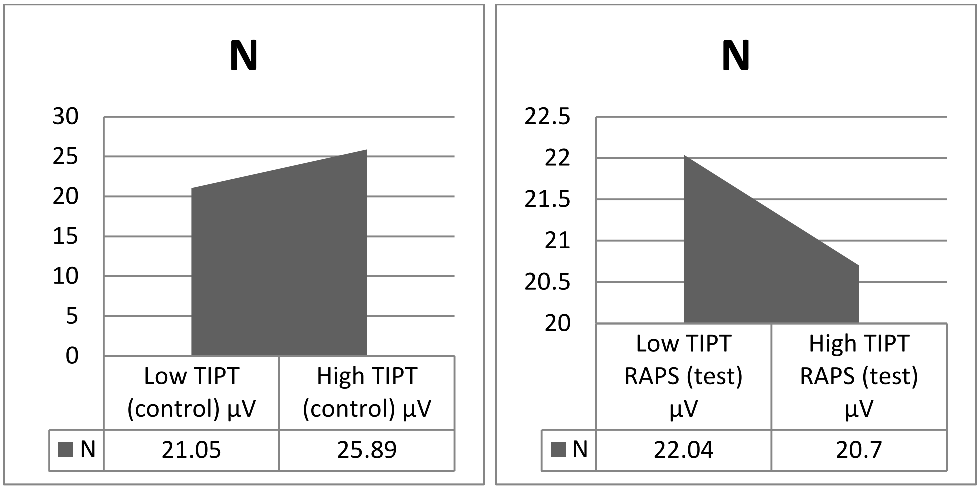


Figure 6-39 ***MWL low (control)/high (control) and low (test)/high (test) tasks – Subject N***

Figure 6-39 indicates that subject N -had a similar experience to that of subject H where the MWL recorded an increase in one of the compared tasks and a decrease in the other. There was an increase of 4.84µV between the low TIPT (control) task and the high TIPT (control) task, and a decrease of 1.34µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) task. Subject H, experienced an increase of 22.99% and a decrease of 6.08% respectively.

6.1.2 Comparing the MWL - Low TIPT (control) Task with the High TIPT (control) Task

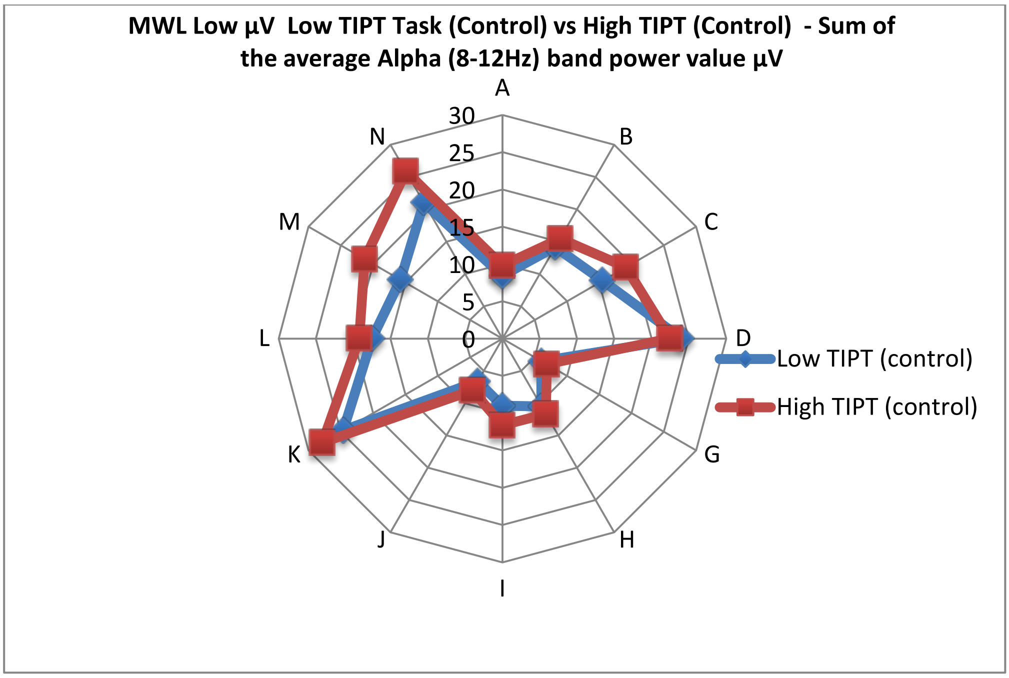


Figure 6-40 ***MWL µV low TIPT task (control) vs high TIPT (control) - Sum of the average band power (value) alpha (8-12Hz)***

Microsoft Excel was used to carry out Paired T Tests to establish the mean between the low TIPT (control) and the high TIPT (control) data. In Figure 6-40 this radar plot provides a visual mapping of all subjects' MWL results between the low TIPT (control) task and the high TIPT (control) task. As derived from Table 5-14 with 11 out of 12 subjects, 91% demonstrated an increase in MWL with increases between 9.17% and 35.11% recorded; therefore the MWL across all subjects increased on average by 18.59%. The remaining 8.3%, a single subject, experienced a decrease of 6.41%.

The results demonstrated that between the low TIPT (control) tasks and the high TIPT (control) tasks there was an overall average increase in MWL of 16.51%. The most significant increase in MWL recorded was 35.11 % for subject M and the most significant decrease in MWL recorded was 6.41 % for subject D.

The mean MWL for low TIPT (control) was 14.48 µV and the mean MWL for high TIPT (control) was 16.62µV, with an increase in the mean MWL of 2.14µV between the low TIPT (control) and the high TIPT (control) across all subjects. This supports the use of EEG data as an indicator of MWL during a task.

The T - Test results indicated that the probability of this result being down to chance was 0.002%.

6.1.2.1 Comparing the MWL - Low TIPT (test) task with the High TIPT (test) task

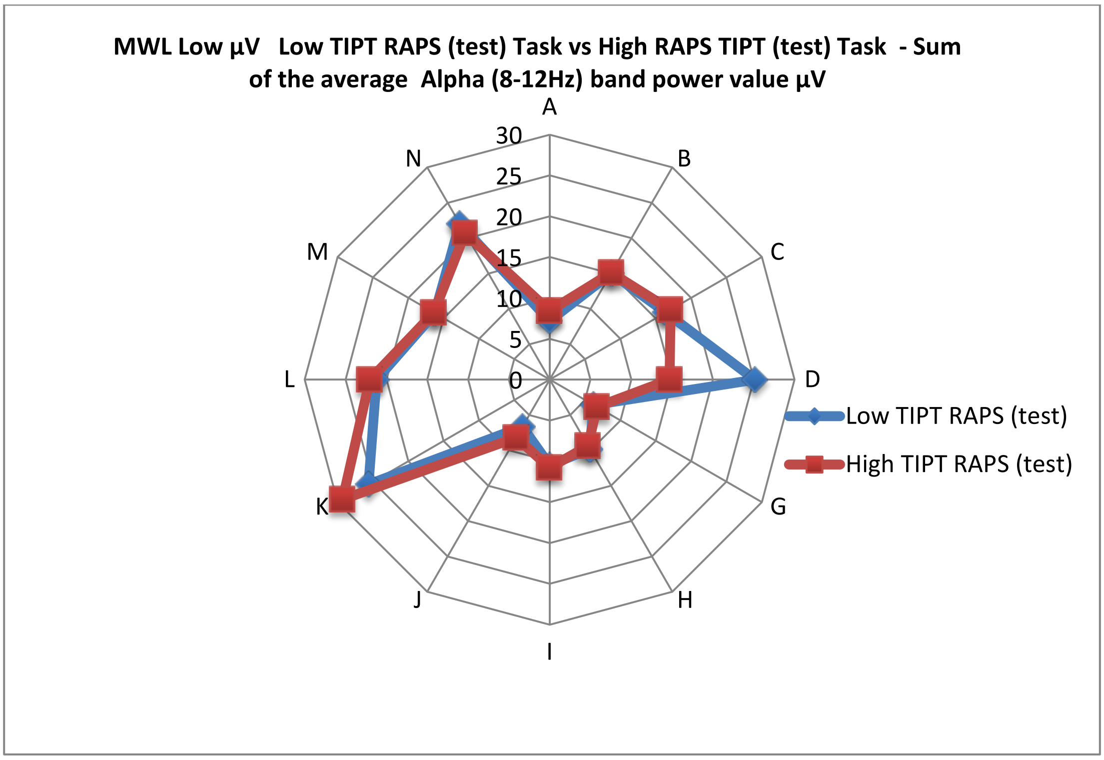


Figure 6-41 MWL μV low TIPT RAPS (test) task vs high RAPS TIPT (test) task - Sum of the average α (8-12Hz) band power value (alpha) μV

Microsoft Excel was used to carry out Paired T Tests to establish the mean between: low TIPT RAPS (test) and high TIPT RAPS (test) data. In Figure 6-41 this radar plot provides a visual mapping of all subjects MWL results between the low TIPT RAPS (test) task and the high TIPT RAPS (test) task. As was derived from Table 5-15, 9 out of the 12 subjects, or 75% displayed an increase in MWL, with increases between 0.13% - 23.12% being recorded. The results demonstrate that between the low TIPT RAPS (test) and the high TIPT RAPS (test) cognitive tasks there was an overall average increase in MWL of 8.26%. The most significant increase in MWL recorded was 23.12 % for subject J.

The mean MWL for the low TIPT RAPS (test) was 15.18µV and the mean MWL for the high TIPT RAPS (test) was 14.90µV. The increase in the mean MWL of 1.87µV between the low TIPT RAPS (test) and the high TIPT RAPS (test) across all subjects supported the use of EEG data as an indicator of MWL during a task.

The data supported the researchers who rely on the Alpha (8-12) band as an indicator of increased MWL.

In answering the research question. “How does the MWL differ between a low cognitive demanding transient information processing task (TIPT) and a high cognitive demanding TIPT?” The overall results indicated that MWL, the neural activity required to process transient information, could be seen to increase as a task increased in complexity. In this case the duration of the stimuli was the determinant of the level of task complexity. The transient information was presented in an audio format. The data illustrated a pattern of increased, numerical values as the cognitive demand task became more complex. The alpha (8-12Hz) band showed above all other bands a pattern in conjunction with the stimuli presented. Full numerical EEG data details are given in Appendix L. It can be inferred that MWL increases between low cognitive level demanding tasks and high cognitive level demanding tasks.

6.1.3 Research question 2

What impact does the use of RAPS have on the MWL imposed during a low cognitive demanding TIPT and a high cognitive demanding TIPT?

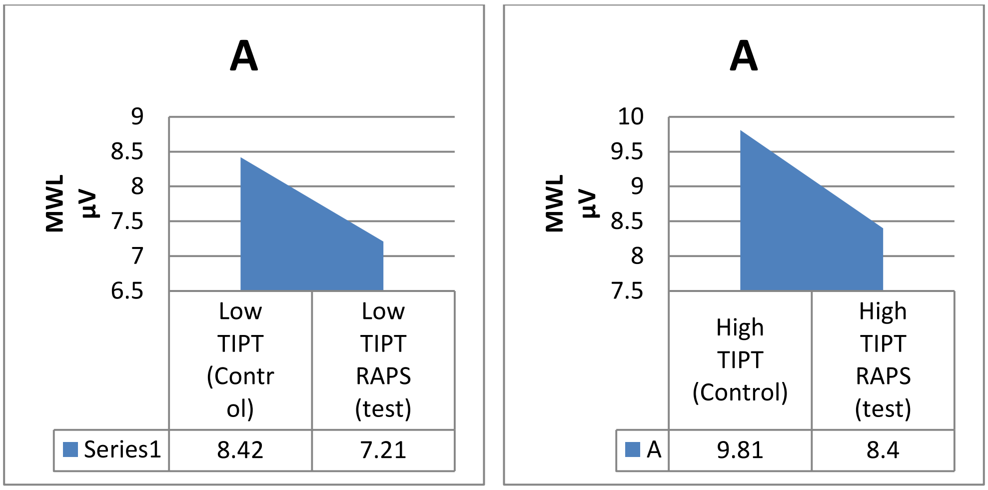


Figure 6-42 ***MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject A***

Figure 6-42 illustrates that subject A - recorded a decrease in MWL in both pairs of compared tasks. The results display a decrease of 1.21µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 1.41µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject A experienced a 14.37% decrease in both experimental trials.

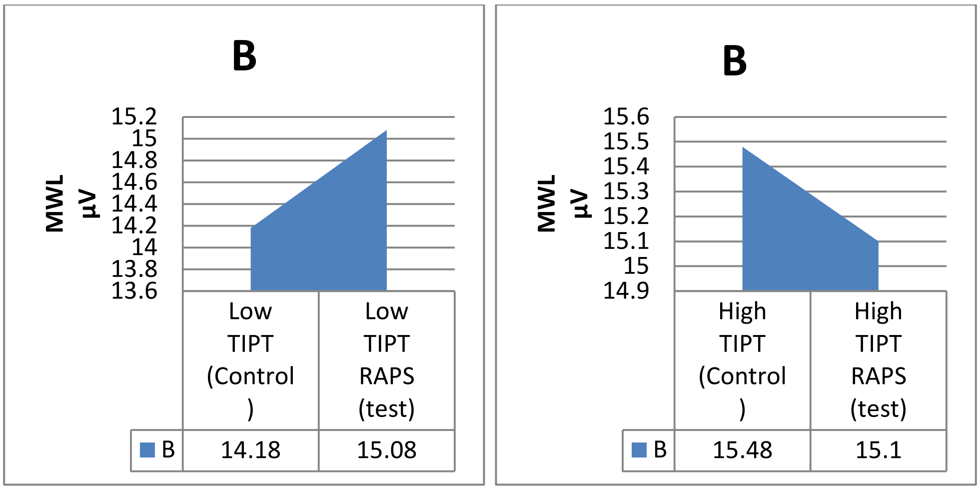


Figure 6-43 ***MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject B***

Figure 6-43 shows that subject B - experienced an increase in MWL in the first of the two trials and a decrease in the second trial. The results displayed an increase of 0.90µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 0.38µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject B experienced a 6.35% increase in the low cognitive demanding task followed by a decrease of 2.45% in the high cognitive demanding experimental trial when presented with the RAPS.

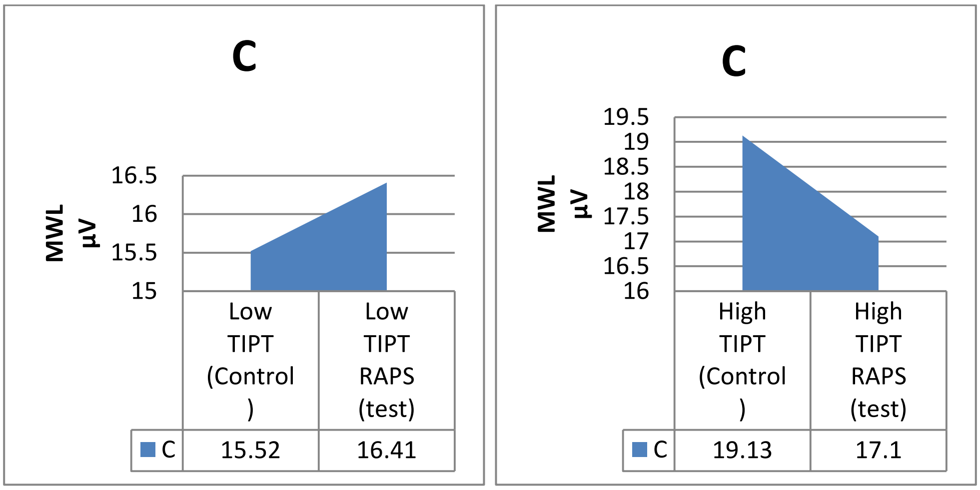


Figure 6-44 ***MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject C***

Figure 6-44 shows that subject C - experienced an increase in MWL in the first of the two trials and a decrease in the second trial. The results displayed an increase of 0.89µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 2.03µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject C experienced a 5.73% increase in the low cognitive demanding task followed by a decrease of 10.61% in the high cognitive demanding experimental trial when presented with the RAPS.

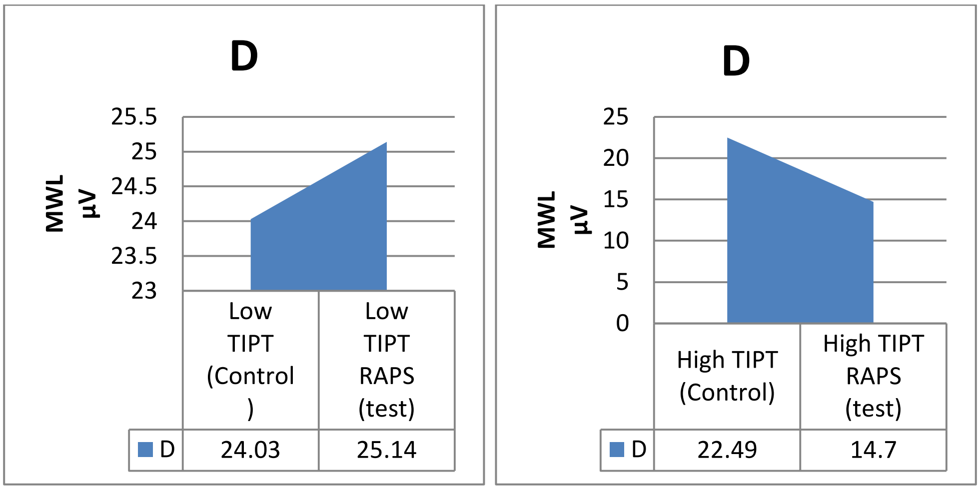


Figure 6-45 ***MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject D***

Figure 6-45 shows that subject D - experienced an increase in MWL in the first of the two trials and a decrease in the second trial. The results displayed an increase of 1.11µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 7.79µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject D experienced a 4.62% increase in the low cognitive demanding task followed by a decrease of 34.64% in the high cognitive demanding experimental trial when presented with the RAPS.

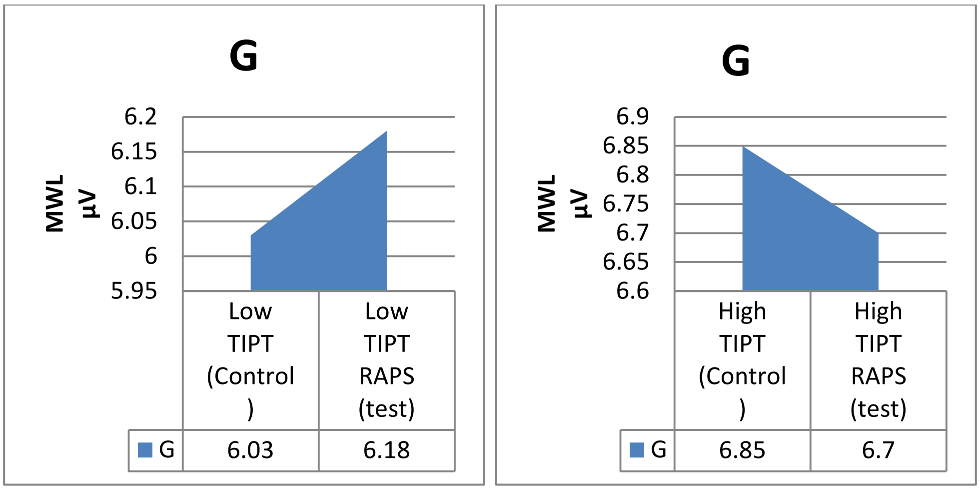


Figure 6-46 *MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject G*

Figure 6-46 shows that subject G - experienced an increase in MWL in the first of the two trials and a decrease in the second trial. The results displayed an increase of 0.15µV between the low TIPT (control) and the low TIPT RAPS (test) task and a decrease of 0.15µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject G experienced a 2.49% increase in the low cognitive demanding task followed by a decrease of 2.19% in the high cognitive demanding experimental trial when presented with the RAPS.

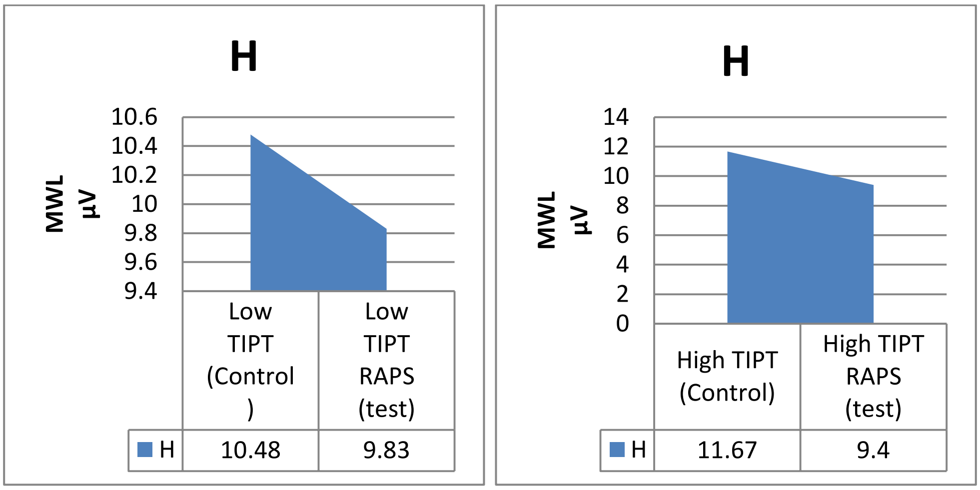


Figure 6-47 *MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject H*

Figure 6-47 illustrates that subject H, recorded a decrease in MWL in both pairs of compared tasks. There was a decrease of 0.65µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 2.27µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject H experienced a decrease of 6.20% in the low level cognitive demanding trial and a 19.45% decrease in the high cognitive demanding trial when presented with the RAPS.

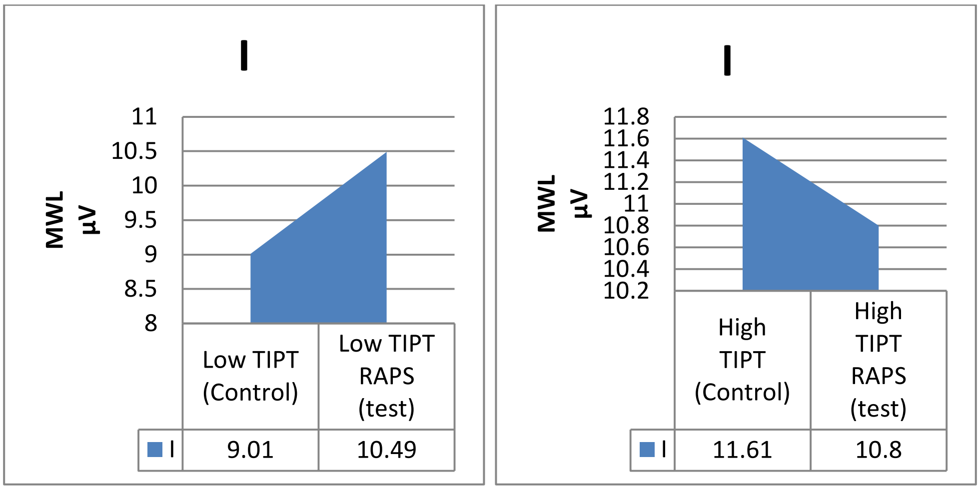


Figure 6-48 MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject I

Figure 6-48 shows that subject I - experienced an increase in MWL in the first of the two trials and a decrease in the second trial. The results displayed an increase of 1.48µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 0.81µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject I experienced a 16.43% increase in the low cognitive demanding task followed by a decrease of 6.98% in the high cognitive demanding experimental trial when presented with the RAPS.

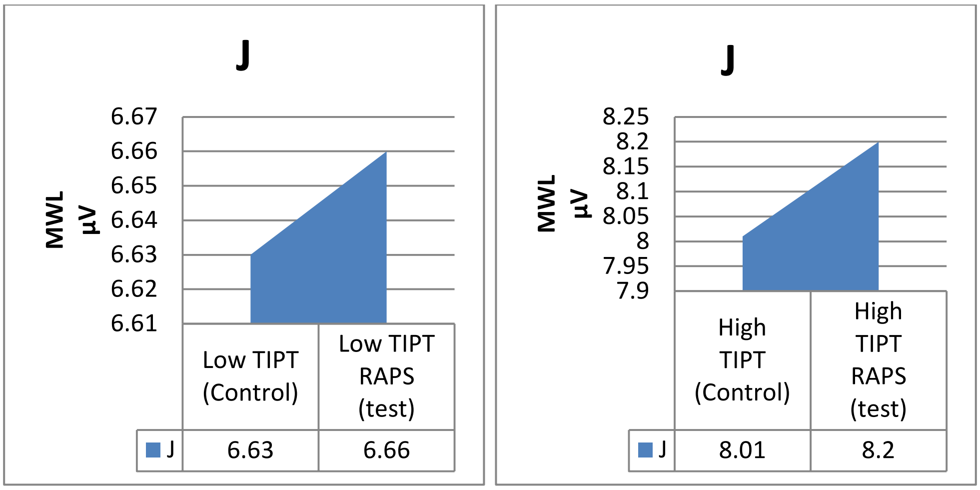


Figure 6-49 MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject J

Figure 6-49 illustrates that subject J - recorded an increase in MWL in both pairs of compared tasks. There was an increase of 0.03µV between the low TIPT (control) task and the low TIPT RAPS (test) task and an increase of 0.19µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject J experienced a 0.45% increase in the low cognitive demanding trials and an increase in MWL of 2.37% in the high cognitive demanding trial from the control to the test intervals.

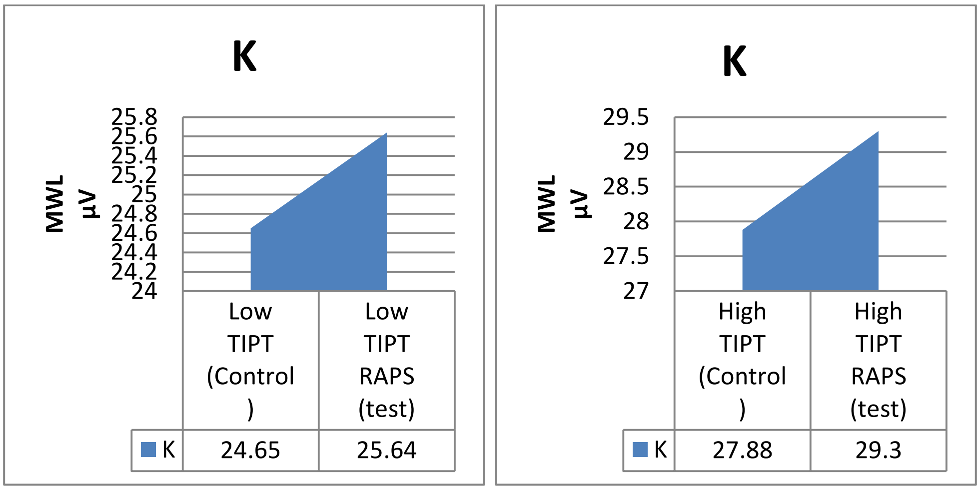


Figure 6-50 MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject K

Figure 6-50 illustrates that subject K - as like subject J recorded an increase in MWL in both pairs of compared tasks. There was an increase of 0.99µV between the low TIPT (control) task and the low TIPT RAPS (test) task and an increase of 1.42µV between the high TIPT (control) task and the high TIPT RAPS (test) task.

Subject K experienced a 4.02% increase in the low cognitive demanding trials and an increase in MWL of 5.09% in the high cognitive demanding trial from the control to the test intervals.

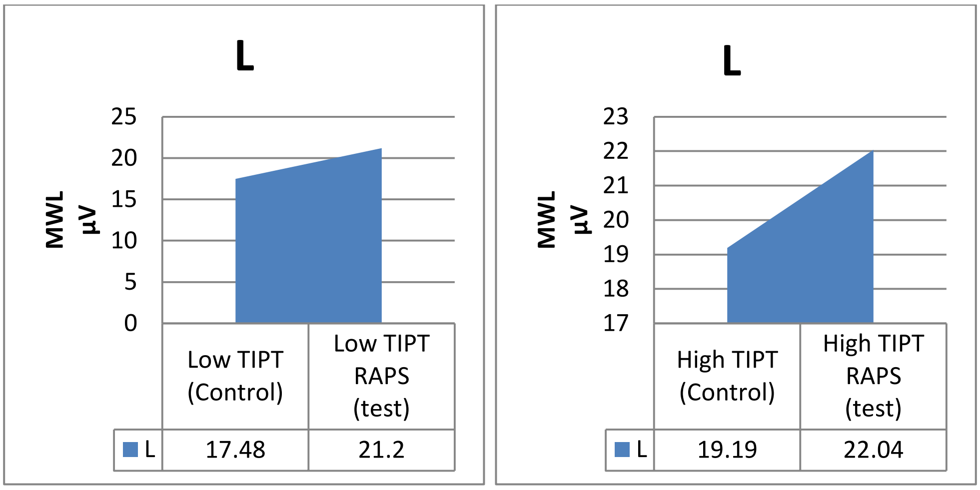


Figure 6-51 MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject L

Figure 6-51 illustrates that subject L - recorded an increase in MWL in both pairs of compared tasks. There was an increase of 3.72 µV between the low TIPT (control) task and the low TIPT RAPS (test) task and an increase of 2.85µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject L, experienced a 21.28% increase in the low cognitive demanding trials and an increase in MWL of 14.85% in the high cognitive demanding trial from the control to the test intervals.

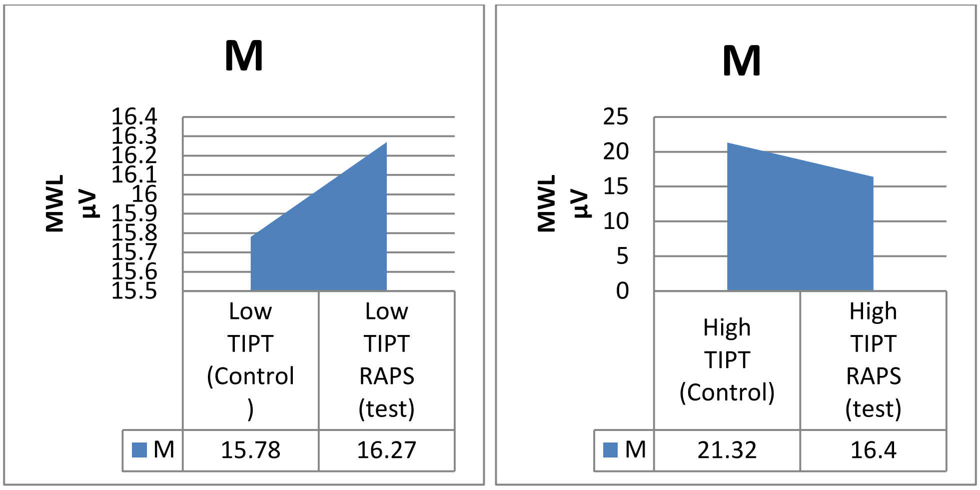


Figure 6-52 *MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject M*

Figure 6-52 shows that subject M, experienced an increase in MWL in the first of the two trials and a decrease in the second trial. Results displayed an increase of 0.49µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 4.92µV between the high TIPT (control) task and the high TIPT RAPS (test) task. Subject M experienced a 3.11% increase in the low cognitive demanding task followed by a decrease of 23.08% in the high cognitive demanding experimental trial when presented with the RAPS.

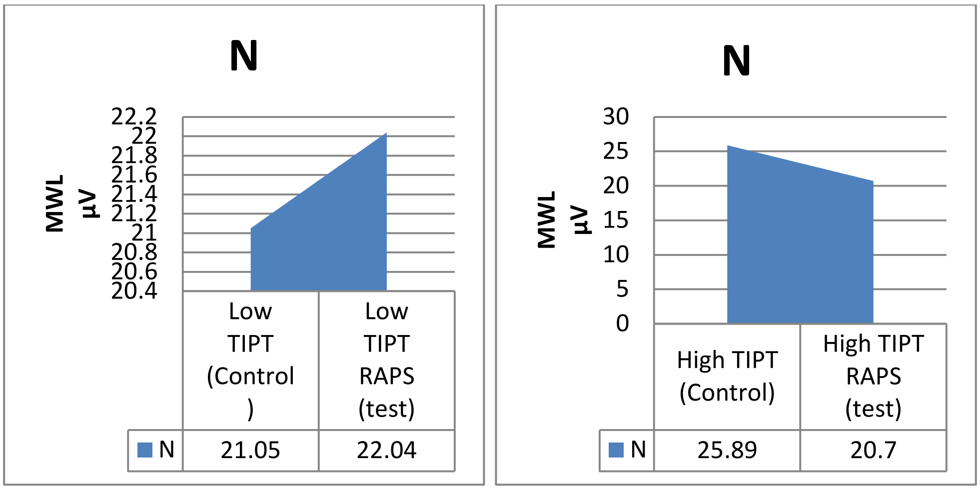


Figure 6-53 *MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/high TIPT RAPS (test) – Subject N*

Figure 6-53 shows that subject N, experienced an increase in MWL in the first of the two trials and a decrease in the second trial. Results displayed an increase of 0.99µV between the low TIPT (control) task and the low TIPT RAPS (test) task and a decrease of 5.19µV between the high TIPT (control) task and the high TIPT

RAPS (test) task. Subject N, experienced a 4.70% increase in the low cognitive demanding task followed by a decrease of 20.05% in the high cognitive demanding experimental trial when presented with the RAPS.

6.1.4 Research question 3

What impact does the use of RAPS have on the performance results achieved across both low and high level TIPT's?

Figures 6-53 to 6-64 provide a side by side column graph representation of the different performance scores achieved by each subject during the low TIPT (control) vs the low TIPT RAPS (test) and the high TIPT (control) vs the high TIPT RAPS (test) intervals.

6.1.4.1 Individual Performance Score Analysis

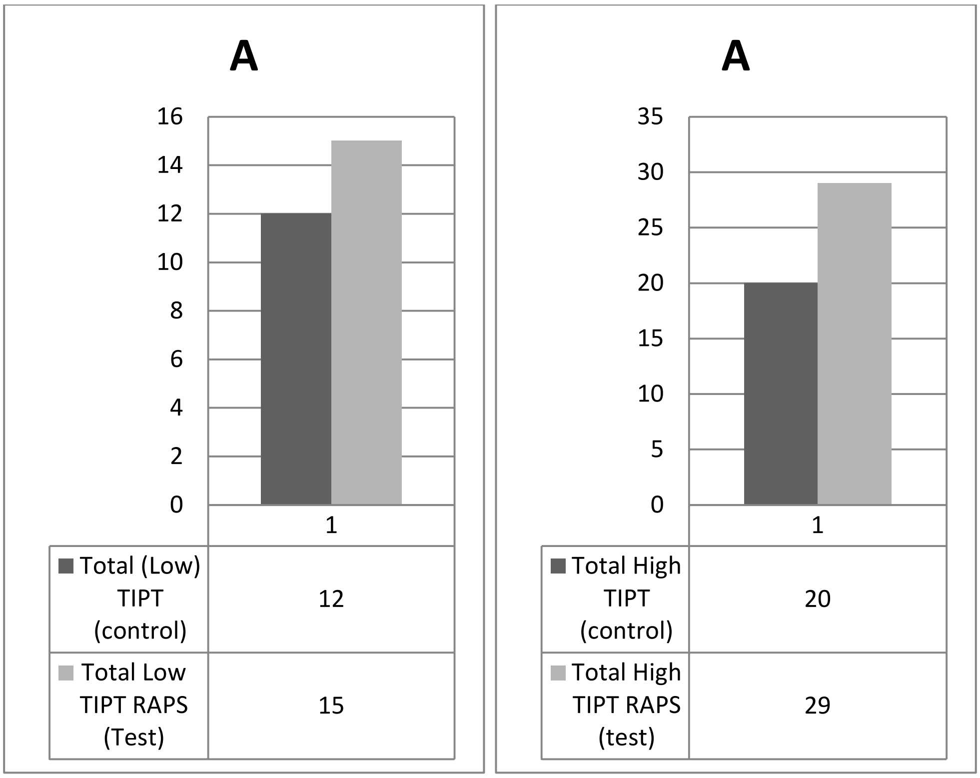


Figure 6-54 Performance scores low TIPT (control)/ (test) and high TIPT (control)/(test) Subject A

Figure 6-54 illustrates that subject A recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 12 and 15 respectively and for the high TIPT (control) and the high TIPT RAPS (test) post assessment tasks 20 and 29 respectively. Subject A, experienced a 20% increase between control and RAPS test intervals of the low cognitive demanding TIPT task trial and an increase of 30% between the control and RAPS test intervals for the high cognitive demanding task trial.

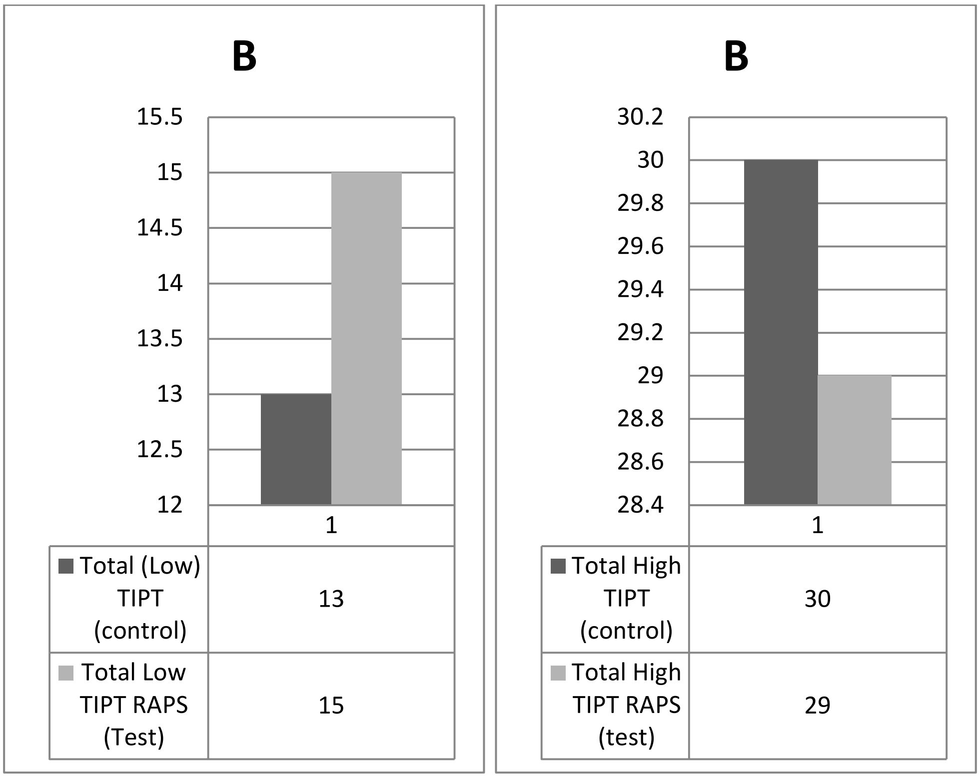


Figure 6-55 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject B

Figure 6-55 illustrates that subject B, recorded an increase in the performance score achieved between the low TIPT (control) and low TIPT RAPS (test) intervals and a decrease between the high TIPT (control) and the high TIPT RAPS (test) intervals. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 13 and 15 respectively and for the high TIPT (control) and the high TIPT RAPS (test) post assessment tasks 30 and 29 respectively. Subject B experienced a 13% increase between control and RAPS test intervals of the low cognitive demanding TIPT task trial and a decrease of 3% between control and RAPS test intervals of the high cognitive demanding TIPT task trial.

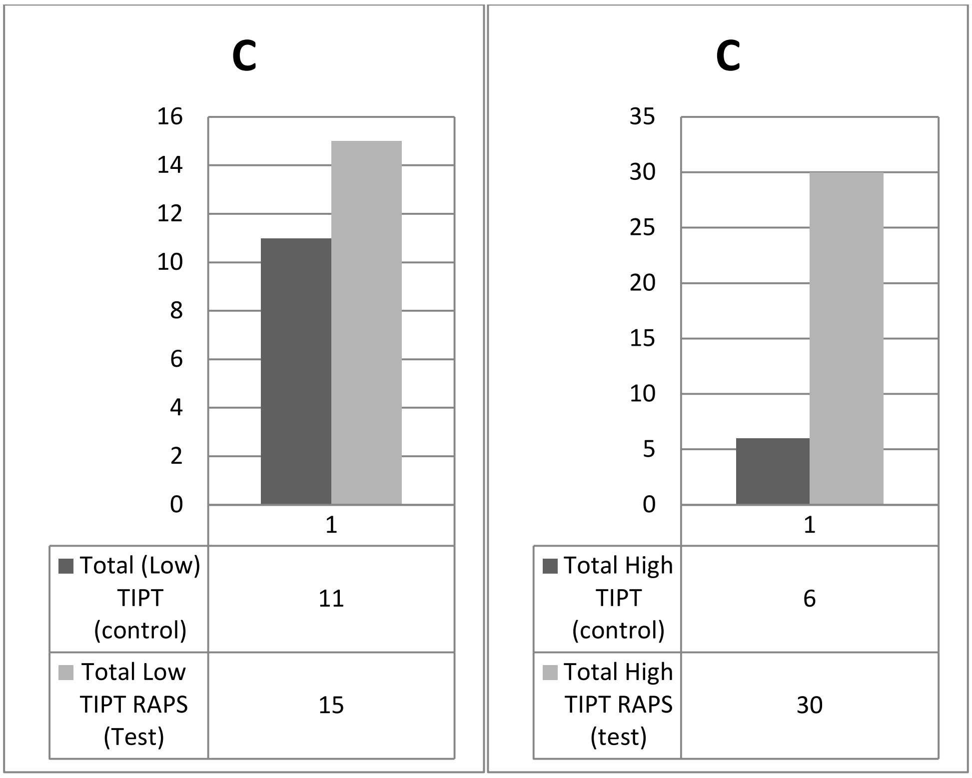


Figure 6-56 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject C

Figure 6-56 illustrates that subject C recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieve in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 11 and 15 respectively and for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks 6 and 30 respectively. Subject C, experienced a 27% increase between control and RAPS test intervals of the low cognitive demanding TIPT task trial and an increase of 80% between control and RAPS test intervals of the high cognitive demanding TIPT task trial.

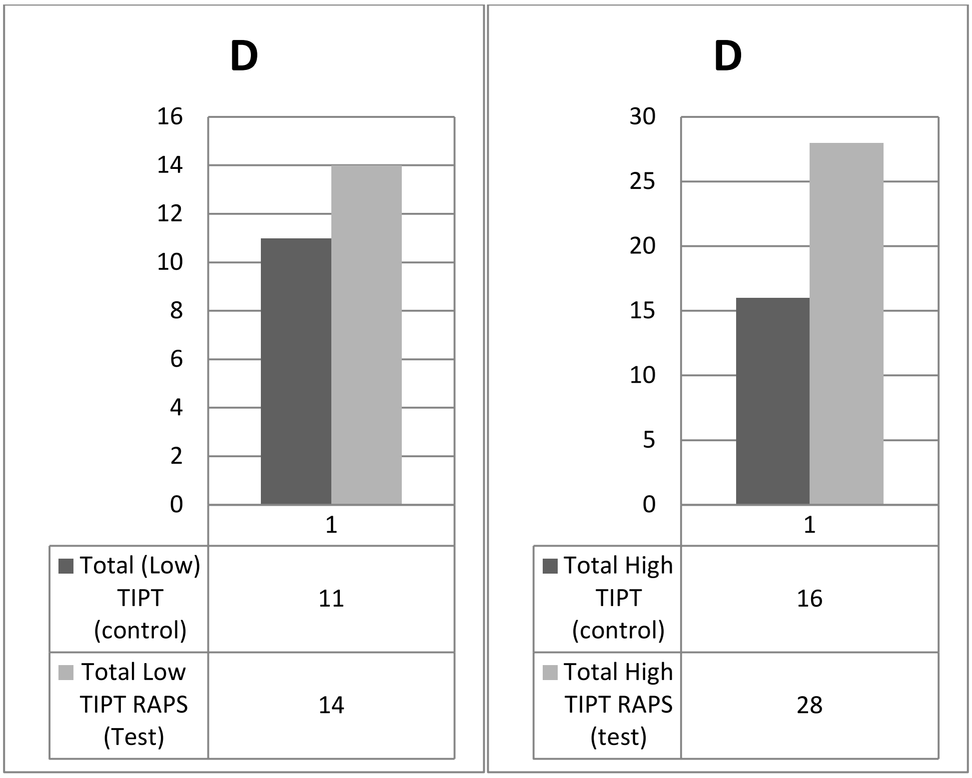
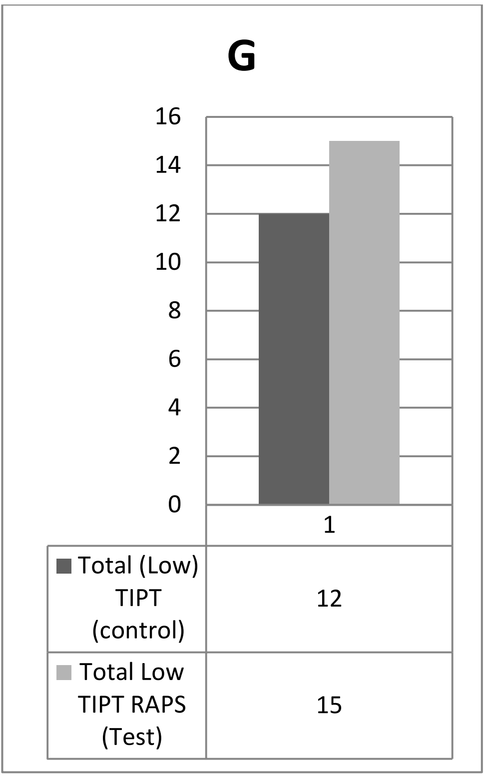


Figure 6-57 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test)- Subject D

Figure 6-57 illustrates that subject D recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 11 and 14 respectively and for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks 16 and 28 respectively. Subject D experienced a 20% between control and RAPS test intervals of the low cognitive demanding TIPT task trial and an increase of 40% between control and RAPS test intervals of the high cognitive demanding TIPT task trial.



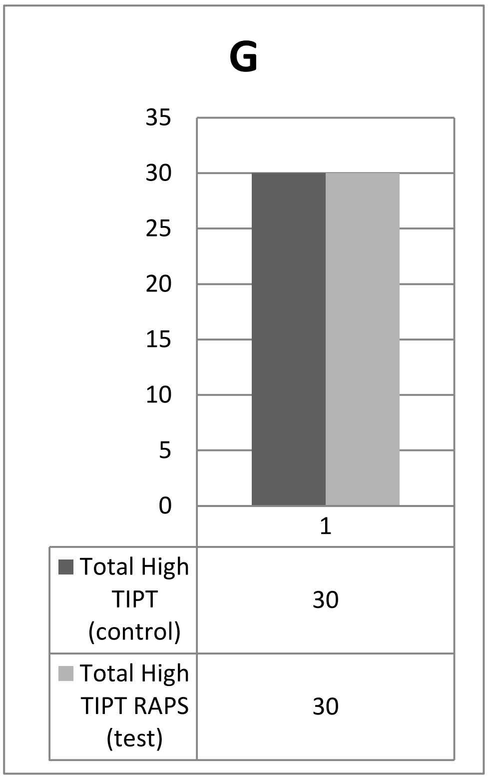


Figure 6-58 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject G

Figure 6-58 illustrates that subject G, recorded an increase in the performance score achieved between the low TIPT (control) and low TIPT RAPS (test) intervals and no change to the full score both in the high TIPT (control) and in the high TIPT RAPS (test) intervals. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 12 and 15 respectively and for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks were 30 and 30 respectively. Subject G experienced a 20% increase between the low cognitive demanding task trial and 0% in change between the high cognitive demanding task trial.

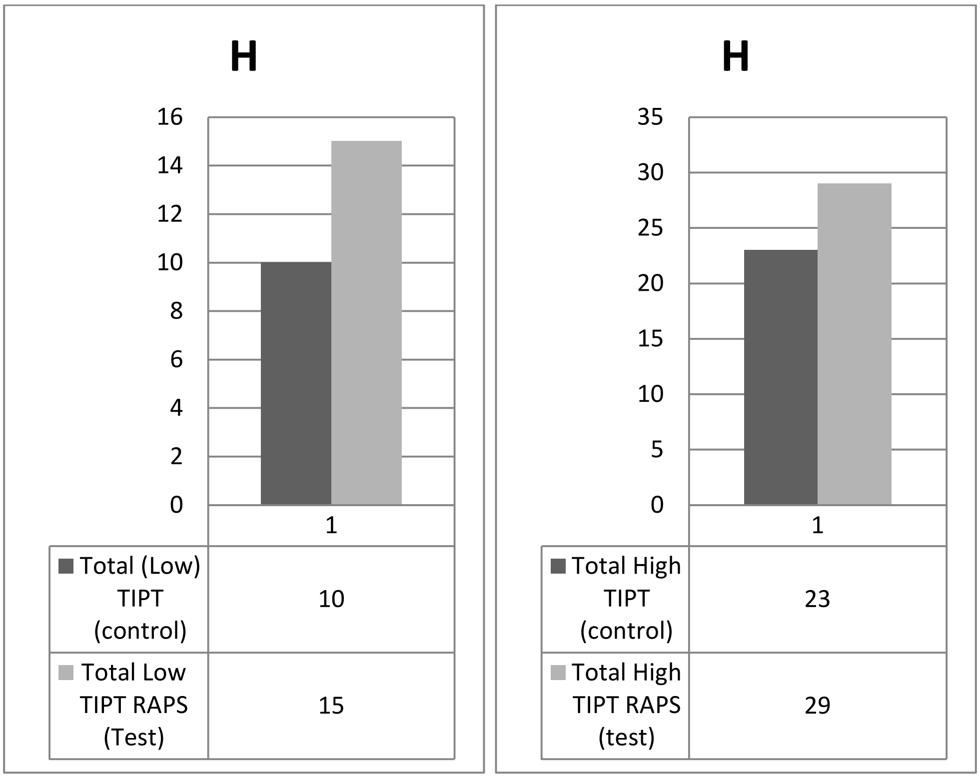


Figure 6-59 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject H

Figure 6-59 illustrates that subject H recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 10 and 15 respectively and for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks 23 and 29 respectively. Subject H experienced a 33% increase between the control and RAPS test intervals of the low cognitive demanding task trial and an increase of 20% between the control and RAPS test intervals of the high cognitive demanding task trial.

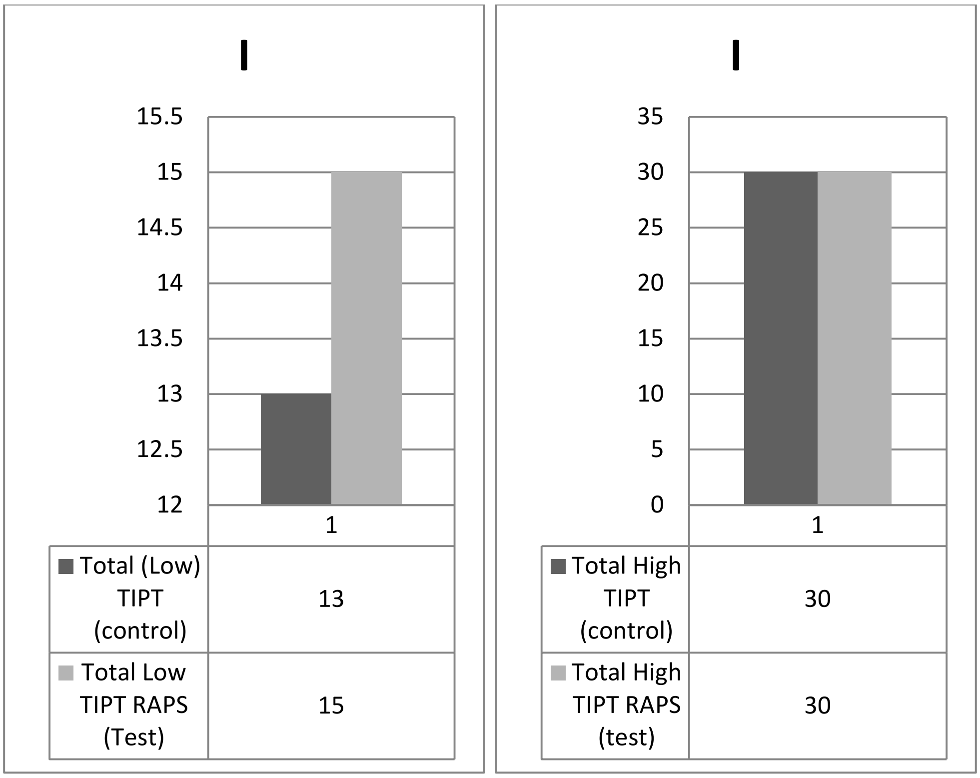


Figure 6-60 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject I

Figure 6-60 illustrates that subject I, recorded an increase in the performance score achieved between the low TIPT (control) and the low TIPT RAPS (test) intervals and, as with subject G, there was no change with the full score in both the high TIPT (control) and the high TIPT RAPS (test) intervals. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 13 and 15 respectively - for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks they were 30 and 30 respectively. Subject I experienced a 13% increase between the control and RAPS test intervals of the low cognitive demanding task trial and 0% in change between the control and RAPS test intervals of the high cognitive demanding task trial.

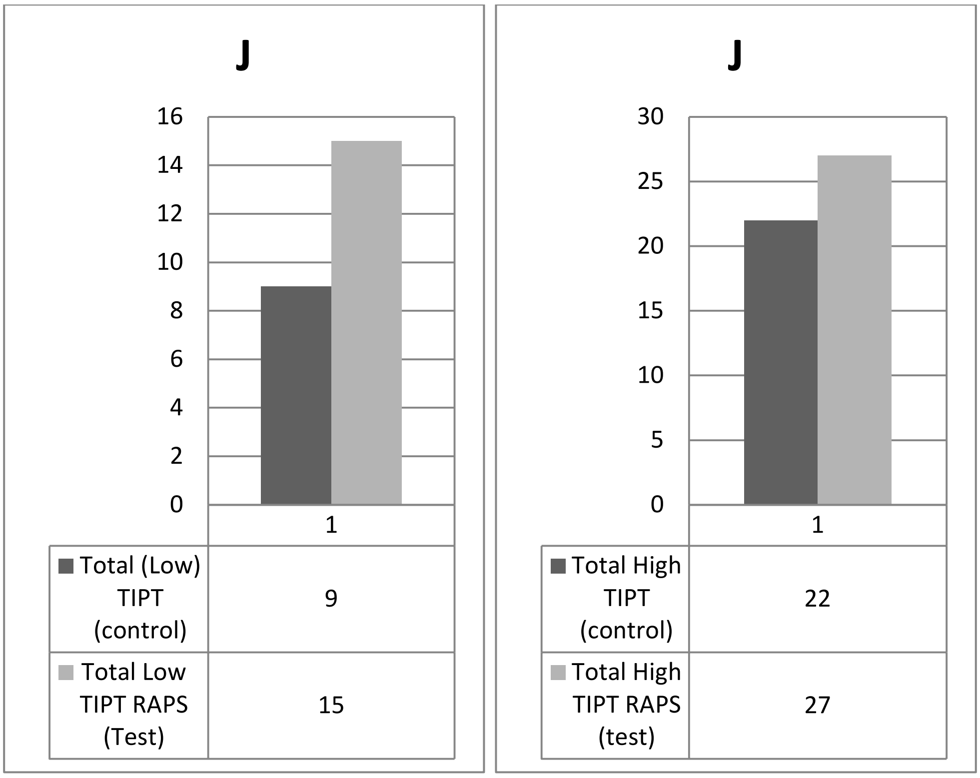


Figure 6-61 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject J

Figure 6-61 illustrates that subject J recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 9 and 15 respectively and for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks 22 and 27 respectively. Subject J experienced a 40% increase between the control and the RAPS test intervals during the low cognitive demanding task trial and an increase of 17% between the control and RAPS test intervals during the high cognitive demanding task trial.

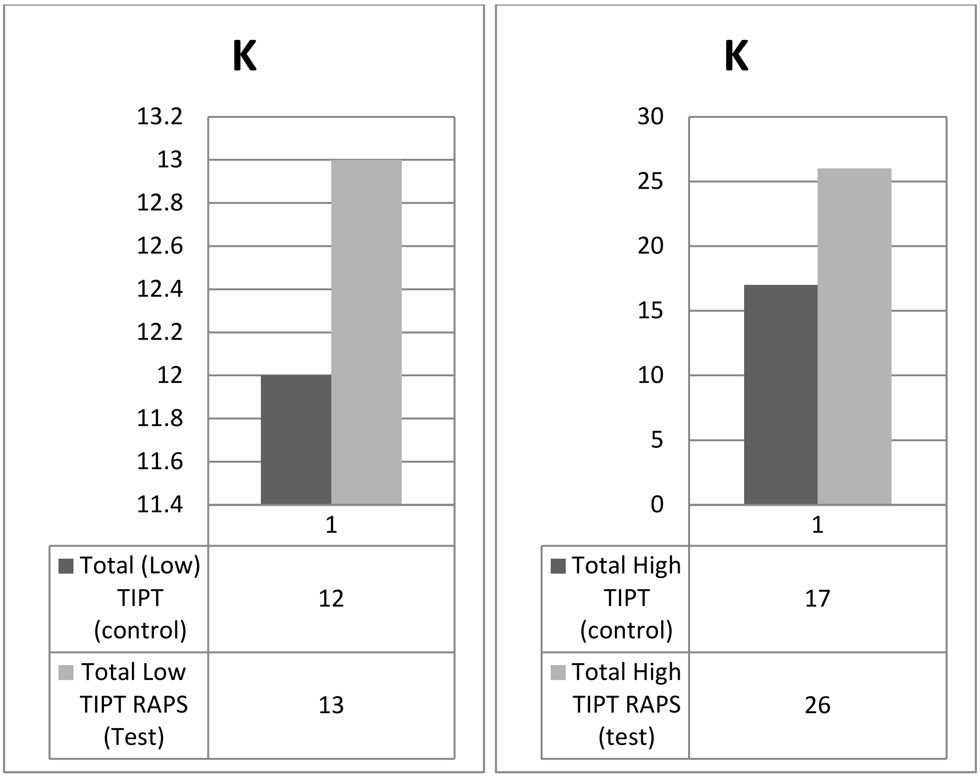


Figure 6-62 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject K

Figure 6-62 illustrates that subject K recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 12 and 13 respectively and for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks 17 and 26 respectively. Subject K experienced a 7% increase between the control and RAPS test intervals during the low cognitive demanding task trial and an increase of 30% between control and RAPS test intervals of the high cognitive demanding task trial.

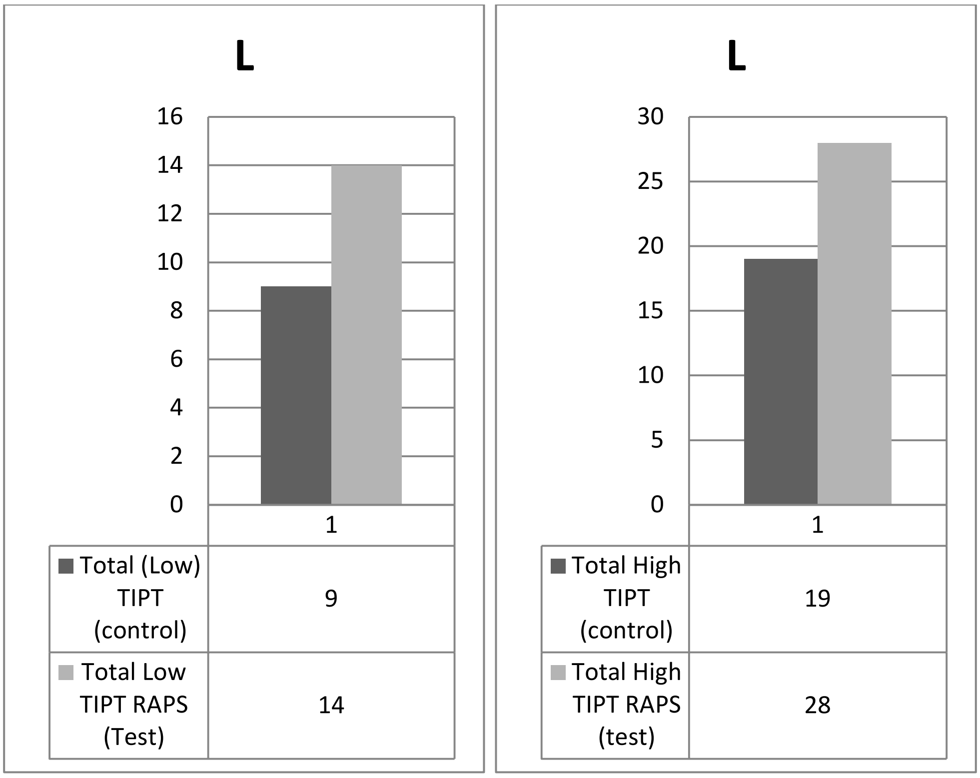


Figure 6-63 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject L

Figure 6-63 illustrates that subject L recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieve in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 9 and 14 respectively and for the high TIPT (control) and the high TIPT RAPS (test) post assessment tasks 19 and 28 respectively. Subject L experienced a 33% increase between the control and the RAPS test intervals during the low cognitive demanding task trial and an increase of 30% between the control and the RAPS test intervals during the high cognitive demanding task trial.

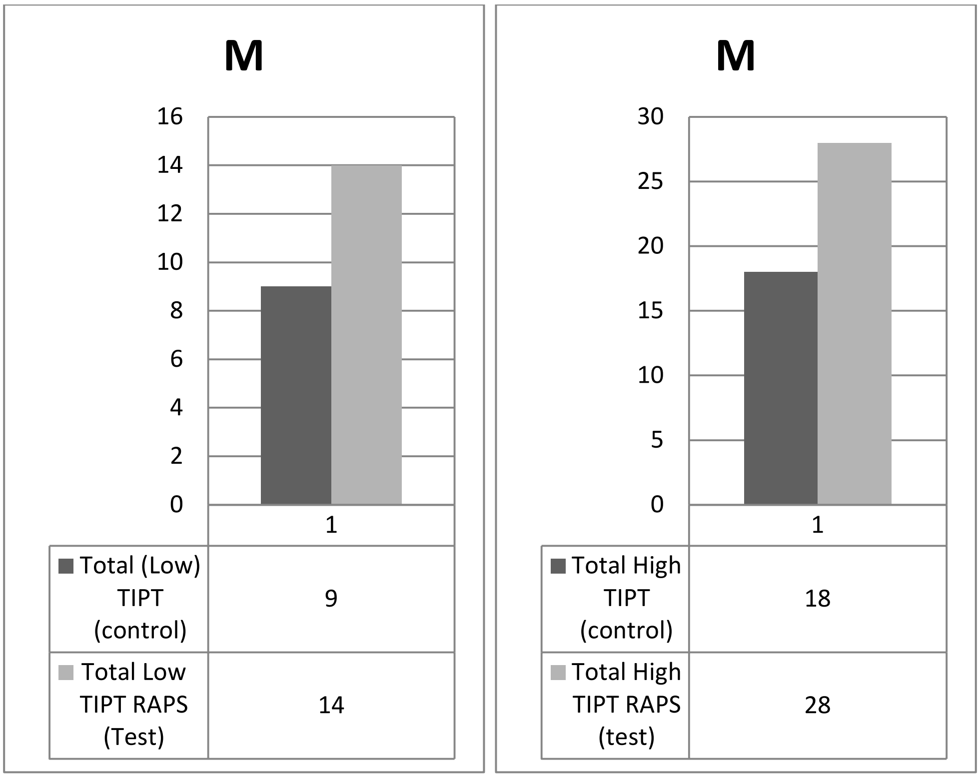


Figure 6-64 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject M

Figure 6-64 illustrates that subject M recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 9 and 14 respectively and for the high TIPT (control) and the high TIPT RAPS (test) post assessment tasks 18 and 28 respectively. Subject M experienced a 33% increase in both the low cognitive demanding and the high cognitive demanding task trial.

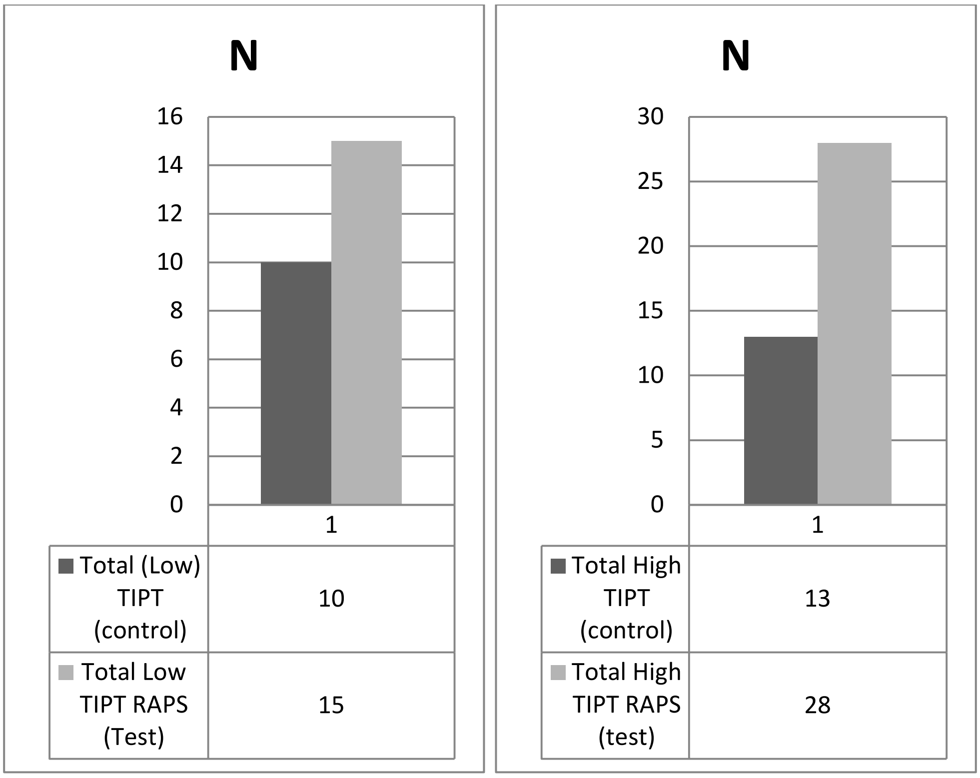


Figure 6-65 Performance scores low TIPT (control)/(test) and high TIPT (control)/(test) Subject N

Figure 6-65 illustrates that subject N recorded an increase in the performance score achieved in both pairs of compared tasks. The performance scores achieved in the low TIPT (control) and the low TIPT RAPS (test) post assessment tasks were 10 and 15 respectively and for the high TIPT (control) and high TIPT RAPS (test) post assessment tasks 13 and 28 respectively. Subject N experienced a 33% increase between the control and RAPS test intervals during the low cognitive demanding task trial and an increase of 50% between the control and RAPS test interval during the high cognitive demanding task trial.

6.1.4.2 Collective Performance Score Analysis

6.1.4.3 The Impact of RAPS on Low level Cognitive Tasks

Microsoft Excel was used to carry out Paired T Tests to establish the mean between the Low TIPT (control) and the Low TIPT RAPS (test). They were as follows:

- Mean MWL low TIPT (control) 14.43µV
- Mean MWL low TIPT RAPS (test) 15.17µV

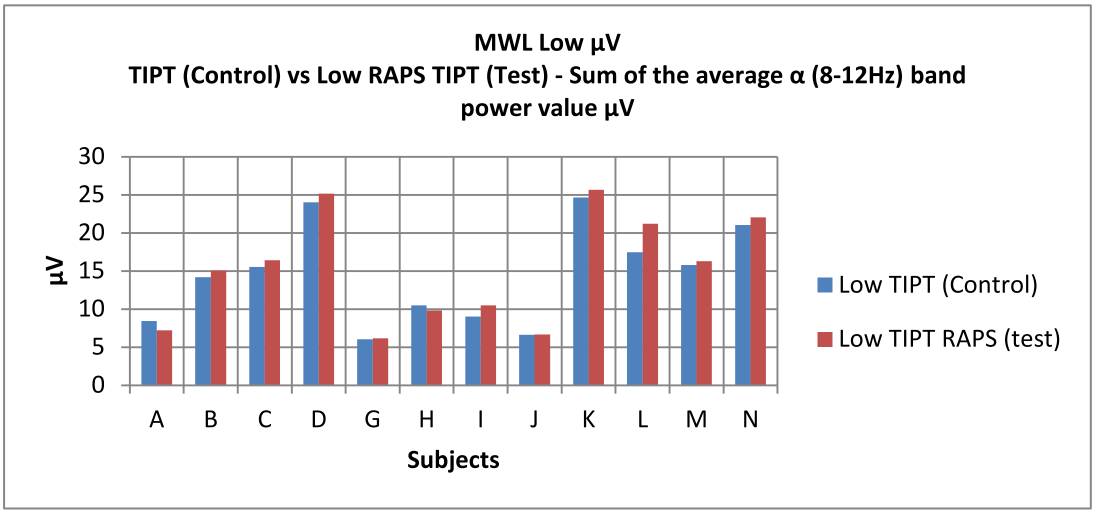


Figure 6-66 MWL low TIPT (control) vs low RAPS TIPT (test) - Sum of the average α (8-12Hz) band power value µV

Figure 6-66 shows the results of the low TIPT (control) and the low TIPT RAPS (test) intervals clustered by subject. This column uses visual representation to demonstrate that in 83% of the cases, or for 10 out of the 12 subjects the RAPS had no effect on reducing the MWL. The variability in the MWL experienced during the low TIPT intervals was as follows: minimum variance was an increase of 0.45% and there was a maximum increase of 16.43% with an average of 6.91% across all subjects.

Figure 6-66 also shows the results of the low TIPT (control) and the low TIPT RAPS (test) intervals clustered by subject. This column uses visual representation to demonstrate that 16.6% of the cases, or 2 out of the 12 subjects experienced a positive effect with RAPS, with a decrease in MWL. The variability in the .MWL experienced during the low TIPT intervals was as follows: minimum variance was an increase of 6.20% and the maximum increase was 14.37% with an overall average reduction in MWL of 10.25% across all subjects as in Table 5-16.

Drawing from Table 5-16 it can be noted that the most significant impacts that RAPS had during low cognitive demanding intervals were as follows: an increase in MLW of 14.37% for subject A; and a decrease in MLW by 21.28% experienced by subject L.

6.1.4.4 The Impact of RAPS on a high level task

Microsoft Excel was used to carry out Paired T Tests to establish the mean between: High TIPT (control) and High TIPT RAPS (test). They were as follows:

- Mean MWL high TIPT (control) 16.61µV
- Mean MWL high TIPT RAPS (test) 14.09µV

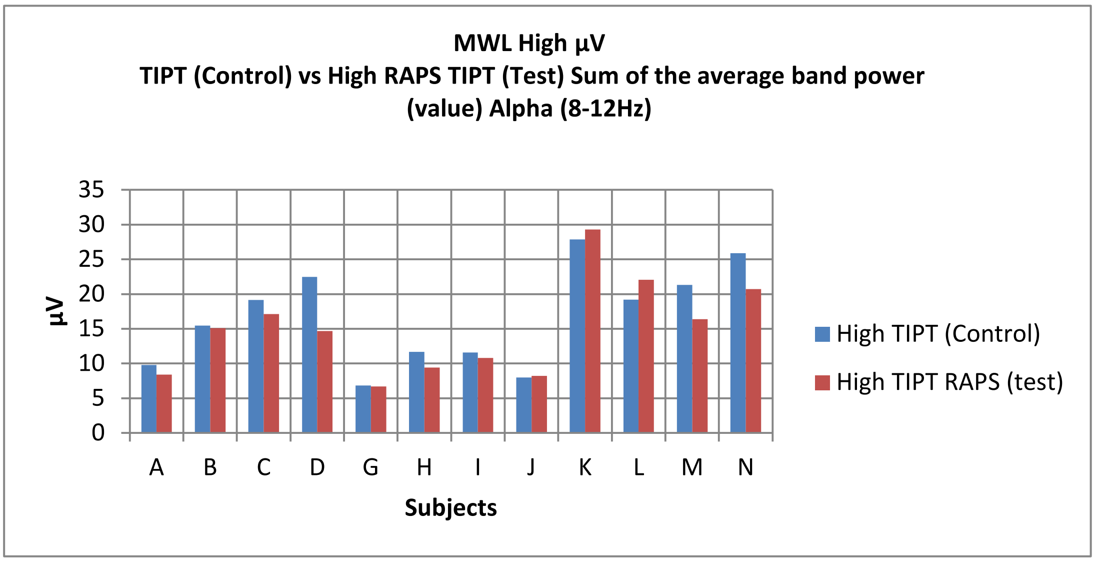


Figure 6-67 MWL high TIPT (control) vs high RAPS TIPT (test) - sum of the average α (8-12Hz) band power value µV

Drawing from Table 5-17, and Figure 6-67 demonstrates the results of the high TIPT (control) and high TIPT RAPS (test) intervals clustered by subject. This column visual representation demonstrates that 75%, or 9 out of the 12 subjects, experienced a positive effect with RAPS, with a decrease in MWL. The variability in the MWL experienced during the high TIPT intervals was as follows: the minimum variance was a decrease between 2.19% and the maximum decrease of 34.64% with an overall average reduction in MWL of 14.89% across all subjects. Figure 6-66 shows that 25% of subjects, 3 out of 12, revealed a null or negative effect in reducing the MWL. The MWL increased between 2.37% and 14.85%, with an average of a 7.4% increase in MWL. The range was between 2.19% and 34.64%, with an overall average decrease of 9.29%.

Drawing from Table 5-17 and Figure 6-66, it can be noted that the most significant impacts of RAPS during the high level cognitive intervals were as follows: an increase in MLW by 14.85% for subject L; and a decrease in MLW by 34.64% experienced by subject D.

Figure 6-68 ***Radar map of MWL low TIPT (control) vs low RAPS TIPT (test) - sum of the average α (8-12Hz) band power value µV***

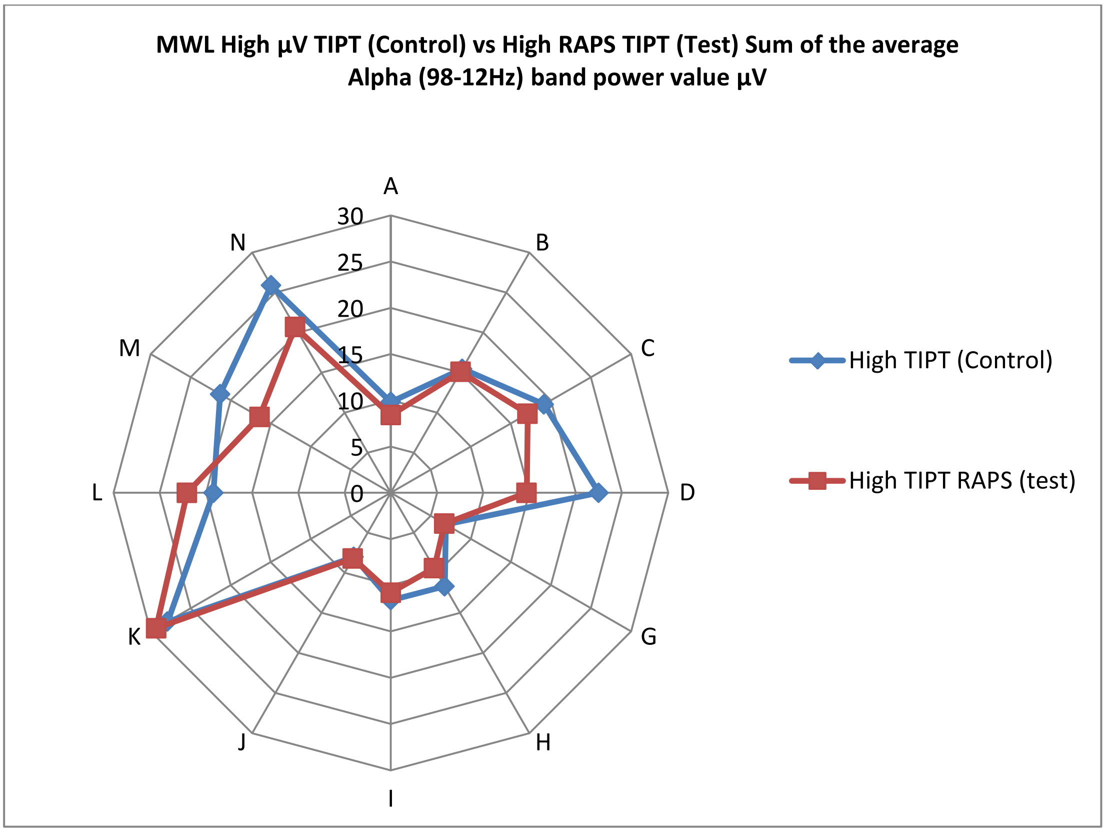


Figure 6-69 ***Radar map MWL high TIPT (control) vs high RAPS TIPT (test) - sum of the average α (8-12Hz) band power value µV***

Figures 6-68 and 6-69 display an aerial view of the difference in MWL experienced across all subjects. Figure 6-68 illustrates the low cognitive demanding intervals - low TIPT (control) and low TIPT RAPS (test) - and Figure 6-69 the high cognitive demanding intervals - high TIPT (control) and high TIPT RAPS (test). The research question to be answered was: What impact does the use of RAPS have on the MWL imposed during a low cognitive demanding TIPT and a high cognitive demanding TIPT?

Results demonstrated that RAPS had minimal impact in reducing MWL during a low TIPT; however, the two subjects who did experience a reduced MWL did also experience an improvement in performance: 20% for subject A and 33% for subject L.

Over all subjects RAPS demonstrated an increase in MWL of 4.05% with a low level cognitive task.

The overall impact of RAPS was positive, with an average of a 9.29% decrease in MWL across all subjects with high level tasks.

6.1.4.5 Comparing the low TIPT (control) task with the low TIPT RAPS (test) task

Microsoft Excel was used to carry out Paired T Tests to establish the mean between - low TIPT (control) and low TIPT RAPS (test). They were as follows:

- Mean performance scores low TIPT (control) 10.92
- Mean performance scores low TIPT RAPS (test) 14.61

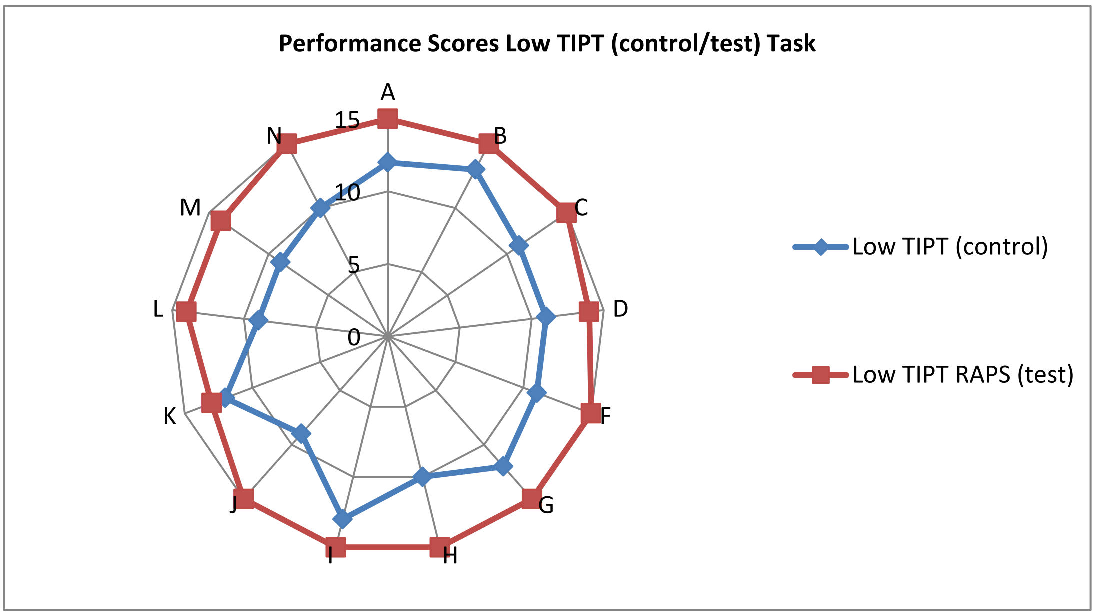


Figure 6-70 Performance scores low TIPT (control/test) task

Drawing from Table 5-16 and Figure 6-70 demonstrates the results of the collective performance results for low TIPT (control) vs low TIPT RAPS (test) intervals, shown by subject. This radar graph is used as a visual representation and demonstrates that 76.92% of subjects, or 10 out of 13 experienced an increase of 20% or more in the performance scores achieved in post assessment tasks when presented with the RAP stimuli. It was established that a positive effect was reached whilst using RAPS as a strategy to improve human performance during a TIPT.

Table 5-16 and Figure 6-70 show that 7.6% of the subjects, or 1 out of 13, experienced an increase of 40% - 30.7% of the subjects, or 4 out of 13 experienced an increase of 33% - 15.38% of the subjects, or 2 out of 13, experienced an increase of 27% - 23.07% of the subjects, or 3 out of 13, experienced an increase of 20% : and 76.92% of the subjects, or 10 out 13, experienced an increase of 20% in performance scores achieved when presented with the RAP stimuli.

The variability in the performance scores achieved during the low TIPT intervals was as follows: the minimum variance was an increase of 7.0% with subject J: and the maximum increase was 40% with subject K. The overall average increase in performance scores during low TIPT (control) to low TIPT RAPS (test) was 33% across all subjects.

Results showed that the use of RAPS had a significantly positive impact on the improvement of human performance, despite the minimal impact that RAPS had on reducing the MWL during low cognitive demand task intervals.

6.1.4.6 Comparing the high TIPT (control) with the high TIPT RAPS (test) task

Microsoft Excel was used to carry out Paired T Tests to establish the mean between: High TIPT (control) and High TIPT RAPS (test). They were as follows:

- Mean performance scores high TIPT (control) 20.75
- Mean performance scores high TIPT RAPS (test) 28.5

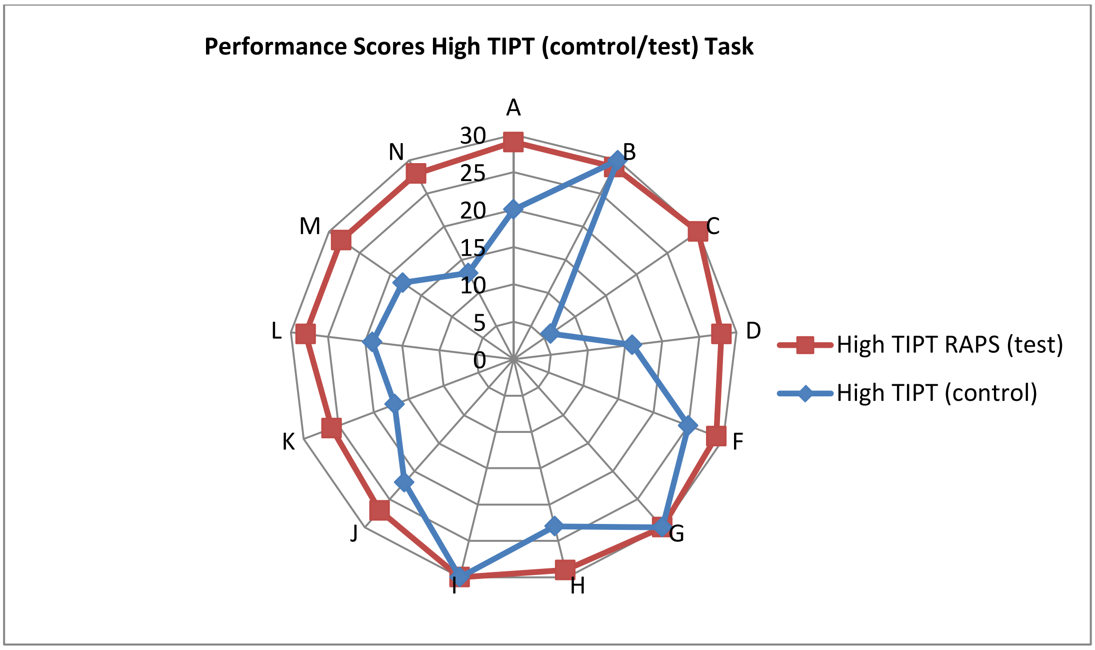


Figure 6-71 Performance scores high TIPT (control/test) task

Table 5-17 and Figure 6-71 demonstrate the results of collective performance for high TIPT (control) vs high TIPT RAPS (test) intervals, shown by subject. This radar graph is used as a visual representation and demonstrates that 100% of the subjects, or 13 out of 13, experienced an increase in the performance scores achieved in post assessment tasks when presented with the RAP stimuli. The results showed that a positive effect was reached with RAPS in an attempt to improve human performance during TIPT's.

Table 5-17 and Figure 6-71 indicate that 7.6% of the subjects, or 1 out of 13, experienced an increase of 80%: and that - 7.60% of the subjects, or 1 out of 13, each experienced an increase of 50%, 40% and 33% respectively. Furthermore 23% of the subjects, or 3 out of 13, experienced an increase of 27% - 23.07% of the subjects, or 3 out of 13, experienced an increase of 30%: and 7.60%, or 1 out of 13, subjects and 76.9%, 10 out of 13 subjects experienced an increase of 20% or more in performance when presented with the RAP stimuli.

The variability in the performance scores achieved during the high TIPT intervals was as follows: the minimum variance was an increase of 80% for subject C, and there was a decrease of 3.0% with subject B.

The overall average increase in performance scores between high TIPT (control) and high TIPT RAPS (test) was 26% across all subjects. Results showed that the use of RAPS had a significant positive impact on the improvement of human performance, despite the minimal impact that RAPS had on reducing the MWL during low cognitive demand task intervals.

From a high (control) task to a high (test) cognitive task there was an overall average increase in performance scores of 26%. Results showed that a positive impact was evident in that 92% of subjects experienced an increase in their performance results achieved from a high TIPT control to a high TIPT RAPS test.

6.1.4.7 Correlations of performance scores and MWL

Performance Scores and MWL Low TIPT (Control) vs Low RAPS TIPT (Test)

Subject	Baseline	Low TIPT (control) Performance Score	zLow TIPT (control) Performance Score	Low TIPT (control) MWL µv	zLow TIPT (control) MWL µV	Low TIPT RAPS (test) Performance Score	zLow TIPT RAPS (test) Performance Score	Low TIPT RAPS (test) MWL µv	zLow TIPT RAPS (test) MWL µv	MWL Difference µv	Performance Score differences
A	8.40	12	0.72	9.81	-0.96	15	0.62	8.4	-0.96	-1.41	3
B	14.55	13	1.38	15.48	-0.16	15	0.62	15.1	0.03	-0.38	2
C	14.99	11	0.06	19.13	0.36	15	0.62	17.1	0.33	-2.03	4
D	23.92	11	0.06	22.49	0.83	14	-0.87	14.7	-0.03	-7.79	3
G	4.95	12	0.72	6.85	-1.38	15	0.62	6.7	-1.22	-0.15	3
H	9.19	10	-0.61	11.67	-0.70	15	0.62	9.4	-0.82	-2.27	5
I	6.45	13	1.38	11.61	-0.71	15	0.62	10.8	-0.61	-0.81	2
J	5.26	9	-1.27	8.01	-1.22	15	0.62	8.2	-0.99	0.19	6
K	8.58	12	0.72	27.88	1.60	13	-2.37	29.3	2.13	1.42	1
L	7.13	9	-1.27	19.19	0.37	14	-0.87	22.04	1.06	2.85	5
M	5.73	9	-1.27	21.32	0.67	14	-0.87	16.4	0.22	-4.92	5
N	20.26	10	-0.61	25.89	1.31	15	0.62	20.7	0.86	-5.19	5

Table 6-1 Performance scores and MWL low TIPT (control) vs low RAPS TIPT (test)

Table 5-16 details the performance scores and the MWL μV for low TIPT (control) and low TIPT RAPS (test) intervals across all subjects as performance scores and MWL μV are measured on different scales. z scores were calculated for both prior to plotting results. The following equation was used to establish z scores: *(x-mean)/stdev) = z score* for the MWL low TIPT (control), performance score low TIPT (control) and MWL low TIPT (test), performance score low TIPT RAPS (test).

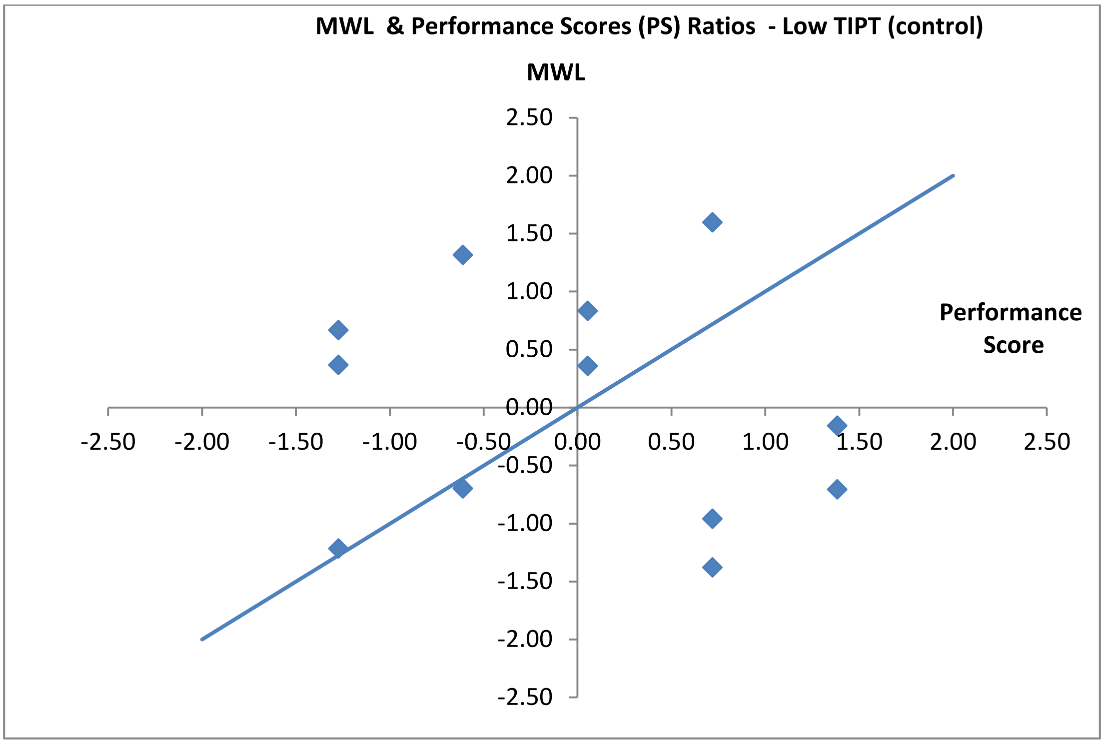


Figure 6-72 MWL and performance scores low TIPT (control)

In Figure 6-72 a scatter graph illustrates the following MWL and performance score results with respect to correlations between the performance scores achieved by each individual subject and the MWL experienced during low TIPT (control) intervals.

Individual MWL/PS results were as follows:

- With a zperformance score of >0 (0.72) and a <0 (-0.96) zMWL recording subject A achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (1.38) and a <0 (-0.16) zMWL recording subject B achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.06) and a >0 (0.36) zMWL recording subject C achieved an above average MWL/PS ratio.

- With a zperformance score of >0 (0.06) and a >0 (0.83) zMWL recording subject D achieved an above average MWL/PS ratio.
- With a zperformance score of >0 (0.72) and a <0 (-1.38) zMWL recording subject G achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.61) and a <0 (-.70) zMWL recording subject H achieved a slightly below average MWL/PS ratio.
- With a zperformance score of >0 (1.38) and a <0 (-0.71) zMWL recording subject I achieved a below average MWL/PS ratio.
- With a zperformance score of <0 (-1.27) and a <0 (-1.22) zMWL recording subject J achieved an average MWL/PS ratio.
- With a zperformance score of >0 (0.72) and a >0 (1.6) zMWL recording subject K achieved a below average MWL/PS ratio.
- With a zperformance score of <0 (-1.27) and a >0 (0.37) zMWL recording subject L achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-1.27) and a >0 (0.67) zMWL recording subject M achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.61) and a >0 (01.31) zMWL recording subject N achieved an above average MWL/PS ratio.

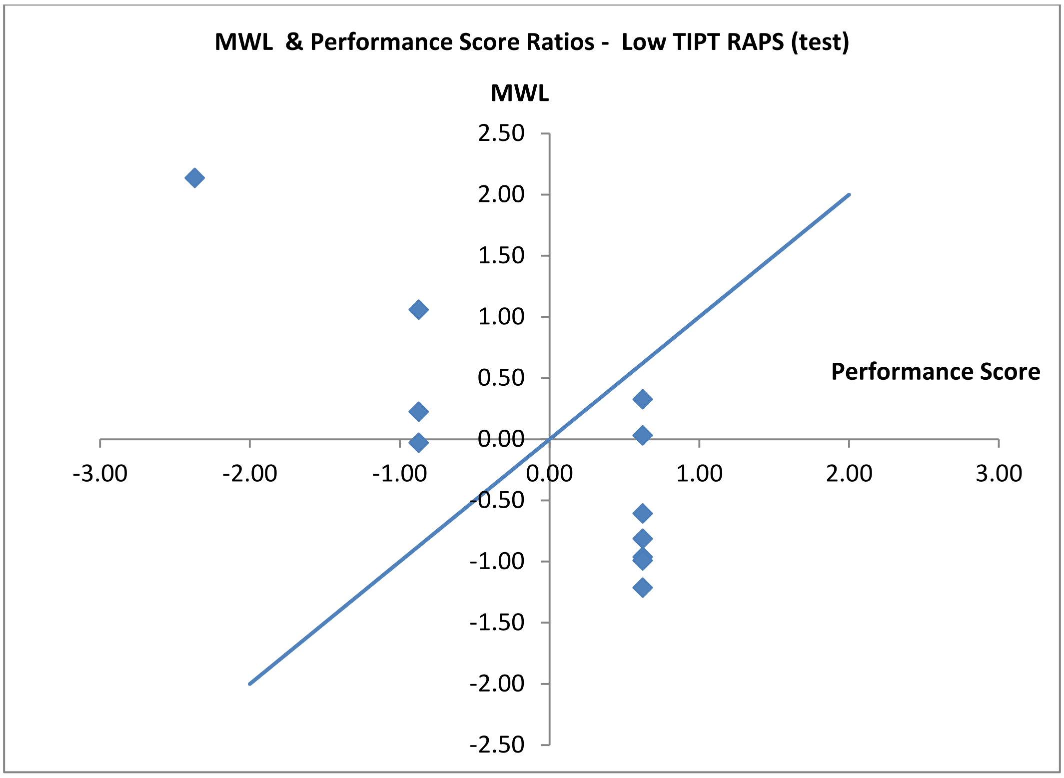


Figure 6-73 *MWL and performances Scores low TIPT RAPS (test)*

In Figure 6-73 a scatter graph illustrates the following with respect to correlations between the performance scores achieved by each individual subject and the MWL experienced during the low TIPT RAPS (test) intervals.

Individual MWL/PS results were as follows:

- With a zperformance score of >0 (0.62) and a <0 (-0.96) zMWL recording, subject A achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.62) and a >0 (0.03) zMWL recording, subject B achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.62) and a >0 (0.33) zMWL recording, subject C achieved a less than average MWL/PS ratio.
- With a zperformance score of <0 (-0.87) and a <0 (-0.03) zMWL recording, subject D achieved an above average MWL/PS ratio.
- With a zperformance score of >0 (0.62) and a <0 (-1.22) zMWL recording, subject G achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.62) and a <0 (-0.82) zMWL recording, subject H achieved a less than average MWL/PS ratio.

- With a zperformance score of >0 (1.62) and a <0 (-0.61) zMWL recording, subject I achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.62) and a <0 (-0.99) zMWL recording, subject J achieved a less than average MWL/PS ratio.
- With a zperformance score of <0 (-2.37) and a >0 (2.13) zMWL recording, subject K achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.87) and a >0 (1.06) zMWL recording, subject L achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (0.87) and a >0 (0.22) zMWL recording, subject M achieved an above average MWL/PS ratio.
- With a zperformance score of >0 (0.62) and a >0 (0.86) zMWL recording, subject N achieved a less than average MWL/PS ratio.

Performance Scores and MWL High TIPT (Control) vs High TIPT RAPS (Test)

Subject	Baseline	High TIPT (Control) Performance Score	zHigh TIPT (Control) Performance Score	High TIPT (control) MWL µV	zHigh TIPT (control) MWL µV	High TIPT RAPS (test) Performance Score	zHigh TIPT RAPS (test) Performance Score	High TIPT RAPS (test) MWL µV	zHigh TIPT RAPS (test) MWL µV	MWL Difference µV	Performance Score difference
A	8.40	20	-0.05	9.81	-0.96	29	0.40	8.4	-0.96	-1.41	9
B	14.55	30	1.32	15.48	-0.16	29	0.40	15.1	0.03	-0.38	-1
C	14.99	6	-1.96	19.13	0.36	30	1.21	17.1	0.33	-2.03	24
D	23.92	16	-0.59	22.49	0.83	28	-0.40	14.7	-0.03	-7.79	12
G	4.95	30	1.32	6.85	-1.38	30	1.21	6.7	-1.22	-0.15	0
H	9.19	23	0.37	11.67	-0.70	29	0.40	9.4	-0.82	-2.27	6
I	6.45	30	1.32	11.61	-0.71	30	1.21	10.8	-0.61	-0.81	0
J	5.26	22	0.23	8.01	-1.22	27	-1.21	8.2	-0.99	0.19	5
K	8.58	17	-0.46	27.88	1.60	26	-2.01	29.3	2.13	1.42	9
L	7.13	19	-0.18	19.19	0.37	28	-0.40	22.04	1.06	2.85	9
M	5.73	18	-0.32	21.32	0.67	28	-0.40	16.4	0.22	-4.92	10
N	20.26	13	-1.00	25.89	1.31	28	-0.40	20.7	0.86	-5.19	15

Table 6-2 ***Performance scores high TIPT (control) vs high RAPS TIPT (test)***

Table 5-17 detailed the performance scores and MWL µV for high TIPT (control) and high TIPT RAPS (test) intervals across all subjects. As performance scores and MWL µV are measured on different scales, z scores were calculated for both prior to plotting the results. The following equation was used to establish z scores: *(x-mean)/stdev) = z score* for the MWL high TIPT (control), performance score high TIPT (control) and MWL high TIPT (test), performance score high TIPT RAPS (test).

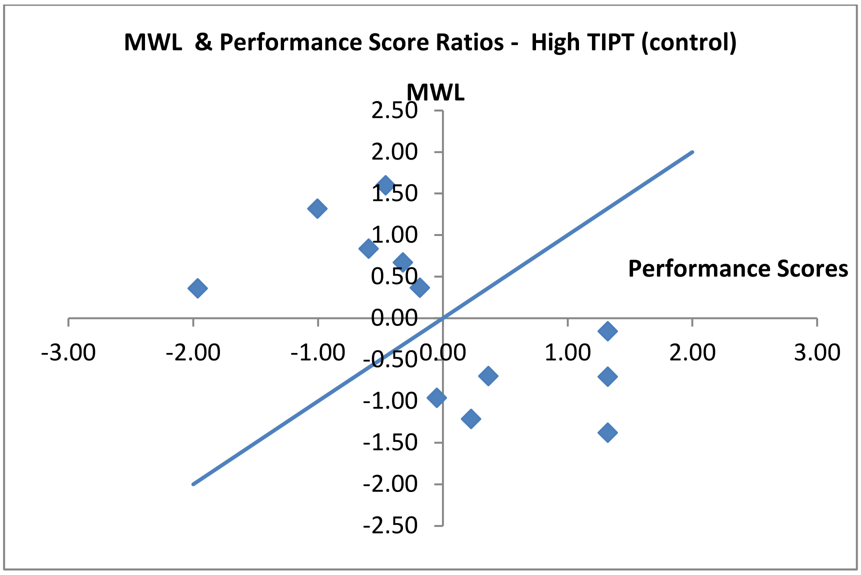


Figure 6-74 MWL and performance scores high TIPT (control)

In Figure 6-74 a scatter graph illustrates the following with respect to correlations between performance scores achieved by each individual subject and the MWL experienced during high TIPT (control) intervals:

- With a zperformance score of <0 (-0.05) and a <0 (-0.96) zMWL recording, subject A achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (1.32) and a <0 (-0.16) zMWL recording, subject B achieved a less than average MWL/PS ratio.
- With a zperformance score of <0 (-1.96) and a >0 (0.36) zMWL recording, subject C achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.59) and a >0 (0.83) zMWL recording, subject D achieved an above average MWL/PS ratio.
- With a zperformance score of >0 (1.32) and a <0 (-1.38) zMWL recording, subject G achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.37) and a <0 (-0.70) zMWL recording, subject H achieved a less than average MWL/PS ratio.

- With a zperformance score of >0 (1.32) and a <0 (-0.71) zMWL recording, subject I achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.23) and a <0 (-1.22) zMWL recording, subject J achieved a less than average MWL/PS ratio..
- With a zperformance score of <0 (-0.46) and a >0 (1.60) zMWL recording, subject K achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.18) and a >0 (0.37) zMWL recording, subject L achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.32) and a >0 (0.67) zMWL recording, subject M achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-1.00) and a >0 (01.31) zMWL recording, subject N achieved an above average MWL/PS ratio.

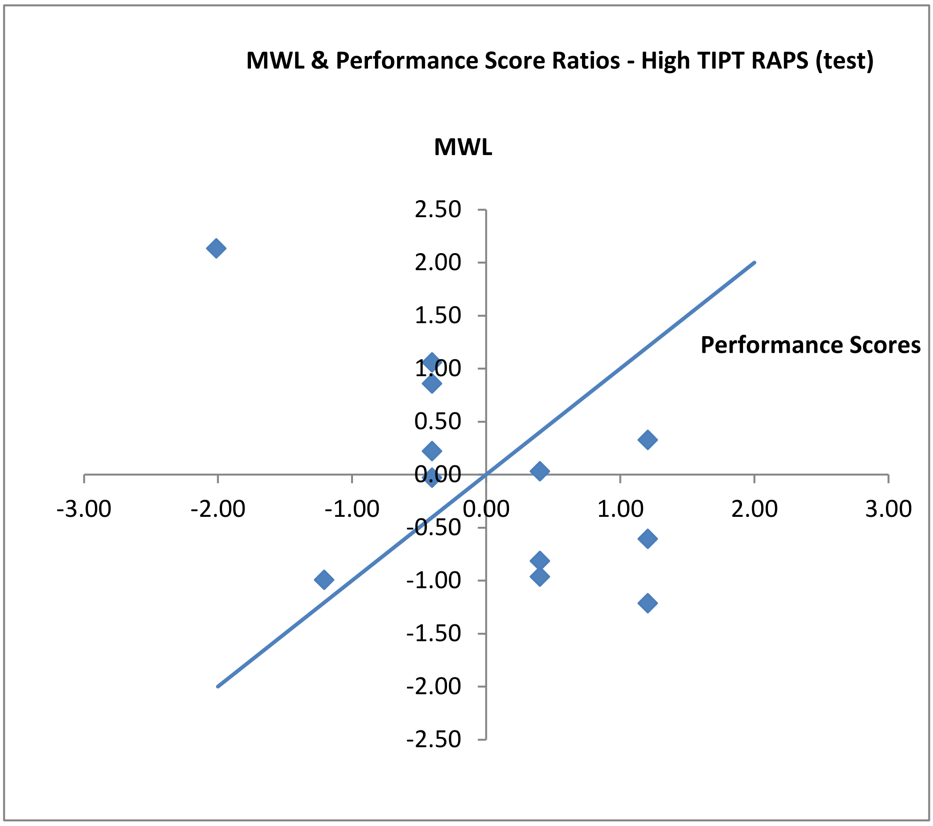


Figure 6-75 MWL and performance scores high TIPT RAPS (test)

In Figure 6-75 a scatter graph illustrates the following with respect to correlations between performance scores achieved by each individual subject and the MWL experienced during the high TIPT RAPS (test) intervals:

- With a zperformance score of >0 (0.40) and a <0 (-0.96) zMWL recording, subject A achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.40) and a >0 (0.3) zMWL recording, subject B achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (1.21) and a >0 (0.33) zMWL recording, subject C achieved a less than average MWL/PS ratio.
- With a zperformance score of <0 (-0.40) and a <0 (-0.03) zMWL recording, subject D achieved an above average MWL/PS ratio.
- With a zperformance score of >0 (1.21) and a <0 (-1.22) zMWL recording, subject G achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (0.40) and a <0 (-0.82) zMWL recording, subject H achieved a less than average MWL/PS ratio.
- With a zperformance score of >0 (1.21) and a <0 (-0.61) zMWL recording, subject I achieved a less than average MWL/PS ratio.
- With a zperformance score of <0 (-1.21) and a <0 (-0.99) zMWL recording, subject J achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-2.01) and a >0 (2.13) zMWL recording, subject K achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.40) and a >0 (1.06) zMWL recording, subject L achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.40) and a >0 (0.22) zMWL recording, subject M achieved an above average MWL/PS ratio.
- With a zperformance score of <0 (-0.40) and a >0 (0.86) zMWL recording, subject N achieved an above average MWL/PS ratio.

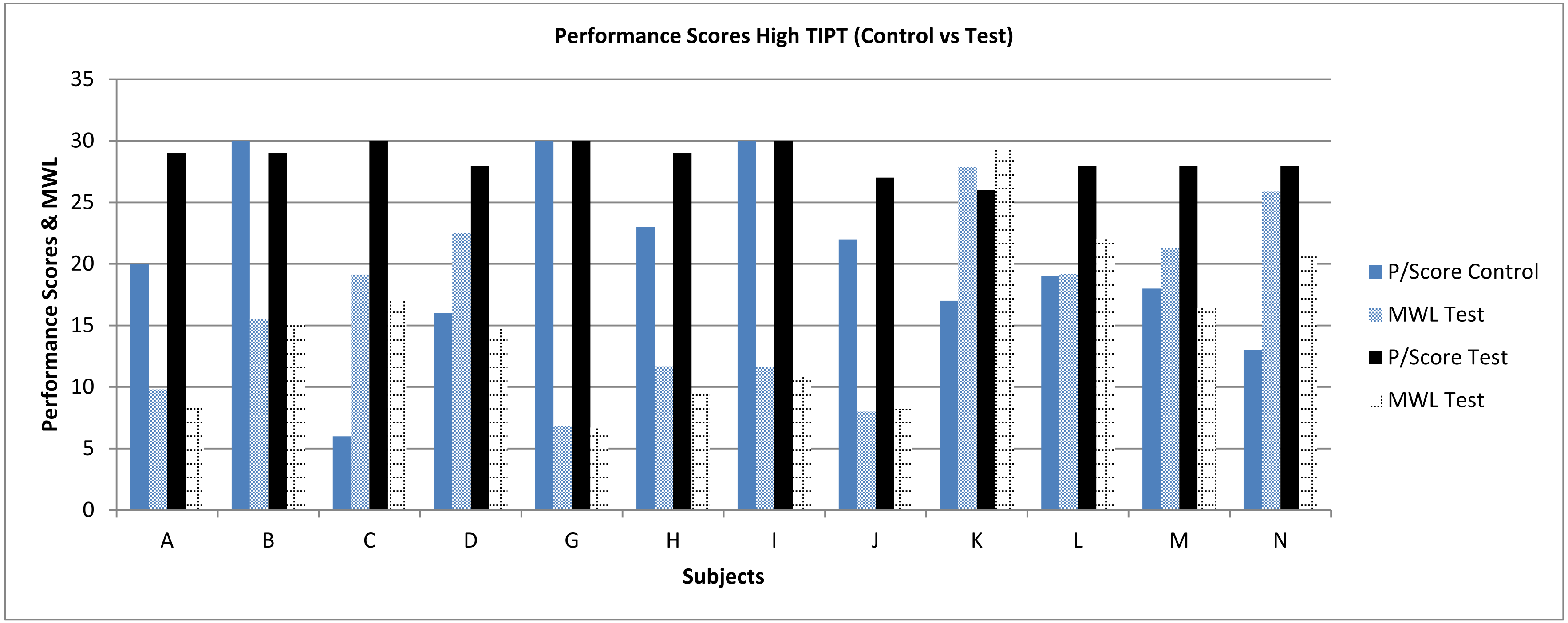


Figure 6-76 ***Performance scores high TIPT (control) vs high TIPT RAPS (test)***

Figure 6-76 illustrates the visual relationship between the MWL and the performance scores achieved. Performance scores were higher in all but one case during the test intervals and yet the MWL was either level or reduced between the high TIPT (control) and the high TIPT RAPS (test) intervals.

The research question to be answered was: What impact does the use of RAPS have on the performance results achieved across both low and high level TIPT’s?

RAPS not only produced a positive result in the performance improvement of post task assessment results achieved it also demonstrated a positive result in reducing the MWL during a high cognitive demanding task.

6.1.5 Research question 4

What impact does the use of RAPS have on the overall CE achieved across both low and high level TIPT’s?

In order to calculate the CE the UHCI needed to be established. This required the MWL baseline for each subject and the MWL for each of the following stimuli events - low TIPT (control): low TIPT RAPS (test): high TIPS (control): and high TIPT RAPS (test). The UHCI measure expresses the degree of variance from the baseline MWL and other events as a %.

Table 6-3 specifies each subject’s MWL for the baseline interval and the control and test interval’s for the low level cognitive tasks.

MWL across Baseline - Low TIPT (control) and Low TIPT RAPS (test)			
Subject	**Baseline**	**Low TIPT (control)**	**Low TIPT RAPS (Test)**
A	8.40	8.42	7.21
B	14.55	14.18	15.08
C	14.99	15.52	16.41
D	23.92	24.03	25.14
G	4.95	6.03	6.18
H	9.19	10.48	9.83
I	6.45	9.01	10.49
J	5.26	6.63	6.66
K	8.58	24.65	25.64
L	7.13	17.48	21.2
M	5.73	15.78	16.27
N	20.26	21.05	22.04

Table 6-3 MWL across baseline - low TIPT (control) and low TIPT RAPS (test)

Figure 6-76 illustrates the MWL for the baseline interval and the, control and test interval's for the low level cognitive tasks for all subjects.

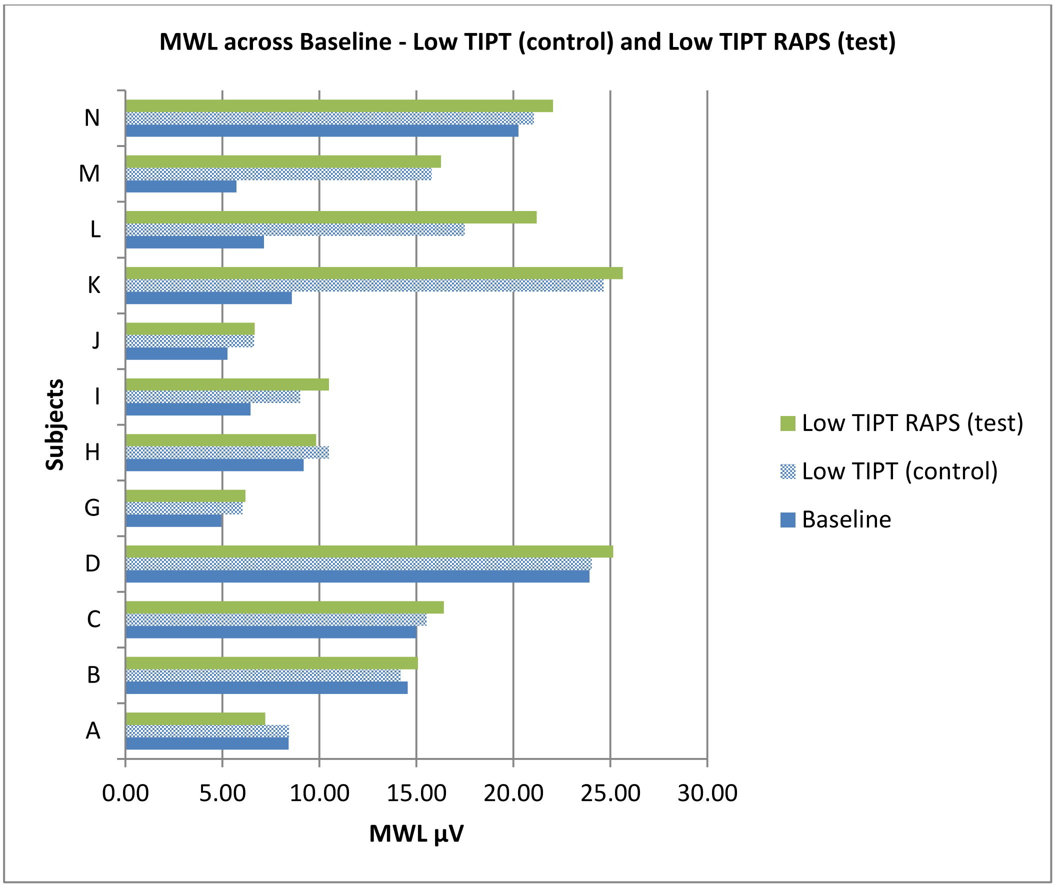


Figure 6-77 MWL - baseline, low TIPT (control) and low TIPT RAPS (test)

Figure 6-77 illustrates that the subjects C, D, G, I, J, K, L, M and N stood out with an increase from low TIPT (control) and low TIPT RAPS (test) intervals.

The following equation was used to calculate the Unique Human Cognitive Investment: (Test Interval MWL - Baseline MWL)/ Baseline MWL *100

UHCI - MWL variances between baseline and control & test tasks - Sum of the average alpha (8-12Hz) band power value µV					
Subject	Baseline	Low TIPT (control) µV	UHCI Low TIPT (Control) %	Low TIPT RAPS (Test) µV	UHCI Low TIPT RAPS (Test) %
A	8.40	8.42	0.20	7.21	-14.20
B	14.55	14.18	-2.54	15.08	3.64
C	14.99	15.52	3.54	16.41	9.47
D	23.92	24.03	0.46	25.14	5.10
G	4.95	6.03	21.82	6.18	24.85
H	9.19	10.48	14.04	9.83	6.96
I	6.45	9.01	39.69	10.49	62.64
J	5.26	6.63	26.05	6.66	26.62
K	8.58	24.65	187.30	25.64	198.83
L	7.13	17.48	145.02	21.2	197.17
M	5.73	15.78	175.63	16.27	184.19
N	20.26	21.05	3.90	22.04	8.79
mean		14.44	51.26	15.18	59.51
Stdev		6.50	72.86	7.15	82.88

Table 6-4 ***UHCI – low TIPT (control) an low TIPT RAPS (test)***

Table 6-4 details the MWL for baseline, low TIPT (control) and low TIPT RAPS (test) intervals and the UHCI for the low TIPT (control) and low TIPT RAPS (test) intervals. Table 6-5 shows the UHCI results for the low TIPT (control) and low TIPT RAPS (test) intervals extracted separately.

UHCI - Low TIPT (control) and (test)		
Subject	**Low TIPT (control)**	**Low TIPT RAPS (test)**
A	0.20	-14.20
B	-2.54	3.64
C	3.54	9.47
D	0.46	5.10
G	21.82	24.85
H	14.04	6.96
I	39.69	62.64
J	26.05	26.62
K	187.30	198.83
L	145.02	197.17
M	175.63	184.19
N	3.90	8.79

Table 6-5 ***UHCI- low TIPT (control) and low TIPT (test)***

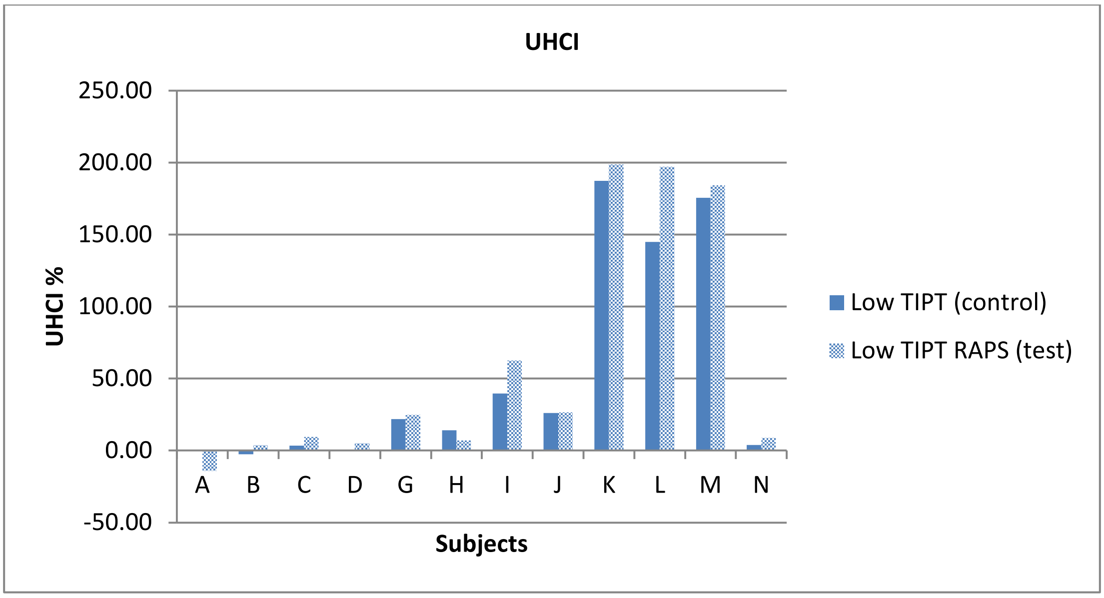


Figure 6-78 UHCI - low TIPT (control) and low TIPT RAPS (test)

Figure 6-78 shows that only subjects A and H experienced a reduction in UHCI between the low TIPT (control) and the low TIPT RAPS (test) tasks compared with 10 out of 12 who demonstrated an increase in UHCI.

9 out of 12 subjects, 75%, experienced an increase in MWL from a baseline MWL with a range of 2.19% to 10009.09%. 3 out of 12 subjects, 25% experienced a decrease in MWL from a baseline MWL with a range of -50.39 to -7117.65.

Microsoft Excel was used to carry out Paired T Tests to establish the mean and standard deviation across all subjects: High TIPT (control) and High TIPT RAPS (test).

They were as follows:

- UHCI low TIPT (control) 51.26 % with a standard deviation of 72.86 %.
- UHCI low TIPT RAPS (test) 59.51% with standard deviation of 82.88%.

With a mean increase for UHCI from Low Control to Low Test of 8.25%, no positive impact resulted in the use of RAPS in the Low TIPT.

Table 6-6 specifies each subjects MWL for the baseline interval and the control and test intervals for the high level cognitive tasks.

MWL across Baseline - High TIPT (control) and (test)			
Subject	Baseline	High TIPT (control)	High TIPT RAPS (test)
A	8.40	9.81	8.4
B	14.55	15.48	15.1
C	14.99	19.13	17.1
D	23.92	22.49	14.7
G	4.95	6.85	6.7
H	9.19	11.67	9.4
I	6.45	11.61	10.8
J	5.26	8.01	8.2
K	8.58	27.88	29.3
L	7.13	19.19	22.04
M	5.73	21.32	16.4
N	20.26	25.89	20.7

Table 6-6 *MWL across baseline - high TIPT (control) and (test)*

Figure 6-79 illustrates the MWL for the baseline interval and the control and tests interval for the low level cognitive tasks for all subjects.

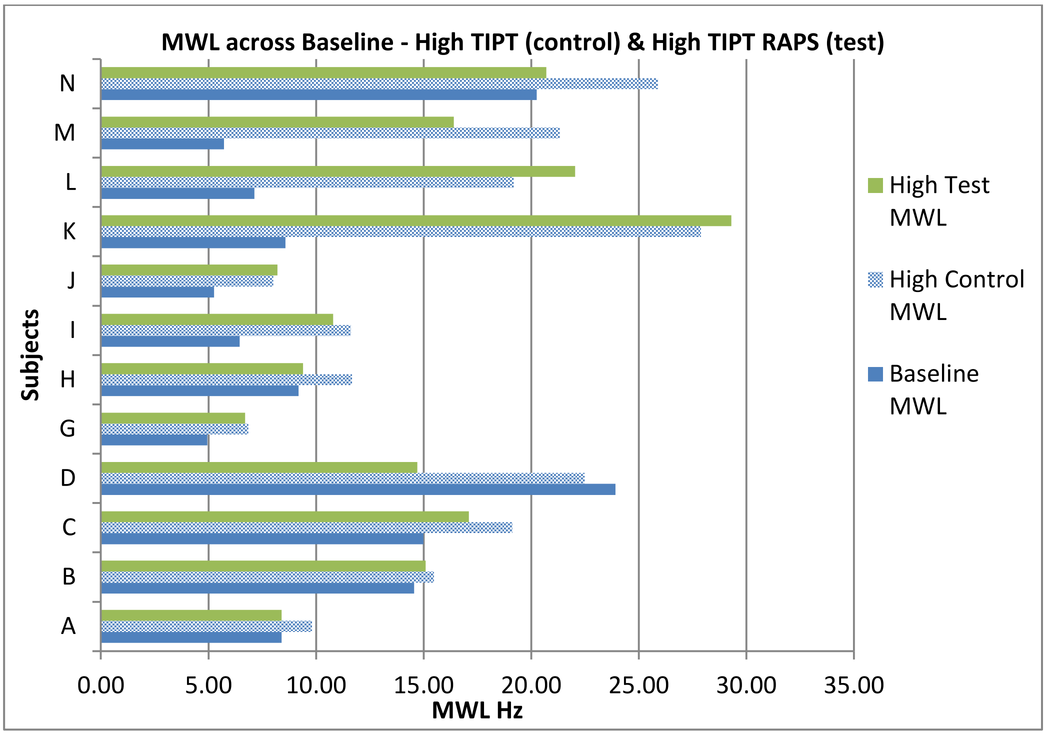


Figure 6-79 ***Baseline, high TIPT (control) and high TIPT RAPS (test)***

Figure 6-79 illustrates that subjects A, B C, D, G, H, I, M and N stood out with a decrease from high TIPT (control) and high TIPT RAPS (test) intervals.

The same process was repeated for the high level cognitive tasks across all subjects in order to calculate the UHCI: (test interval MWL - baseline MWL)/ baseline MWL *100.

UHCI - MWL differences between baseline and High TIPT (control) & High TIPT RAPS (test) tasks - Sum of the average band power value alpha (8-12Hz)					
Subject	Baseline	High TIPT (control) μv	UHCI High TIPT (Control) %	High TIPT RAPS (test) μV	UHCI High TIPT RAPS (Test) %
A	8.40	9.81	16.74	8.4	-0.04
B	14.55	15.48	6.39	15.1	3.78
C	14.99	19.13	27.62	17.1	14.08
D	23.92	22.49	-5.98	14.7	-38.55
G	4.95	6.85	38.38	6.7	35.35
H	9.19	11.67	26.99	9.4	2.29
I	6.45	11.61	80.00	10.8	67.44
J	5.26	8.01	52.28	8.2	55.89
K	8.58	27.88	224.94	29.3	241.49
L	7.13	19.19	168.99	22.04	208.94
M	5.73	21.32	272.40	16.4	186.46
N	20.26	25.89	27.79	20.7	2.17

Table 6-7 UHCI – high TIPT (control) and (test)

Table 6-7 details the MWL for the baseline, high TIPT (control) and high TIPT RAPS (test) intervals and the UHCI for the high TIPT (control) and the high TIPT RAPS (test) intervals. Table 6-8 shows the UHCI results for the high TIPT (control) and the high TIPT RAPS (test) intervals extracted separately.

UHCI - High TIPT (control) and High TIPT RAPS (test)		
Subject	High TIPT (control)	High TIPT RAPS (test)
A	16.74	-0.04
B	6.39	3.78
C	27.62	14.08
D	-5.98	-38.55
G	38.38	35.35
H	26.99	2.29
I	80.00	67.44
J	52.28	55.89
K	224.94	241.49
L	168.99	208.94
M	272.40	186.46
N	27.79	2.17

Table 6-7 UHCI - high TIPT control and high test (RAPS)

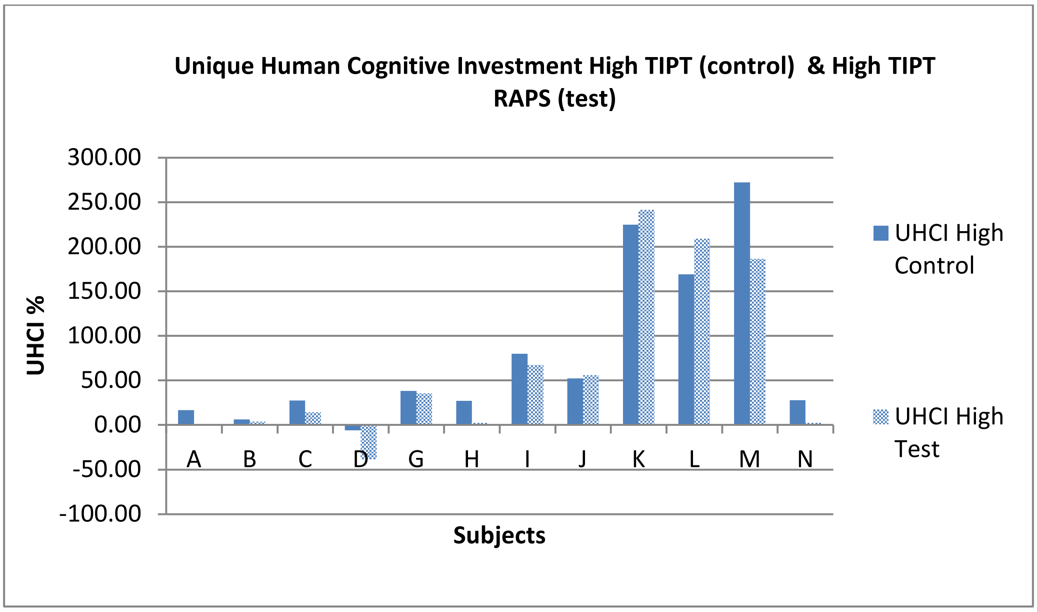


Figure 6-80 UHCI high TIPT (control) and high TIPT RAPS (test)

Figure 6-80 shows that subjects A, B, C, D, G, H, I, M and N experienced a reduction in UHCI between the high TIPT (control) and high TIPT RAPS (test) tasks compared with J, K, and L, who demonstrated an increase in UHCI.

Microsoft Excel was used to carry out Paired T Tests to establish the mean and standard deviation across all subject: high TIPT (control) and high TIPT RAPS (test). They were as follows:

- Mean UHCI high TIPT (control) 78.04 % with a standard deviation of 92.19%.
- Mean UHCI high TIPT RAPS (test) 64.94% with standard deviation of 93.79%.

6.1.5.1 Unique human cognitive investment/performance score analysis

Microsoft Excel was used to carry out paired T tests to establish the mean among: UHCI, low TIPT (control) and performance scores low TIPT (control).

As performance scores and UHCI were used to establish the CE and they were measured on different scales from each other, z scores were calculated for both prior to plotting the results. The following equation was used to establish z scores: *(x-mean)/stdev = z score* for the MWL low TIPT (control), performance score low TIPT (control) and MWL low TIPT (test), performance score low TIPT RAPS (test).

UHCI/PS Ratios Low (Control vs Test) TIPT													
Subject	UHCI Low TIPT (control)	zUHCI Low TIPT (control)	Low TIPT (control) Performance Score	zLow TIPT (control) Performance Score	zUHCI - Zperformance Score	CE Score Low (Control) TIPT	UHCI Low TIPT RAPS (test)	zUHCI Low TIPT RAPS (test)	Low TIPT RAPS (test) Performance Score	zLow TIPT RAPS (test) Performance Score	zUHCI - zPerformance Score	CE Score Low (Test) TIPT	Difference In Overall CE
A	0.20	-0.70	12	0.72	1.42	1.00	-14.20	-0.89	15	0.62	1.51	1.07	0.07
B	-2.54	-0.74	13	1.38	2.12	1.50	3.64	-0.67	15	0.62	1.30	0.92	-0.58
C	3.54	-0.66	11	0.06	0.71	0.50	9.47	-0.60	15	0.62	1.23	0.87	0.37
D	0.46	-0.70	11	0.06	0.75	0.53	5.10	-0.66	14	-0.87	-0.22	-0.15	-0.68
G	21.82	-0.40	12	0.72	1.12	0.79	24.85	-0.42	15	0.62	1.04	0.74	-0.06
H	14.04	-0.51	10	-0.61	-0.10	-0.07	6.96	-0.63	15	0.62	1.26	0.89	0.96
I	39.69	-0.16	13	1.38	1.54	1.09	62.64	0.04	15	0.62	0.59	0.41	-0.68
J	26.05	-0.35	9	-1.27	-0.93	-0.66	26.62	-0.40	15	0.62	1.02	0.72	**1.38**
K	187.30	1.87	12	0.72	-1.15	-0.81	198.83	1.68	13	-2.37	-4.05	-2.86	-2.05
L	145.02	1.29	9	-1.27	-2.56	-1.81	197.17	1.66	14	-0.87	-2.53	-1.79	0.02
M	175.63	1.71	9	-1.27	-2.98	-2.11	184.19	1.50	14	-0.87	-2.38	-1.68	0.43
N	3.90	-0.65	10	-0.61	0.04	0.03	8.79	-0.61	15	0.62	1.24	0.87	0.84

Table 6-8 CE low (control vs test) TIPT

Table 6-9 depicts the raw data results and the z scores for the UHCI, performance scores and calculated CE scores achieved by all subject during the low TIPT (control) and the low TIPT RAPS (test) intervals.

Figure 6-81 illustrates a collective visual representation of the UHCI/Performance Score (PS) ratios achieved across all subjects.

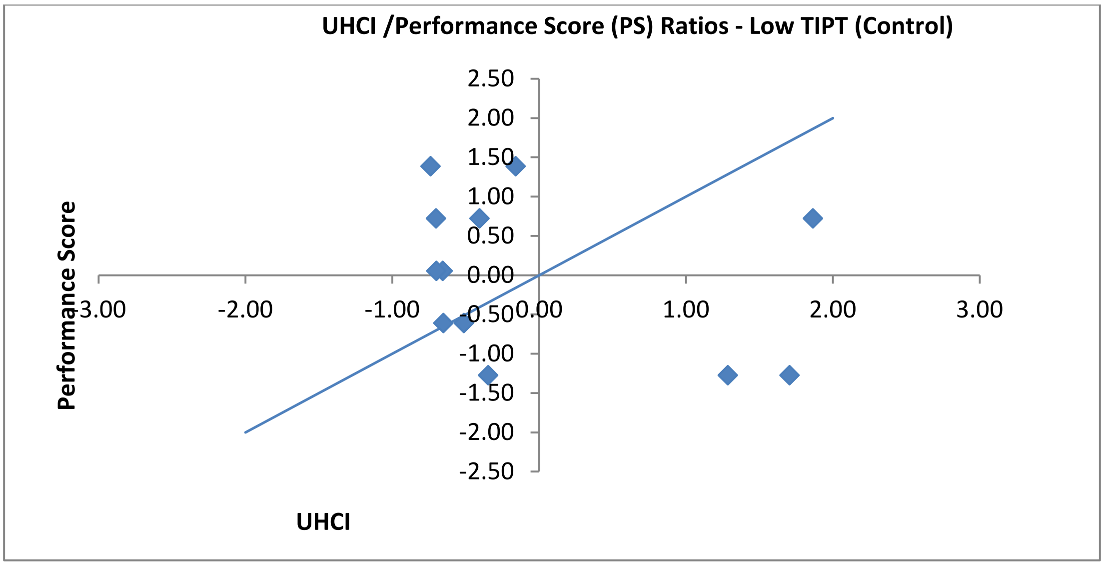


Figure 6-81 UHCI/PS ratio. low TIPT (control)

Figure 6-81 plots the subjects' UHCI/PS ratii achieved during the low TIPT (control) interval. The plot positions each of the subjects as follows:

- With a zUHCI result of <0 (-0.70) and a >0 (0.72) and a zperformance score, subject A achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.74) and a >0 (1.38) and a zperformance score, subject B achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.66) and a >0 (0.06) and a zperformance score, subject C achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.70) and a >0 (0.06) and a zperformance score, subject D achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.40) and a >0 (0.72) and a zperformance score, subject G achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.51) and a <0 (-0.61) and a zperformance score, subject H achieved an average UHCI/PS ratio.

- With a zUHCI result of <0 (-0.16) and a >0 (1.38) and a zperformance score, subject I achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.35) and a <0 (-1.27) and a zperformance score, subject J achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (1.87) and a >0 (0.72) and a zperformance score, subject K achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (1.29) and a <0 (-1.27) and a zperformance score, subject L achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (1.71) and a <0 (-1.27) and a zperformance score, subject M achieved a below average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.70) and a >0 (0.72) and a zperformance score, subject N achieved an above average UHCI/PS ratio.

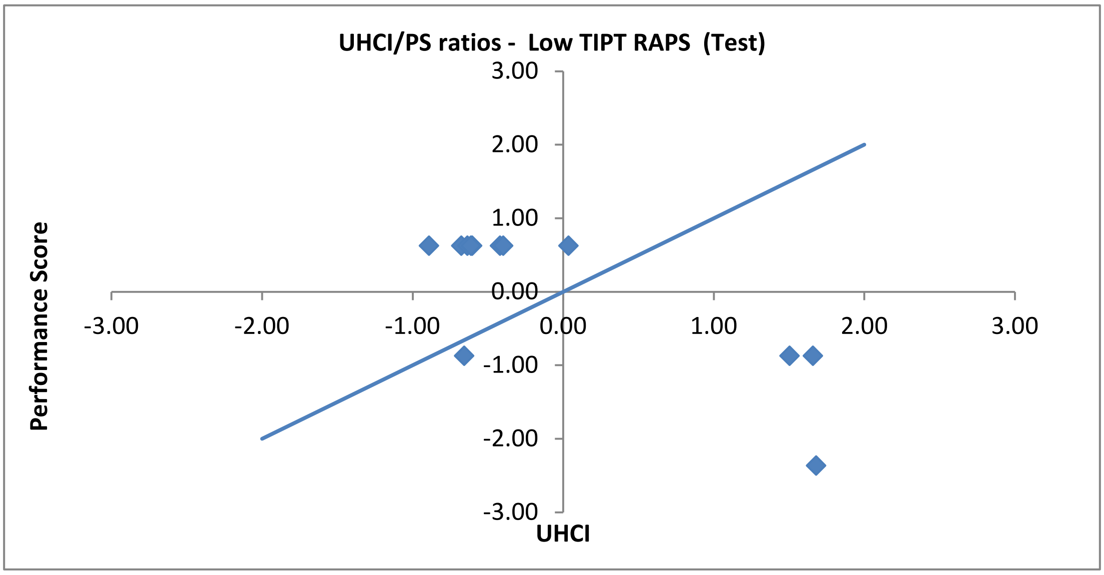


Figure 6-82 UHCI/Performance score ratio low TIPT RAPS (test)

Figure 6-82 plots the subjects UHCI/PS ratii achieved during the low TIPT RAPS (test) interval. The plot positions each of the subjects as follows:

- With a zUHCI result of <0 (-0.89) and a >0 (0.62) and a zperformance score, subject A achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.67) and a >0 (0.62) and a zperformance score, subject B achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.60) and a <0 (-0.87) and a zperformance score, subject C achieved an above average UHCI/PS ratio.

- With a zUHCI result of <0 (-0.66) and a <0 (-0.87) and a zperformance score, subject D achieved a lower than average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.42) and a >0 (0.62) and a zperformance score, subject G achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.63) and a >0 (0.62) and a zperformance score, subject H achieved an average UHCI/PS ratio.
- With a zUHCI result of >0 (0.04) and a >0 (0.62) and a zperformance score, subject I achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.40) and a >0 (0.62) and a zperformance score, subject J achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (1.68) and a <0 (-2.37) and a zperformance score, subject K achieved a lower than average UHCI/PS ratio.
- With a zUHCI result of >0 (1.66) and a <0 (-0.87) and a zperformance score, subject L achieved a lower than average UHCI/PS ratio.
- With a zUHCI result of >0 (1.50) and a <0 (-0.87) and a zperformance score, subject M achieved a below average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.61) and a >0 (0.62) and a zperformance score, subject N achieved an above average UHCI/PS ratio.

UHCI/PS Ratios High TIPT (control) and High TIPT RAPS (test)													
Subject	UHCI High TIPT (control)	zUHCI High TIPT (control)	High TIPT (control) Performance Score	zHigh TIPT (control) Performance Score	zUHCI - Zperformance Score	CE Score High (Control) TIPT	UHCI High TIPT RAPS (test)	zUHCI High TIPT RAPS (test)	High TIPT RAPS (test) Performance Score	zHigh TIPT RAPS (test) Performance Score	zUHCI - zPerformance Score	CE Score High (Test) TIPT	Difference In Overall CE
A	16.74	-0.66	20	-0.05	0.62	0.44	-0.04	-0.69	29	0.40	1.10	0.77	0.34
B	6.39	-0.78	30	1.32	2.10	1.49	3.78	-0.65	29	0.40	1.05	0.75	-0.74
C	27.62	-0.55	6	-1.96	-1.42	-1.00	14.08	-0.54	30	1.21	1.75	1.24	2.24
D	-5.98	-0.91	16	-0.59	0.32	0.22	-38.55	-1.10	28	-0.40	0.70	0.50	0.27
G	38.38	-0.43	30	1.32	1.75	1.24	35.35	-0.32	30	1.21	1.52	1.08	-0.16
H	26.99	-0.55	23	0.37	0.92	0.65	2.29	-0.67	29	0.40	1.07	0.76	0.11
I	80.00	0.02	30	1.32	1.30	0.92	67.44	0.03	30	1.21	1.18	0.83	-0.09
J	52.28	-0.28	22	0.23	0.51	0.36	55.89	-0.10	27	-1.21	-1.11	-0.78	-1.14
K	224.94	1.59	17	-0.46	-2.05	-1.45	241.49	1.88	26	-2.01	-3.89	-2.75	-1.30
L	168.99	0.99	19	-0.18	-1.17	-0.83	208.94	1.54	28	-0.40	-1.94	-1.37	-0.54
M	272.40	2.11	18	-0.32	-2.43	-1.72	186.46	1.30	28	-0.40	-1.70	-1.20	0.52
N	27.79	-0.55	13	-1.00	-0.46	-0.32	2.17	-0.67	28	-0.40	0.27	0.19	0.51

Table 6-9 UHCI/Performance score ratio high TIPT (control) vs high TIPT RAPS (test)

Table 6-10 depicts the raw data results and the z scores for the UHCI, performance scores and calculated CE scores achieved by all subjects during the high TIPT (control) and high TIPT RAPS (test) intervals.

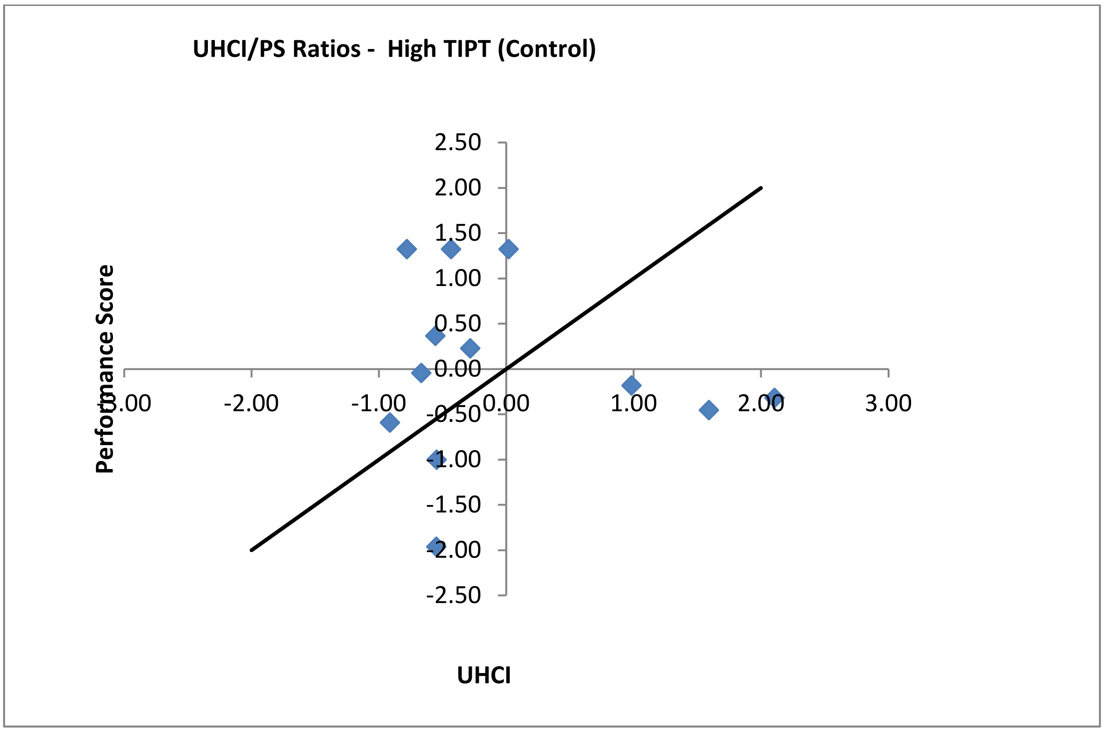


Figure 6-83 UHCI/PS high (control) TIPT

Figure 6-83 plots the subjects' UHCI/PS ratii achieved during the high TIPT (control) interval. The plot positions each of the subjects as follows:

- With a zUHCI result of <0 (-0.66) and a <0 (-0.05) zperformance score, subject A achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.78) and a >0 (1.32) zperformance score, subject B achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.55) and a <0 (-1.96) zperformance score, subject C achieved a below average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.91) and a <0 (-0.59) zperformance score, subject D achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.43) and a >0 (1.32) zperformance score, subject G achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.55) and a >0 (37.0) zperformance score, subject H achieved a slightly below average UHCI/PS ratio.

- With a zUHCI result of >0 (0.02) and a >0 (1.32) zperformance score, subject I achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.28) and a >0 (0.23) zperformance score, subject J achieved an above average UHCI/PS ratio.
- With a zUHCI result of >0 (1.59) and a <0 (-0.46) zperformance score, subject K achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (0.99) and a <0 (-0.18) zperformance score, subject L achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (2.11) and a <0 (-0.32) zperformance score, subject M achieved a below average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.55) and a <0 (-1.00) zperformance score, subject N achieved a below average UHCI/PS ratio.

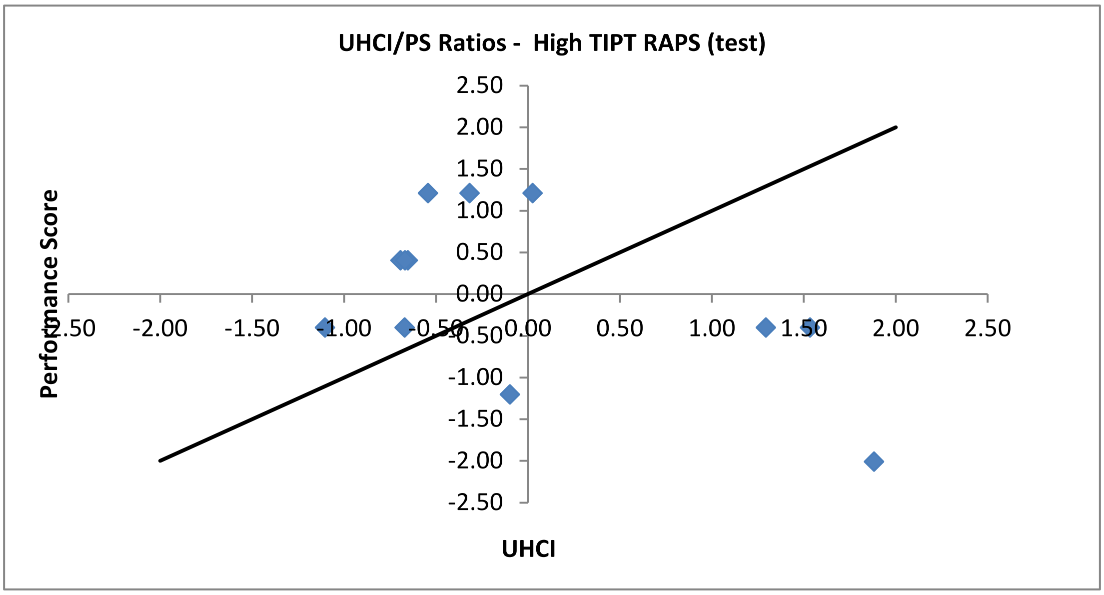


Figure 6-84 UHCI/PS high (test) TIPT

Figure 6-84 plots the subjects' UHCI/PS ratii achieved during the high TIPT RAPS (test) interval. The plot positions each of the subjects as follows:

- With a zUHCI result of <0 (-0.69) and a >0 (0.40) and a zperformance score, subject A achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.65) and a >0 (0.40) and a zperformance score, subject B achieved an above average UHCI/PS ratio.

- With a zUHCI result of <0 (-0.54) and a >0 (1.21) and a zperformance score, subject C achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-1.10) and a <0 (0.40) and a zperformance score, subject D achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.32) and a >0 (1.21) and a zperformance score, subject G achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.67) and a >0 (0.40) and a zperformance score, subject H achieved an above average UHCI/PS ratio.
- With a zUHCI result of >0 (0.03) and a >0 (1.21) and a zperformance score, subject I achieved an above average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.10) and a <0 (-1.21) and a zperformance score, subject J achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (1.88) and a <0 (-2.01) and a zperformance score, subject K achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (1.54) and a <0 (-0.40) and a zperformance score, subject L achieved a below average UHCI/PS ratio.
- With a zUHCI result of >0 (1.30) and a <0 (-0.40) and a zperformance score, subject M achieved a below average UHCI/PS ratio.
- With a zUHCI result of <0 (-0.67) and a <0 (-0.40) and a zperformance score, subject N achieved an above average UHCI/PS ratio.

6.1.5.2 CE analysis

Study results from *Table 6-9* was extracted, and the following equation was used to establish the CE scores: *(zperformance – zUHCI)/sq2 = CE* for the low TIPT (control) and the low TIPT RAPS (test), *trials.*

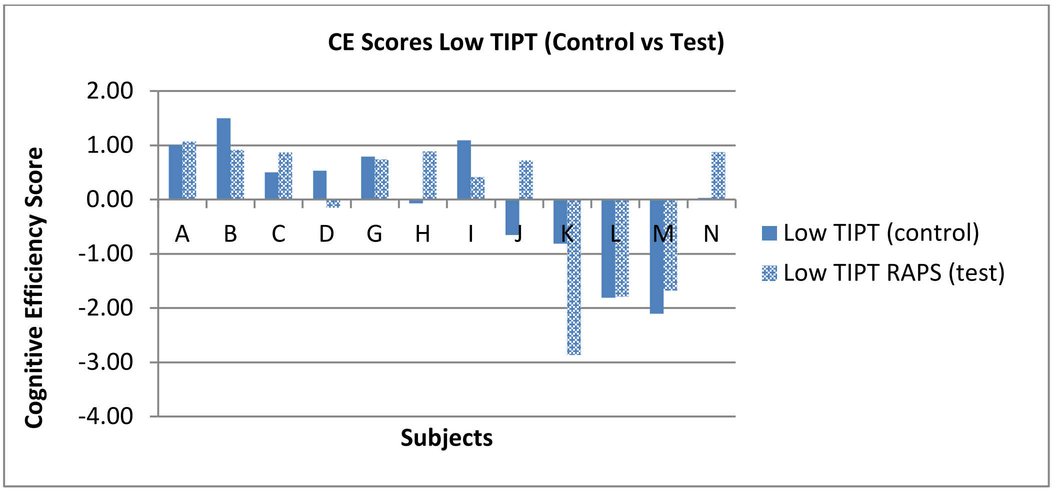


Figure 6-85 CE scores low TIPT (control vs test)

Figure 6-85 displays the level of CE achieved across all subjects during both the low TIPT (control) and the low TIPT RAPS (test) intervals. The results achieved were as follows:

- 58% of subjects, 7 out of 12, achieved a >0 level of CE during the low TIPT (Control) Task and 42% of subjects, 5 out of 12, achieved a <0 level of CE.
- 67% of subjects, 8 out of 12, subjects achieved a > 0 level of CE during the low TIPT (Test) Task and 33% of subjects, 4 out of 12, achieved a <0 level of CE
- A further 0.09% increase in subjects achieving a CE score of >0 was achieved between the control task and the test (RAPS) stimuli.
- 58% of subjects, 7 out of 12, achieved an above average >0 CE score when presented with the test stimuli.
- 42% of subjects, 5 out of 12, achieved an increase in CE when presented with the test stimuli with a collective average of 1.62% in CE across all subjects.
- 8 out of 12 subjects, 58%, achieved an increase in CE when presented with the test stimuli with a collective average of 51% in CE across all subjects
- 5 out of 12 subjects, 42% achieved a decrease in CE when presented with the test stimuli with a collective average of 1.62 in CE across all subjects.

The process was repeated using Microsoft Excel to carry out paired T tests to establish the mean between - UHCI high TIPT (control) and performance scores high TIPT (control).

As performance scores and UHCI were used to establish the CE and both are as they were measured on different scales from each other, z scores were calculated for both prior to plotting the results. The following equation was used to establish z scores: *(x-mean)/stdev) = z score* for the MWL high TIPT (control), performance score high TIPT (control) and MWL high TIPT (test), performance score high TIPT RAPS (test).

Study results displayed in Table 6-10 were extracted and the following equation was used to establish the CE scores: (zPerformance – zUHCI)/sq2 = CE for the high TIPT (control) and the high TIPT RAPS (test), trials.

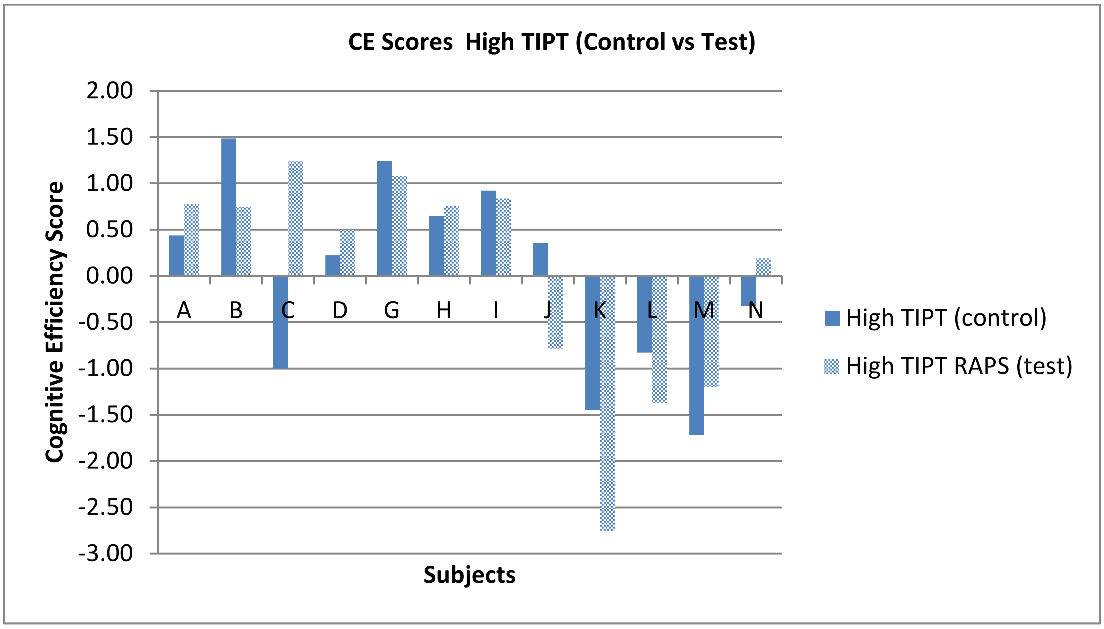


Figure 6-86 ***CE scores high TIPT (control vs test)***

Figure 6-86 displays the level of CE achieved across all subjects during both the high TIPT (control) and the high TIPT RAPS (test) intervals. The results achieved were as follows:

- 58% of subjects, 7 out of 12, achieved an above average (>0) level of CE during the low TIPT (Control) Task and 42% of subjects -the remaining 5 subjects, achieved a below (<0) average level of CE.

- 67% of subjects, 8 out of 12, achieved an above average (> 0) level of CE during the Low TIPT RAPS (test) Task and 4 out of 12, or 33%, achieved a below average (<0) level of CE.
- A further 9% increase in subjects achieving an above average CE score of >0 was achieved between the control task and the test (RAPS) stimuli.
- 50% of subjects, 6 out of 12, achieved an increase in CE when presented with the test stimuli, with a collective average of 70% in CE across all subjects.
- 50% of subjects, 6 out of 12, achieved an decrease in CE when presented with the test stimuli, with a collective average of 62% in CE across all subjects.

This study has answered the research question: What impact does the use of RAPS have on the overall CE achieved across both low and high level TIPT's?

This chapter provided both descriptive and quantitative analysis of the data with reference to the study's research questions, commencing firstly with: How does the MWL differ between a low cognitive demanding transient information processing task (TIPT) and a high cognitive demanding TIPT? The findings indicate: the sum of the average band power μV - ϴ (3-8Hz), α (8-12Hz) and β (8-30Hz) across all tasks for each subject, a collective sum of the average band power μV - ϴ (3-8Hz), α (8-12Hz) and β (8-30Hz) across all tasks, MWL low (control)/ high (control) and low (test)/ high (test) tasks per subject, low μV low TIPT RAPS (test) task vs high RAPS TIPT (test) task - sum of the average alpha (8-12Hz) band power value μV of all subjects. The focus shifts to research question 2: What impact does the use of RAPS have on the MWL imposed during a low cognitive demanding and a high cognitive demanding TIPT? The MWL low TIPT (control)/low TIPT RAPS (test) and high TIPT (control)/ high TIPT RAPS (test) have been displayed for each subject. Research question 3: What impact does the use of RAPS have on the performance results achieved across both low and high level TIPT's? The individual performance score analysis demonstrated - PS low TIPT (control)/(test) and high TIPT (control)/(test) for each subject. Finally, showing the data results were used to address research question 4: What impact does the use of RAPS have on the overall CE achieved across both low and high level TIPT’s? The UHCI/PS analysis and corresponding CE analysis have been illustrated here.

Figure 6-85 demonstrates the overall results of the CE achieved in the low TIPT (control) and the low TIPT RAPS (test) intervals and Figure 6-86 illustrates the CE achieved during the high TIPT (control) and the high TIPT RAPS (test) intervals. Results across both trials demonstrated that 58% of the subjects achieved an above average level >0 of CE between the control and the test intervals. Figures 116 and 117 results indicated an increase of 8% of subjects achieving an above average level of CE when presented with the RAPS stimuli.

Chapter 7 Discussion and Outcomes

The previous chapter took the data collected and provided a detailed analysis according to the research questions. The data were presented in a linear and iterative format, with each data set building on the previous set. Both individual and collective data averages were shown.

This chapter highlights the study's outcomes, discusses the results of the study in view of relevant current literature and outlines the implications of the study's findings within the broader community. The limitations of the study are acknowledged and possible future research is mooted, with special mention of the specific contributions to knowledge by this study.

7.1 Outcomes

Key outcomes of this study included the following:

In summary, this study established that MWL from a neurophysiological measure differed between a low cognitive demanding transient information processing task (TIPT) and a high cognitive demanding TIPT in both settings where subjects completed the low and high TIPT (control) tasks and the low and high TIPT RAPS (test) tasks.

The use of reverse assessment priming stimuli (RAPS) had minimal impact on the MWL imposed during a low cognitive demanding TIPT. However, this study highlighted that the use of RAPS can prove to be an effective strategy in reducing the MWL experienced during a high cognitive demanding TIPT.

The results of this study confirmed that the use of RAPS resulted in a positive impact on the performance results achieved across both low and high level TIPTs in all possible situations.

Findings demonstrated that the use of RAPS had a positive impact on, and promoted an increase in the cognitive efficiency (CE) that can be achieved during a TIPT.

7.2 Discussion

This study investigated the MWL and cognitive demand placed on individuals as they undertook a task. The task was made up of transient information. There were two levels of task complexity: a low transient information task that was two minutes in duration; and a high transient information task that was four minutes in duration.

Each participant completed six low and six high TIPT's and of the six, three were control tasks and three were test interval tasks. The test interval tasks included the use of a RAPS strategy being tested as to the impact that it may have on the cognitive demand experienced by individuals. All tasks were presented in audio format as this is categorised as speech and out of the control of the listener so that they have no control over the rate of speed at which it is presented, they cannot alter this nor can they make a more permanent record of the information as it is presented other than relying on their own cognitive capacity. Owing to these reasons this task is categorised as a transient information task, implying that the information appears and disappears before the human cognitive system can effectively process it.

Collectively the results demonstrated that the use of RAPS as an instructional, information transfer, knowledge construction design principle or strategy can have positive results. This study showed that a positive impact was experienced when RAPS was used as a strategy. It demonstrated success in reducing the MWL during the completion of a TIPT, RAPS also showed that it can assist in increasing the level of human performance that can be achieved during the transient tasks. This was calculated by using post assessment task scores and then, by combining them with a unique set of metrics, it was established that RAPS had a positive impact on improving the overall level of CE achieved during a TIPT.

Results established and supported the use of EEG in measuring the objective MWL experienced during a TIPT. Individual and collective results illustrated that MWL increased as a task became more complex, increased the demand on working memory and required more information to be held, linked and processed in order to complete a task. The neural activity increased in 91% of subjects between the low and high TIPT (control) tasks and in 75% of subjects between the low and high RAPS (test) tasks.

RAPS had a minimal effect on the low cognitive demanding tasks, although as the level of task complexity increased so too did the positive impact of using RAPS. This study has established that the use of RAPS is an effective strategy to reduce MLW during a TIPT; in this study it resulted in a decrease of up to 34.64% in MWL.

The study's outcomes demonstrated that in 100% of subjects an increase was achieved in the human performance between the low TIPT (control) and the low TIPT RAPS (test) tasks, recording an increase of up to 40% in the performance scores achieved. Furthermore during the high TIPT (control) and high TIPT RAPS (test) intervals, in fact wherever an increase was at all possible an increase was experienced and evident in the performance score results. Therefore the results of this study demonstrated that in 100% of situations subjects experienced an increase in performance scores of up to 80%.

CE was increased as a result of using RAPS. There was an 8% increase in subjects achieving an above average >0 CE score between the control and the test intervals, thereby confirming that RAPS had a positive impact on the overall CE achieved during a TIPT.

The study's results supported that strategies designed to assist in reducing the cognitive demand or improving performance during a TIPT typically increase in their effectiveness as the task difficulty increases. Results revealed that minimal impact if any was achieved during a simple cognitive task as indicated in previous cognitive research.

The results of this human cognitive performance study, the neurophysiological data and the post task assessment data have demonstrated that RAPS is an effective strategy and can be used to reduce MWL, improve human performance and contribute to achieving an overall higher level of CE during TIPT. This finding has supported the overarching belief that how we process information and therefore how we learn are reliant on the HCA (Hatsidimitris, 2012).

The cognitive demand of the TIPT in this study was developed to evoke the "transient effect" as devised by Sweller et al. (2011d). With differing levels of demand, the cognitive resources required would also vary. In viewing information as a load on cognitive resources, it was appropriate to adopt a relevant strategy (Sweller, Ayres, & Kalyuga, 2011c) for the design and development that were imposed; therefore the RAPS was developed.

This study highlights that without consideration of the HCA we run the risk of ineffective cognitive processing. This proposition has already been asserted by Reed (2012), who stated that “as a result of interrupting the natural HCA information-processing stages that learners use to encode, store and modify information” (p. 1452) effective information processing is hindered and optimal results are unlikely. Further, Sweller (2012) stated that “the manner in which the components that constitute human cognition are organised” (p. 15). The sensory information stage was flooded with incoming sensory information that before long proved to overwhelm the subjects. Effective processing is then dependent on the cognitive capacity of an individual to continue with the other sub stages that are required in processing, reducing and elaborating on new information. This study’s results indicated that the storage and the recovery of information suffered as a result of the inability to make a more permanent record of a continual flow of auditory information (Neisser, 1967, p. 4), thereby resulting in what is known as phonological attention rehearsal interruption (PARI) whereby rehearsal is hindered by the continual flow of information. This finding supported the findings in the literature that “the extent to which any instruction is effective depends heavily on whether it takes the characteristics of human cognition into account” (Sweller, 2008b, p. 370).

This study was designed to push the capacity boundaries of the HCA. Stimuli were purposefully created to impose a varied level of cognitive demand on the subjects at both a low and high levels of complexity. Revithis et al. (2010) stated that, “in such an architecture, the impact of cognitive load on knowledge acquisition is substantial” (p. 299). The results of this study provided evidence that this is actually the case and that stimuli are not compatible with the structure and functionality of the HCA will struggle to achieve successful knowledge integration and as shown on this study the level of CE is not optimised.

In considering the HCA, the literature discusses a wide range of strategies that may be applied to instructional design and to concept mapping interactive animations, both of which have demonstrated the ability to impact on the degree of learning achieved (Verhoeven et al., 2009; West et al., 1991). West et al. (1991) recommended taking a “hybridization, or combination of cognitive strategies” (p. 19) approach. This is unlike most design strategies that are applied to content in an attempt to reduce the cognitive demand placed on the individual or to increase the degree of knowledge construction that takes place, the format or the modality of the information being presented.

The RAPS strategy was designed to be a high level model and open to being replicated across a broad range of contexts and domains. The intent was to test the priming factor against what in most workplaces and learning environments would be referred to as “outcomes” or “key pieces of information”. A specific objective was in mind when designing RAPS; it was an intentional consideration that the RAPS model would have the capacity to be applied within an organisational context whereby important strategic and commercial information requires a high level of knowledge transfer, accurate interpretation, understanding and synthesis.

The RAPS strategy was essentially designed to simulate a previous event or exposure in order to fast track an individual’s schema in order to achieve a more desirable and efficient outcome.

The results of this study illustrated that the RAPS technique supports a schema-based learning approach hence the results emphasise the need to appreciate the prior experiences, knowledge and contextual circumstances of an individual or intended audience in order to achieve effective communications through differing modes and formatting of information. This has developed from the perspective that the information presented to the individuals will form prior knowledge and will assist working memory when presented with additional incoming stimuli, thereby enabling the subject to identify a link between the stored knowledge (the newly created schema) and the new information (Lee & Seel, 2012).

The study’s findings have proven true. The aim of the RAPS technique allowed subjects to activate previously stored schema and small well-structured and filed or carefully organised knowledge networks that relate and categorize information to which the individual has previously been exposed (Bransford, 1984), in order to benefit from a schema on or from which they otherwise would not have had to rely or draw to assist them in completing a task (Bransford, 1984) . This simulation of prior experience or exposure to information resulted in the reduction of

MWL or cognitive demand experienced by individuals. Even more impressive was that on top of this result individuals demonstrated an increase in both performance and the overall level of CE achieved during the completion of the TIPT (Bransford, 1984, p. 264).

The success of RAPS can also be aligned with the “narrow limits of change” theory that humans construct knowledge by relying on the long term memory stores and using a series of “small incremental changes” to add new information to current knowledge in narrow increments, RAPS provided a trace or a predeveloped schema in which the new information can be assimilated (Sweller, 2008b, p. 373).

The understanding of the roles and functions of the working memory are accepted throughout the literature albeit with a few variations (Baddeley, 1986, 1992; Baddeley & Hitch, 1974; Carpenter et al., 2000; Daneman & Carpenter, 1980; Engle et al., 1999; Ericsson & Kintsch, 1995; Fougnie, 2008). However, there remains an absence of clearly defined boundaries and interrelated components between attention and working memory. Fougnie (2008) suggested one of the variations whereby attention and working memory overlap as opposed to the working memory being responsible for attention. The results of this study, even within its limited scope, support this view. They do not seem to be able to operate synchronously without depleting the capacity of the other. More research is needed in the area of differentiating these sub structures of the human cognitive system. What was made clear in this study was that, when a person’s attention is guided towards particular stimuli, this can be a successful strategy and can play an influential role in future information processing. Results from this study validated and supported the view of Gazzaley and Nobre (2012) that the stimulus that is successful in gaining the attention of the working memory will maintain the foci and therefore the information presented will go on to be encoded (Gazzaley & Nobre, 2012).

It can be said that a person’s real cognitive capacity is influenced by the way that she or he uses these stored networks and arranges chunks of information to assimilate further new schema into existing schema. This proposition was evidenced in this study’s results as subjects were faced with novel information and with few knowledge construction opportunities or capabilities owing to the nature of the information modality and with RAPS providing a level of existing schema, reducing

MWL and increasing cognitive capacity, resulting in increased performance and efficiency (Hendel et al., 2011).

The TIPT was designed in such a way that the subject was required to listen to the audio information without the opportunity to stop, pause or replay. This posed a major conflict of attentional resources for the human cognitive system. As novel information was received, subjects attempted to process the information, receive the information, make any sense of the information, attempt to find patterns and link it with any previously stored information; this proved to be difficult as simultaneously new information continued to be presented. This is shown in both working memory models, first raised by Atkinson and Shiffrin (1968) as seen in Figure 2-1 and in Baddeley and Hitch's (1974) revised working memory model as shown in Figure 2-2. It can be seen how this situation is not conducive to processing information effectively. Information processing was interrupted at the point when the subject was attempting to rehearse what she or he had heard; this phonological rehearsal acted as an internal voice and assisted in making a more permanent record of the incoming stimuli (Baddeley, 2003; RepovŠ & Baddeley, 2006; Smith & Jonides, 1997). Subjects were faced with a continual flow of auditory stimuli. This interruption took place before much of the information was analysed, consolidated and transferred to the phonological store as new schema and finally as long term memory for future use.

The results of this study reiterated and supported the early literature, as Chandler and Sweller (1991) pointed out that the continuous stream of auditory input may be detrimental to the successful storage and processing of information. Complex auditory stimuli sets without an opportunity for phonological rehearsal stage to take place and without a review of the stimuli will impede the ability to analyse, store and process the information and therefore the acquisition of new knowledge or skills (Chandler & Sweller, 1991). Chandler and Sweller (1991) revealed this challenge in processing information 25 years ago.

Little research is evident other than that of schema acquisition and the effects of different stimuli formats have been heavily studied in recent years, such as presenting text only or diagrams separately, or combining them or in multimodal formats all in an attempt to work with the constructs of the HCA and working memory components (Baddeley, 1998; Ginns et al., 2003; Gog et al., 2009; Sweller &

Chandler, 1994b; Wayne et al., 2003). It is not known throughout the recent research literature whether any progress has been made in researching the reduction of MWL, increasing human performance or achieving a higher level of CE within the areas of transient information processing. Therefore it is both refreshing and significant to report that the findings of this study contribute a new positive insight into a technique that can assist in processing complex auditory processing and that has the potential to be replicated in future research in other cognitive processing settings.

In an age with such advances in technology, the definition of human performance, what it includes and how it is measured have changed dramatically (Rasmussen, 1983; Wei & Salvendy, 2006). With jobs changing and roles evolving, the emphasis and demands of physical motor skills have shifted and a new prominence applies to cognitive capacity (Wei & Salvendy, 2006). This is typical of what can be found across workplaces every day, with copious amounts of information overloading the working memory and not allowing the learner sufficient timing to process the material or forcing the learner to have to go in search of information that at this point in the learning process is difficult to locate (Jong, 2010). Sweller et al. (1998) differentiates between mental load and mental effort: as “the amount of cognitive capacity or resources that is actually allocated to accommodate the task demands” (p. 266). It was an important feature of this study not only to aim to reduce MWL and to increase performance and efficiency level but also to establish a credible, accurate and reliable measure of an individual’s cognitive effort. Accordingly to the Unique Human Cognitive Investment (UHCI) metric was developed to provide an account of mental effort that it required from an individual from a baseline in order to complete a given task.

Sweller et al. (2011d) define the transient information as the resulting effect when learning cannot occur owing to an inadequate length of display time, therefore processing and linking to current information cannot take place. It was also hypothesized by Leahy and Sweller (2011) that “complex information may impose an overwhelming working memory load when presented in transient” (p. 943) format.

Symptomatically of the impact that the TIPT has on an individual’s cognitive processing capacity, this effect has been deemed the PARI cognitive processing effect. Such an interruption inhibits a full phonological processing cycle from taking place. It is thought to have followed the belief of Mayer (Mayer, 2001) as the presentation of transient information may very well engage learners but also require them to pay attention to an onslaught of information, which then requires those learners to process information simultaneously, thereby causing conflict between the roles of the working memory between phonological attention and phonological rehearsal.

Physiological measures have the capacity to provide a continuous account of the cognitive load experienced (Shriram et al., 2009), therefore allowing the option to review the cognitive load in time locked intervals providing continuous and/or averages of periods of time and reference this information back to the stimuli that were presented. The use of EEG was selected in this study to ensure that the data that were collected would be accurate accounts of the continuous stimuli events. It is well known that the field of neuroscience uses technology such as electroencephalography (EEG) to collect data and this method can be seen in the current literature about cognitive behavior and learning whilst also satisfying the increasing need for more “biologic accuracy” (Gregory Ashby & Helie, 2011, p. 273) in the neural activity measurement. Guided by this earlier research, this study focused on the collection and analysis of the alpha rhythm as this is stated as being the most stable of all the brain rhythms (Maltseva & Masloboev, n.d, p. 3).

Aligned with the literature, it was demonstrated in this study’s data and findings that MWL can be determined when there is an increase in alpha band rhythms (Gevins & Smith, 2000). Other interpretations required noting, including the alpha – theta band ratio in order to determine cognitive workload (Berka et al., 2007). Delta, beta, theta and alpha bands were also reviewed for any patterns or indications of change in relation to the change in stimuli. This showed no obvious signs of correlation whereas the relationship between the alpha bad and the stimuli was clearly evident. All MWL and UHCI measures were determined by using the alpha data.

This study is therefore able to confirm that:

- The neural activity of subjects increased between the low and the high TIPT (control) tasks and between the low and the high RAPS (test) tasks.
- The use of RAPS is an effective strategy to reduce MLW during a TIPT.

- An increase was achieved in the human performance between the low TIPT (control) and the low TIPT RAPS (test) tasks.
- During the high TIPT (control) and the high TIPT RAPS (test) intervals, an increase in performance scores was achieved.
- RAPS had a positive impact on the overall CE achieved during a TIPT.

7.3 Implications

The outcome of this study is intended to contribute further to the available literature and to the extensive research completed to date about Cognitive Load Theory (CLT) and the use of the RAPS strategy and the impact on human performance and CE.

Human performance is heavily reliant on an individual’s cognitive capacity. Neuroergonomics enable the design of workplace settings, environments and tasks to consider how the human brain reacts in everyday settings (Wickens, Hollands, Banbury, & Parasuraman, 2013). Learning, memory, problems solving or decision making are all cognitive processes that play an important role in an individual’s ability to perform everyday tasks and contribute in an effective capacity. These processes place demands on our cognitive system, the HCA, which by nature is limited. This study supports the existing literature in that it shows that when information or instructional design strategies take on a human approach and when these limitations are considered, it is possible to reduce the mental demand of a task, improve human performance and achieve a more optimal level of CE.

Human performance is typically measured by an output or a level of task related achievements. When the desired level of performance is perceived not to have been met, generally a process of “performance management” is commenced. Unfortunately this approach assumes that the individual either is not willing to invest the required effort and/or does not possess the required skill set in order to achieve the given task. There are in fact many other elements of and contributing factors in human performance, with an individual’s cognitive capacity being one, albeit a major one. Factors such as task design, environment, and social and affective states all contribute to the overall performance and efficiency of an individual. This study makes a positive contribution to the field of human performance, by further demonstrating how closely MWL is linked with task design and presentation mode. This study also reemphasises the degree of influence that information design strategies can have on human performance and supports the use of neurophysiological methodologies and data as an objective means to measure quantifiably the cognitive demands placed on an individual. Having such clear and measurable data enables the core contributing factors in poor human performance to be identified and tested and solution initiatives to be devised.

7.4 Limitations and future research

Limitations existed whereby the study examined the data from 13 subjects, thereby allowing only a limited case for making generalised statements.

Another limitation of the study was that it was restricted in the cohort of subjects, who were university staff members and students. It is not known whether this had an impact on the data that were collected. It is a possibility that if the subjects had been from a broader demographic the data may or may not have been different and therefore have yielded different results.

This study provides a basis for future research in the specific areas of transient information processing and its impact on cognitive load. Future research should endeavor to study varieties of transiency other than auditory and should encompass the experimental exploration of a range of different strategies that may have a positive impact on the MWL that is placed on learners during the processing or that may improve the performance measures and therefore increase the overall CE achieved.

Areas that can benefit from more specific research are within the fields of cognitive task analysis, cognitive engineering, cognitive ergonomics, human factors and human performance. There are various components of human cognition, each of which can be singled out and studied in specific contexts to inform the workplace, systems and product designers to improve outcomes and human interactions within specific domains.

This study demonstrated positive outcomes in this investigation of TIPT. However, the enquiry should not halt here. In any situation investigating cognitive processing, in particular within the working memory structure and its sub systems, when the natural processes are interrupted, whether as a result of the continual flow of information, as in this study, or by limited viewing time or even the classic information overload of information from multiple modes. The RAPS technique as a reverse engineered stimulus can be created for all contexts where information is to be processed with an expectation of knowledge construction, transfer and application or recall being required, regardless of the type of context, content, task, mode, environment or subject.

The researcher intends to continue research in the field of human performance, specialising in neuroergonomics by utilizing the EEG technologies seen in this study. Research interests will include but are not limited to: how human self-efficacy, workplace wellbeing, stress and fatigue impact on performance. The health sector, emergency services and law enforcement experience high levels of workplace stress. This study's results have increased the importance of conducting research into situational causality of increased MWL in nurses, paramedics and police subjects to provide data and insights about the development of human capital optimization models for improved human measures within organisational contexts.

7.5 Special contributions of this study

This study has made several distinctive contributions to the field of human performance. Specifically, through the neurophysiological nature of the methodology used, specialized measures were devised in order to achieve reliable and accurate metrics for MWL and CE:

- Unique human cognitive investment (UHCI) was designed to provide a unique measure of cognitive investment that allowed the differentiation of the cognitive resources that was required between subjects.
- The Phonological attention and rehearsal interruption (PARI) cognitive processing effect was to reflect the impact and outcome of an event whereby the natural cognitive processing cycle of the sub structure of the working memory was interrupted.
- Albeit not entirely new, the use of EEG to measure MWL is generally shied away from owing to the associated difficulties, such as cost, implementation and the need for specialized knowledge required for the acquisition,

processing and analyse of the neural data. This study aimed for objective data and therefore pursued the use of medical grade neurophysiological technologies for all data collection and processing.

- RAPS was designed with scope and adaptability in mind. In this study it was used specifically to investigate its impact on MWL, human performance and overall CE during a TIPT; however, its purpose and capabilities can be replicated by design to investigate MWL and the impact that RAPS has across domains. A specially designed technique could be to investigate further within areas of human cognitive performance in future research.
- A final contribution – and maybe the most significant – is the ability to collate MWL data, calculate a UHCI and, together with human performance scores, depict a quantifiable level of overall CE achieved. This contribution has used a specially designed set of metrics to provide a universally adaptable CE measure.

7.6 Conclusion

This study, along with many other investigations has used EEG to capture the neural activity during the completion of a task in order to measure the cognitive load experienced. As a result of reviewing the relevant literature, there was no evidence of studies or results having specifically used EEG to capture the brain activity during the TIPT. Event Related Desynchronisation (ERD) was also used as a metric to establish a consistent value of cognitive load experienced across the continuous EEG data. This Unique Human Cognitive Investment Measure provides both a cohort and a unique (for each individual) measure of the cognitive load/MWL experienced during the TIPT. This work extends the existing paradigm of human performance and MWL metrics and measures through the utilisation of EEG.

RAPS is a cognitive optimization technique designed especially for instructional and performance enhancement. This technique, which was developed on the basis of acknowledging human capacity and respecting the limitations of the HCA, has been shown to reduce MWL in a complex TIPT situation. In particular, it aims at achieving increased human performance and optimal CE.

The RAPS strategy works by explicitly priming a person's schema with a simulated stimulus, by exposing her or him to key pieces of information identified as the 'must know' information within a larger body of content, allowing knowledge construction and transfer to be fast tracked. This enables the individual to draw upon previously presented stimuli in a situation whereby the phonological rehearsal processing phase operating within a sub component of the working memory system is interrupted by a continual flow of information. This causes the central executive, as per Baddeley's (2000, p. 418) multi component model of working memory, to shift gears among attention, processing, rehearsal and storage, thereby prompting a conflict n processing the speech input. Without the assistance of RAPS, the individual is without previously constructed schema and therefore attempting to process new information whilst receiving ongoing new information. Ideally an individual is given the opportunity to make a more permanent record, take notes, pause the flow of information or replay the information. However, in today's society with the sheer volume of information surrounding us, in many situations this is just not a realistic option.

Specific implications and special contributions of this study have been detailed in this chapter. Equally it is as important to acknowledge and reflect on the topic areas that provided the foundation of literature in which the study was developed. Reflection allowed for the researcher to see the potential growth within the fields reviewed. The well research yet limited knowledge of the human cognitive architecture appears to have taken on new lease of importance with the introduction of technology, Whilst ever the way in which we process information is reliant on human neural processing capabilities technology not only poses room for advancement yet also raises the risk of poor performance. Usability within all information system requires a solid knowledge of the human cognitive capabilities, the cognitive load imposed in order to design and develop systems that are meet the primary need of increasing efficiency. The working memory is a gateway to cognition; with an opportunity to manipulate the information presented to suite this memory structure will see countless benefits across all types of information systems,

The primary use of subjective techniques to measure cognitive load in the previous decades were deemed appropriate and sufficient, unfortunately with the advancement of technology across educational and business domains the extent of information presented, the varied modalities and formats demanded a more objective technique if we are to truly understand the cognitive efficiency levels achieved or the effects of systems design.

Neural activity captured in this study used medical grade neurophysiological equipment to ensure the data could be analysed with consideration to the signal to noise ratio. A measure otherwise reserved typically for neurophysiological assessment within the medical domain. A method that will be carried forward in future cognitive experience research, user interface design research, user experience, information system design, neural activity research and process design.

As a result of this study, the human capital performance and efficiency management model (HCPEMM) has been designed to encompass the cognitive influence and impact experienced by an individual. A combination of testing new cognitive initiatives, the complexity levels of tasks and cognitive design strategies, along with the understanding and recognition of an individual’s prior knowledge, attitudes and perceptions, are required before an accurate and meaningful assessment of subjective or perceived MWL can be established. Objective MWL can then be recorded and data appropriately cleaned and used to determine the cohort-based measurements of MWL being imposed by a specific task. It is equally important in determining the cognitive capacity or the cognitive demand placed on an individual that one uses a set of human metrics that allow one to determine the variance of MWL experienced from a baseline interval such as the UHCI. This is used together with the performance scores achieved to investigate further the CE achieved.

The Human CKOde, HCPEMM encompasses the approach used within this study. The use of the UHCI allows an understanding of the individual’s MWL. This is a step towards achieving balance in a world where it has been stated that cognitive overload is a brutal fact of modern life; it is not going to disappear. This is a reality that all too often is either overlooked from a cognitive perspective or unfortunately not given the emphasis and focus needed to address the risks that mental overload in the workplace can pose; the load or demand on the cognitive system can experience other pressures. In this study I specifically focused on the increased in alpha band activity as a measure of WML. This study was concerned with the neural activity and

CE. Future studies will extend and explore when MWL exceeds the comfortable or natural effective zone and is then neural activity presenting as stress or at the other end fatigue; this is when efficiency is not the foci but rather the risk becomes more serious. These future studies will focus on the human capital statistical data within organisations that highlight areas of risk whereby stress and/or fatigue may be a contributing factor. This study of human factors has extended the investigations to encompass cognitive ergonomics with the appreciation and understanding of how the HCA operates and a unique combination of measures. This model has provided the metrics needed to design organisational solutions, practices, processes and products and to make human capital decisions that will optimise organisational and human capital efficiency (Kirsh, 2000, p. 48). The uniqueness of combining a range of subjective human equity, prior knowledge scores, post task performance scores and dual neurophysiological measures strengthens the experimental findings and encourages the multifaceted approach to cognitive ergonomics research that this study has exemplified. Results are unique to this study and in order to gain additional quantitative data it is suggested that further investigative studies are conducted to enable further validation with a larger cohort.

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Appendix A Transient information, effect and suggested strategy (Sweller et al., 2011f)

Effect Name	Worked Example
Effect descriptor and cognitive implication	When learners are forced to use a means-end analysis method to solve problems excessive cognitive resources are required to search long term memory for solutions whilst simultaneously keeping the attention on the problem at hand. This worked examples effect involves novice students that are required to solve complex problems, students that have been provided with a full worked example as opposed to using other problem solving methods (Sweller & Cooper, 1985) . “When solving an unfamiliar problem, problem solvers have no choice but to use a generation followed by effectiveness testing procedure” (Sweller, 2008b, p. 374). An alternative is to provide learners with the information that they require to solve the problem “ by providing an organised structure rather than leaving learners to devise their own organisation using their limited capacity working memory should minimise extraneous cognitive load” (Sweller, 2008b, p. 375).
Instructional Strategy	Provide learners a full worked example until which time they have a level of expertise and sufficient information stored in long term memory to draw from in order to search for a solution. The worked example should include all steps that the learner must take in order to solve the problem. There should be no searching required.
Effect Name	**Completion Problem Effect**
Effect descriptor and cognitive implication	“Completion problems are problems for which a given state, and a partial solution are provided to learners who must complete the partial solution”(Sweller et al., 1998, p. 275).
Instructional strategy	“A completion problem is a partial worked example where the learner has to complete some key solution steps” (Sweller, Ayres, & Kalyuga, 2011l, p. 105).
Effect Name	**Goal Free Effect**
Effect descriptor and cognitive implication	This effect is created when the learner is not given an ideal state or a goal state in which to achieve or arrive at, unlike a typical problem solving situation where the learner will be given a goal. “By creating a goal-free environment, learning is not dominated by strategies to connect goals to the givens. Instead, the learner is focused only on the present problem state and how to get to another state (Sweller, Ayres, & Kalyuga, 2011h, p. 90) .

Instructional Strategy	The learner is presented with the detailed problem, the current state of the situation. No instructions are given as to the direction of the solution. This ensures that the learner is focused in the current information and can move forward in thinking (Sweller et al., 2011h).
Effect Name	**Split Attention Effect**
Effect descriptor and cognitive implication	When the learner must pay attention to content coming from two or more sources, as the material requires both pieces of information and each are not intelligible as stand-alone components. This split attention effect occurs in this case whereby the learner must mentally integrate two or more separate pieces of information (Sweller, 2008b, p. 375). An instructional strategy to deal with this effect requires the instruction to "indicate the relation between the two parts" (Sweller, 2008b, p. 375).
Instructional strategy	Present material in an integrated format, for example: labelling a diagram as opposed to listing the labels as a separate list and requiring the learner to mentally integrate the two disparate sources of information (Sweller et al., 1998).
Effect Name	**Modality Effect**
Effect descriptor and cognitive implication	This effect is similar to that of the split-attention effect; the learner is splitting attention some way; however in this case it is the mode in which content is presented. There are multiple channels in which process information, visual and audio channels. (Baddeley, 1992) "the simultaneous use of both processors can expand the effective size of working memory" (Sweller, 2008b, p. 376).
Instructional strategy	"Effective working memory capacity can be increased by using both visual and auditory working memory rather than either memory stream alone" (Sweller et al., 1998, p. 281).
Effect Name	**Redundancy Effect**
Effect descriptor and cognitive implication	This effect is relates to information that may be presented that is not necessary for learning to take place, additional details or content presented in multiple modes, for example in text and graphical. Unlike the spilt attention whereby information required the learner to integrate multiple pieces of information to understand the content, it is also an important aspect not to double up on the same information. "Attending to unnecessary information and attempting to integrate it with essential information requires working memory resources that consequently are unavailable for learning" (Sweller, 2008b, p. 376).

Instructional strategy	Avoid the duplication of identical information in more than a single place or mode (Sweller, 2004).
Effect Name	Expertise Reversal Effect
Effect descriptor and cognitive implication	This effect considers the learners level of expertise, all of the effects mentioned so far assume that the learner is a novice. As it is novices that typically require instruction, however in the case where a learner has a level of knowledge this effect is applicable. This effect specifically relates to those learners that are not novices and therefore don’t require the same level of detail in their instruction. This effect works closely with the redundancy effect, “as expertise increases previously essential information becomes redundant and so imposes an extraneous cognitive load” (Sweller, 2008b, p. 377). The provision of additional information, which is not required for the learner to understand and make sense of the information, is therefore unnecessary and only wasting cognitive resources. “When two sources of information are intelligible in isolation but are presented in integrated format, when the second source of information is merely reiterating the information of the first source in a different form, it is considered redundant” (Schnotz, 2010, p. 319). Sweller and Chandler (1994a) refer to the removal of this redundant information as the redundancy effect.
Instructional strategy	Reducing redundant information according to the learners prior previously acquired schema (Kalyuga, 2009a).

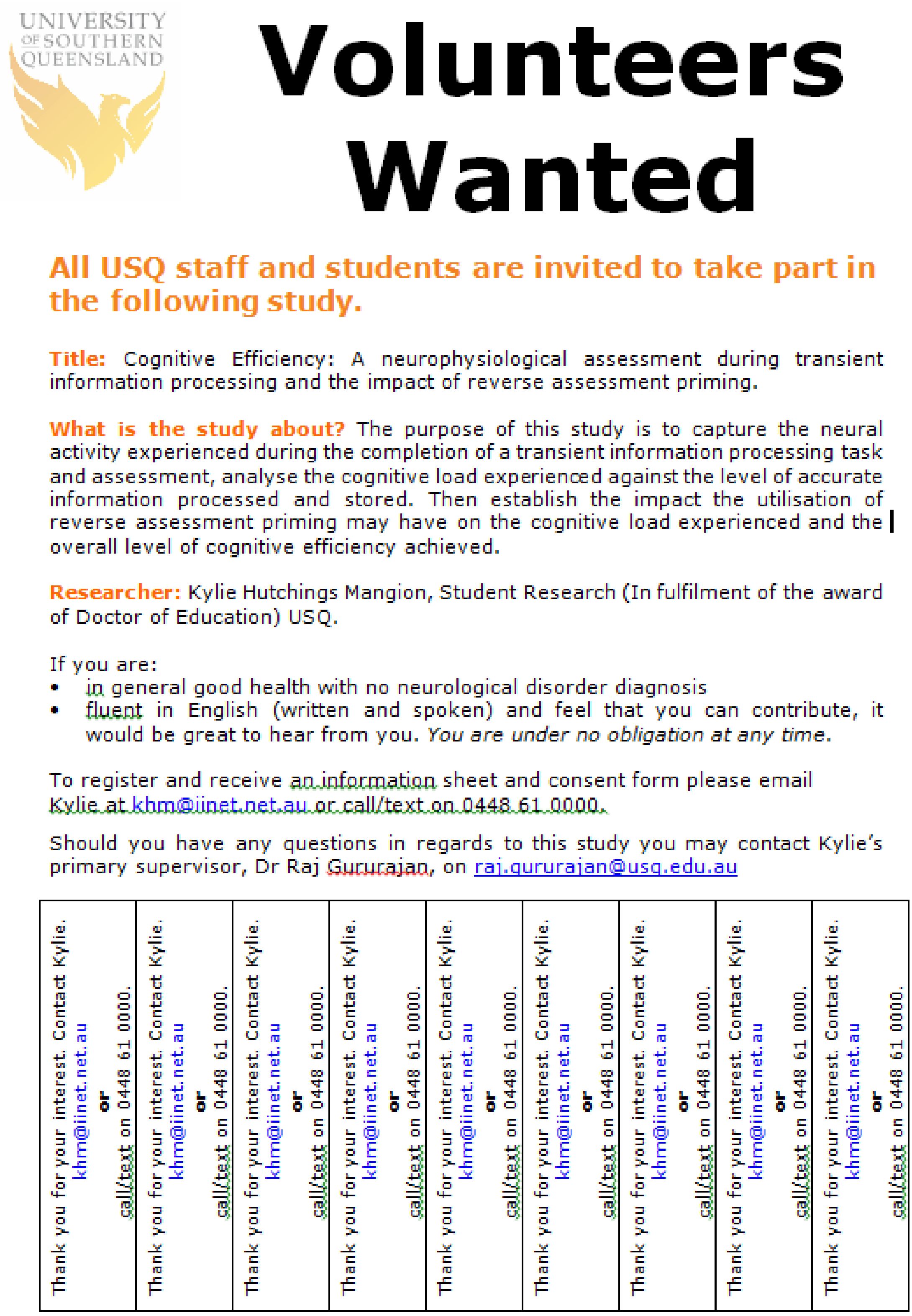
Effect Name	Guidance Fading Effect
Effect descriptor and cognitive implication	The guidance fading effect relates to both the worked example effect and the expertise reversal effect, as learners increase their expertise it is necessary to reduce the direct instructional material, these are called completion problems (Sweller, 2008b; Van Merrienboer, Schuurman, de Croock, & Paas, 2002) Instruction should aim to "initially provide substantial guidance which should be gradually faded as expertise increases" (Lockyer, 2008, p. 378) .
Instructional strategy	Instructional guidance is faded as the learner's expertise increases.
Effect Name	**Imagination Effect**
Effect descriptor and cognitive implication	As expertise increases the imagination effect is also a highly effective instructional approach. This involves asking learners to imagine to concepts, procedure and details involved in completing a task, encouraging the learner consciously run the information through working memory, "which should assist in transferring the information to long term memory (Sweller, 2008b, p. 378). It must be noted though that the learners must already have a level of expertise to draw from (Sweller, 2008b).
Instructional strategy	The learner is required to imagine concepts, steps, procedures, processes and solutions.
Effect Name	**Element Interactivity Effect**
Effect descriptor and cognitive implication	The effects discussed so far have focused on the expertise of the learner; the element interactivity involves the degree at which elements interact and the general complexity of the material. Thoughts should be given to the "differences in the structure of information are equally important" (Sweller, 2008b, p. 378). Depending on the material and whether elements can be understood one at a time will demonstrate the level of element interactivity and therefore determine how the information should be structured for effective instruction.
Instructional strategy	Elements are presented individually if possible as smaller chunks.
Effect Name	**Isolated Interacting Elements Effect**

Effect descriptor and cognitive implication	When there are many elements that interact, it more effective to gain an understanding of each element in isolation; this may seem to come at the expense of understanding how they relate. However if it is not possible for a learner to simultaneously learn and integrate all elements, “once the individual elements have been learned, their interactions can then be emphasised” (Sweller, 2008b, p. 379).
Instructional strategy	Each element is presented in isolation until the learner has a level of knowledge before learning another element. Elements are not presented together until each one is understood in isolation.

Effect Name	Transient Effect
Effect descriptor and cognitive implication	Information that is presented and disappears is known as the transient effect. Oral instructions from a teacher or audio instructions are transient. “By its very nature, all speech is transient” (Sweller et al., 2011f, p. 220). Writing transient information is an attempt to transform its transient nature to a more permanent one (Sweller et al., 2011f). Sweller et al. (2011f, p. 220) defines the “transient information effect as a loss of learning due to information disappearing before the learner has time to adequately process it or link it with new information”.
Instructional strategy	The learner is presented with an opportunity to turn the transient information into a more permanent one; this may be in the form of mental rehearsal or noting information down.

Effect Name	The Collective Working Memory Effect
Effect descriptor and cognitive implication	This new cognitive load effect occurs within collaborative learning environments where learners are extending their own working memory or taking the pressure off by using the borrowing principle. The effect enables the learner to draw from and borrow from a broader range of individuals as opposed to only the teacher. “Individuals obtain higher learning outcomes through collaborative work than learning alone” (Sweller et al., 2011f, p. 230).
Instructional strategy	Use groups to assist learning, enabling students to bounce ideas off each other, split the content and bring the information together. Use tasks, questioning and group exercises to share the mental load.

Appendix B Recruitment flyer



UNIVERSITY OF SOUTHERN QUEENSLAND

Volunteers Wanted

All USQ staff and students are invited to take part in the following study.

Title: Cognitive Efficiency: A neurophysiological assessment during transient information processing and the impact of reverse assessment priming.

What is the study about? The purpose of this study is to capture the neural activity experienced during the completion of a transient information processing task and assessment, analyse the cognitive load experienced against the level of accurate information processed and stored. Then establish the impact the utilisation of reverse assessment priming may have on the cognitive load experienced and the overall level of cognitive efficiency achieved.

Researcher: Kylie Hutchings Mangion, Student Research (In fulfilment of the award of Doctor of Education) USQ.

If you are:

- in general good health with no neurological disorder diagnosis
- fluent in English (written and spoken) and feel that you can contribute, it would be great to hear from you. *You are under no obligation at any time.*

To register and receive an information sheet and consent form please email Kylie at khm@iinet.net.au or call/text on 0448 61 0000.

Should you have any questions in regards to this study you may contact Kylie's primary supervisor, Dr Raj Gururajan, on raj.gururajan@usq.edu.au

Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.	Thank you for your interest. Contact Kylie. khm@iinet.net.au **or** call/text on 0448 61 0000.

Appendix C Letter to interested parties

Cognitive Efficiency: A neurophysiological assessment during transient information processing and the impact of reverse assessment priming

RESEARCHER: Kylie Hutchings Mangion

Letter to Interested Parties

Dear Volunteer

Thank you for your expression of interest shown in taking part in my research study.

I am graduate student with a Bachelor's degree in Teaching (Professional Adult Vocational Education), Bachelor of Learning Design and Master in Educational Technology I am conducting a study as part of my Doctor of Education Thesis, University of Southern Queensland.

The purpose of this study is to capture the neural activity experienced during the completion of a transient information processing task and assessment, analyse the cognitive load experienced against the level of accurate information processed and stored. Then establish the impact the utilisation of reverse assessment priming may have on the cognitive load experienced and the overall level of cognitive efficiency achieved.

Data will be collected from an *Electroencephalography* recording and will require approximately an hour of your time. This involves wearing a headset that records the brain activity during the viewing of an assortment of continuous informational slides and the completion of the relevant questions on the answer sheet provided. As a participant you can receive a copy of the results, please provide your name and email address. To ensure all subjects are within a similar range there are several pre-screening tasks to be completed prior to taking part in the study.

The participation in this study is on a volunteer basis and all participants can withdraw at any time without repercussions.

These include the completion of the following:

- Demographic and prior knowledge questionnaire (approximately 10 question)

In the study findings, participants will not be identified by their personal name, and therefore their identity will not be revealed.

You will find the following documents attached:

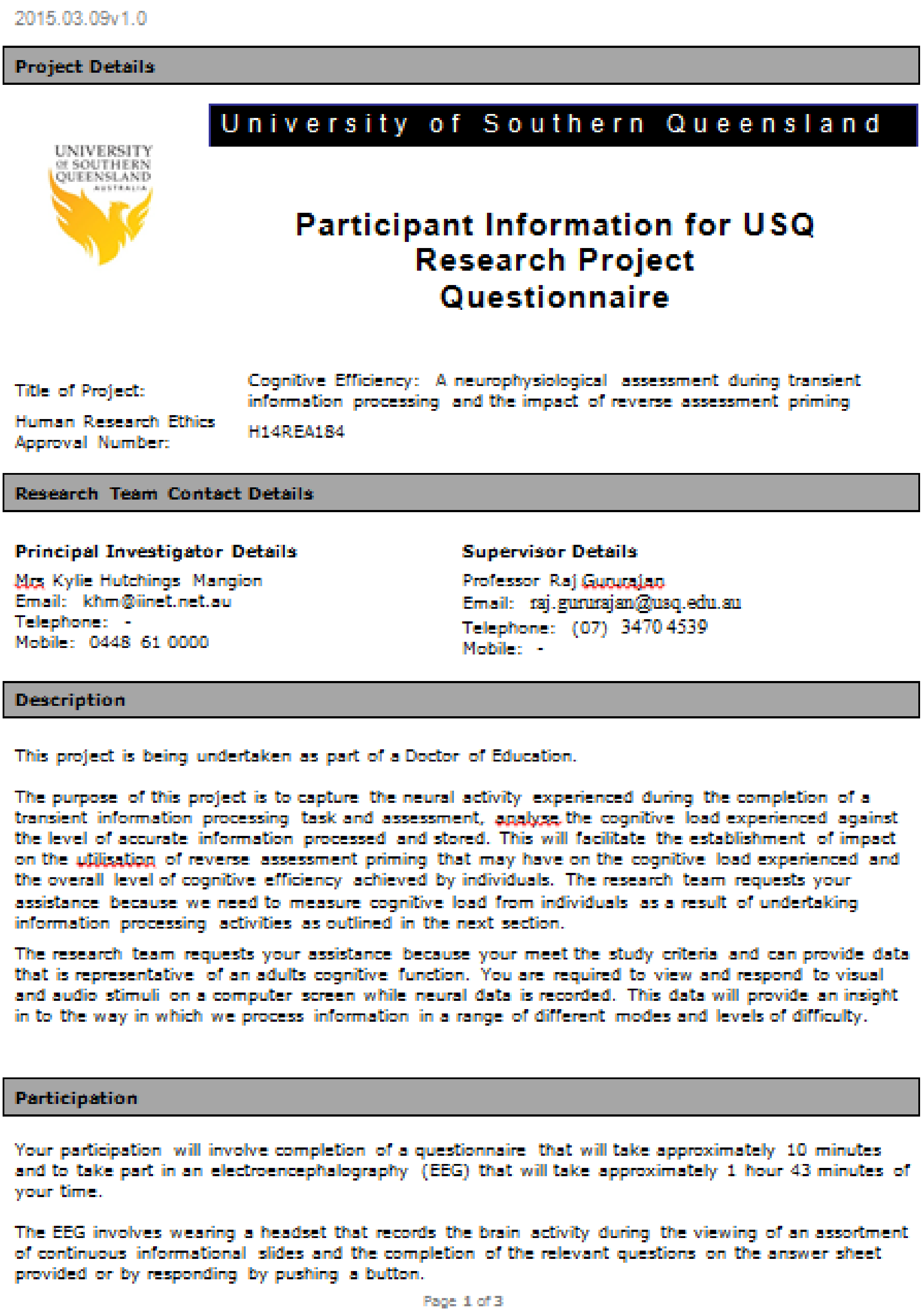
- Participant Information Sheet
- Participant Consent Form

To take parts in the study please complete the consent form attached and email to Kylie Hutchings Mangion on khm@iinet.net.au or call Kylie on 0448610000 should you have any questions contact my primary supervisor Professor Raj Gururajan, raj.gururajan@usq.edu.au

Thank you for your interest.

Kind Regards
Kylie Hutchings Mangion

Appendix D Participant information sheet



2015.03.09v1.0

Project Details

University of Southern Queensland

UNIVERSITY OF SOUTHERN QUEENSLAND AUSTRALIA

Participant Information for USQ Research Project Questionnaire

Title of Project:	Cognitive Efficiency: A neurophysiological assessment during transient information processing and the impact of reverse assessment priming
Human Research Ethics Approval Number:	H14REA184

Research Team Contact Details

Principal Investigator Details
Mrs Kylie Hutchings Mangion
Email: khm@iinet.net.au
Telephone: -
Mobile: 0448 61 0000

Supervisor Details
Professor Raj Gururajan
Email: raj.gururajan@usq.edu.au
Telephone: (07) 3470 4539
Mobile: -

Description

This project is being undertaken as part of a Doctor of Education.

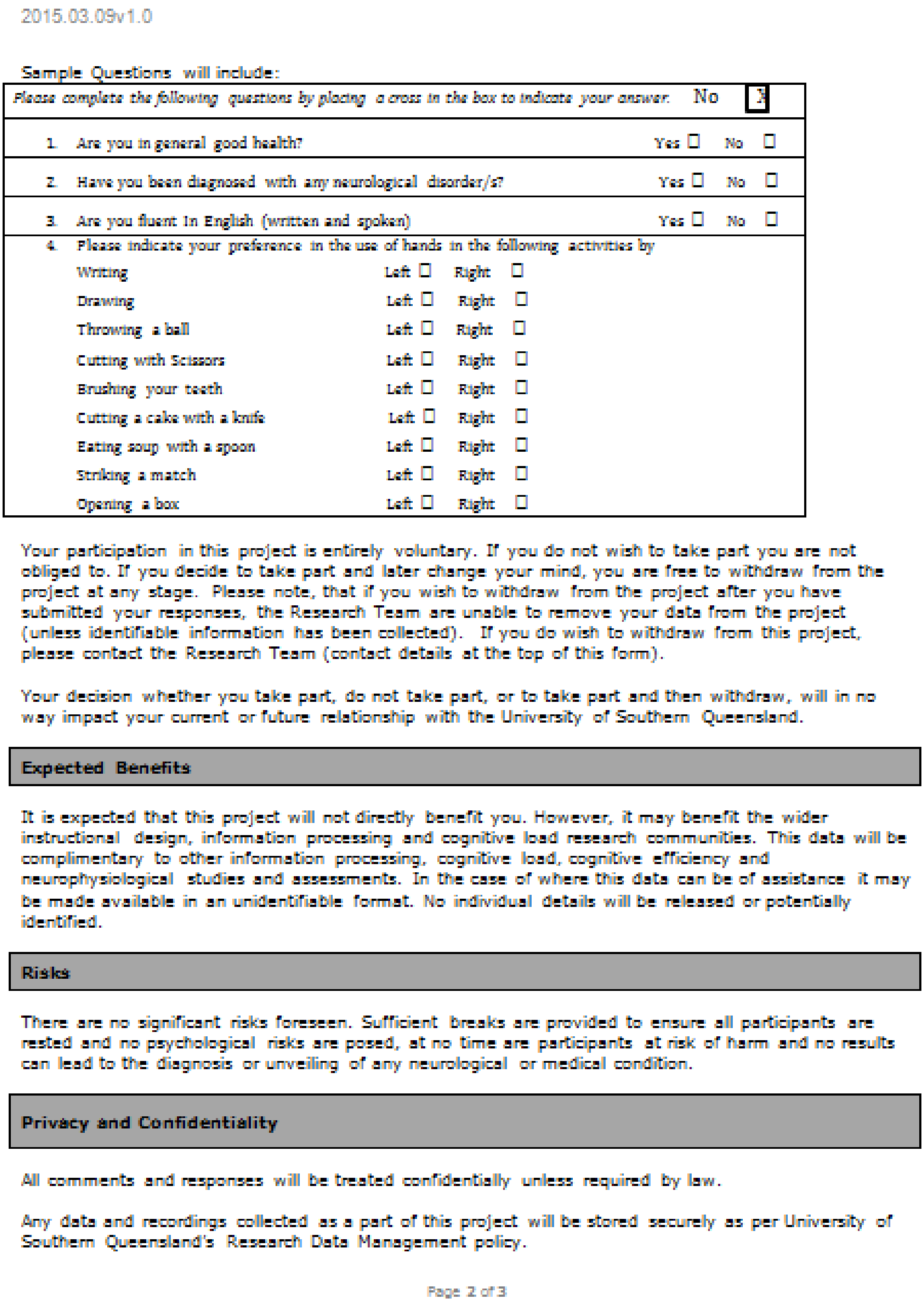
The purpose of this project is to capture the neural activity experienced during the completion of a transient information processing task and assessment, analyse the cognitive load experienced against the level of accurate information processed and stored. This will facilitate the establishment of impact on the utilisation of reverse assessment priming that may have on the cognitive load experienced and the overall level of cognitive efficiency achieved by individuals. The research team requests your assistance because we need to measure cognitive load from individuals as a result of undertaking information processing activities as outlined in the next section.

The research team requests your assistance because your meet the study criteria and can provide data that is representative of an adults cognitive function. You are required to view and respond to visual and audio stimuli on a computer screen while neural data is recorded. This data will provide an insight in to the way in which we process information in a range of different modes and levels of difficulty.

Participation

Your participation will involve completion of a questionnaire that will take approximately 10 minutes and to take part in an electroencephalography (EEG) that will take approximately 1 hour 43 minutes of your time.

The EEG involves wearing a headset that records the brain activity during the viewing of an assortment of continuous informational slides and the completion of the relevant questions on the answer sheet provided or by responding by pushing a button.



Sample Questions will include:

Please complete the following questions by placing a cross in the box to indicate your answer. No ☒		
1. Are you in general good health?	Yes ☐	No ☐
2. Have you been diagnosed with any neurological disorder/s?	Yes ☐	No ☐
3. Are you fluent In English (written and spoken)	Yes ☐	No ☐
4. Please indicate your preference in the use of hands in the following activities by		
Writing	Left ☐	Right ☐
Drawing	Left ☐	Right ☐
Throwing a ball	Left ☐	Right ☐
Cutting with Scissors	Left ☐	Right ☐
Brushing your teeth	Left ☐	Right ☐
Cutting a cake with a knife	Left ☐	Right ☐
Eating soup with a spoon	Left ☐	Right ☐
Striking a match	Left ☐	Right ☐
Opening a box	Left ☐	Right ☐

Your participation in this project is entirely voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. Please note, that if you wish to withdraw from the project after you have submitted your responses, the Research Team are unable to remove your data from the project (unless identifiable information has been collected). If you do wish to withdraw from this project, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.

Expected Benefits

It is expected that this project will not directly benefit you. However, it may benefit the wider instructional design, information processing and cognitive load research communities. This data will be complimentary to other information processing, cognitive load, cognitive efficiency and neurophysiological studies and assessments. In the case of where this data can be of assistance it may be made available in an unidentifiable format. No individual details will be released or potentially identified.

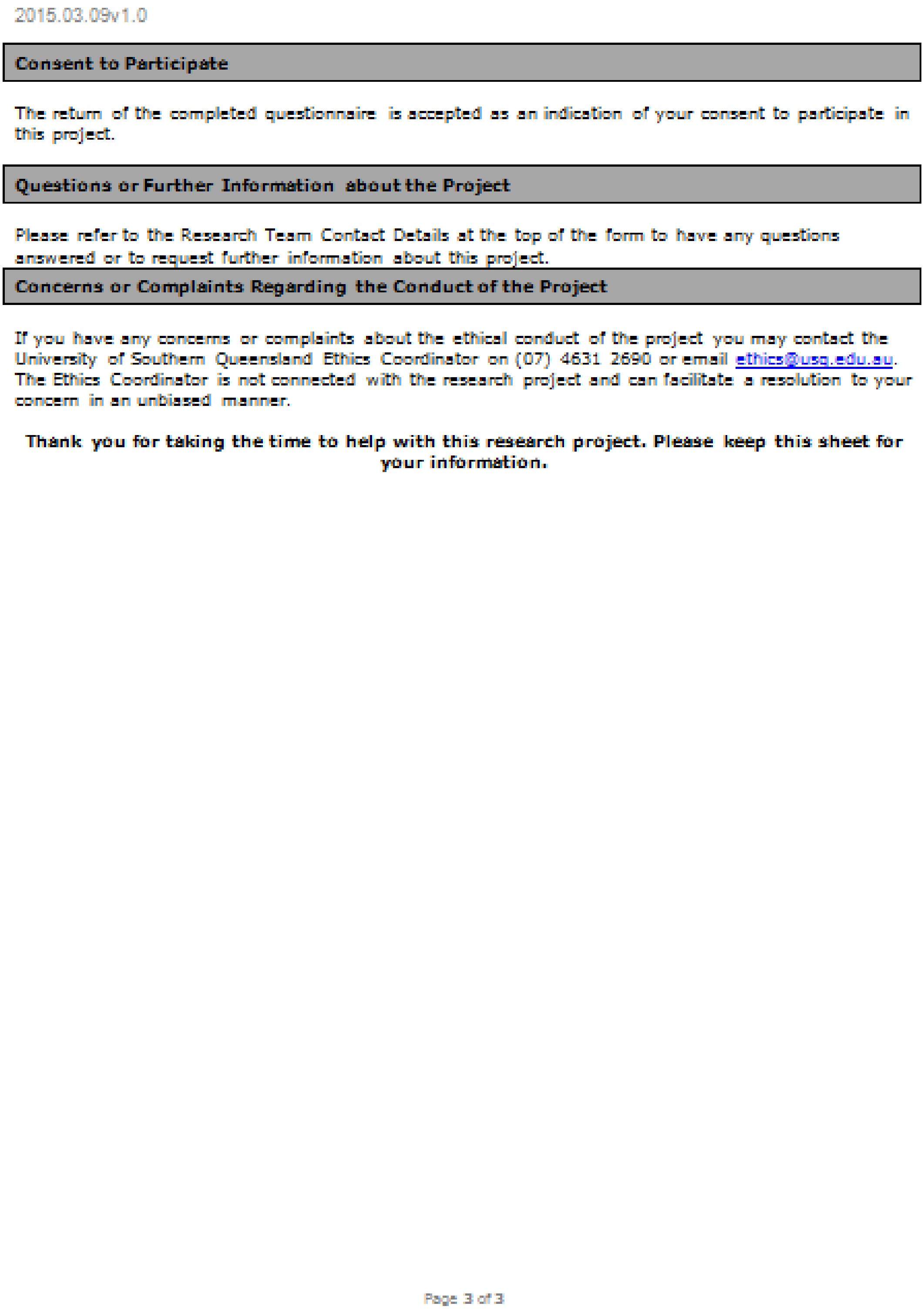
Risks

There are no significant risks foreseen. Sufficient breaks are provided to ensure all participants are rested and no psychological risks are posed, at no time are participants at risk of harm and no results can lead to the diagnosis or unveiling of any neurological or medical condition.

Privacy and Confidentiality

All comments and responses will be treated confidentially unless required by law.

Any data and recordings collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy.



Consent to Participate

The return of the completed questionnaire is accepted as an indication of your consent to participate in this project.

Questions or Further Information about the Project

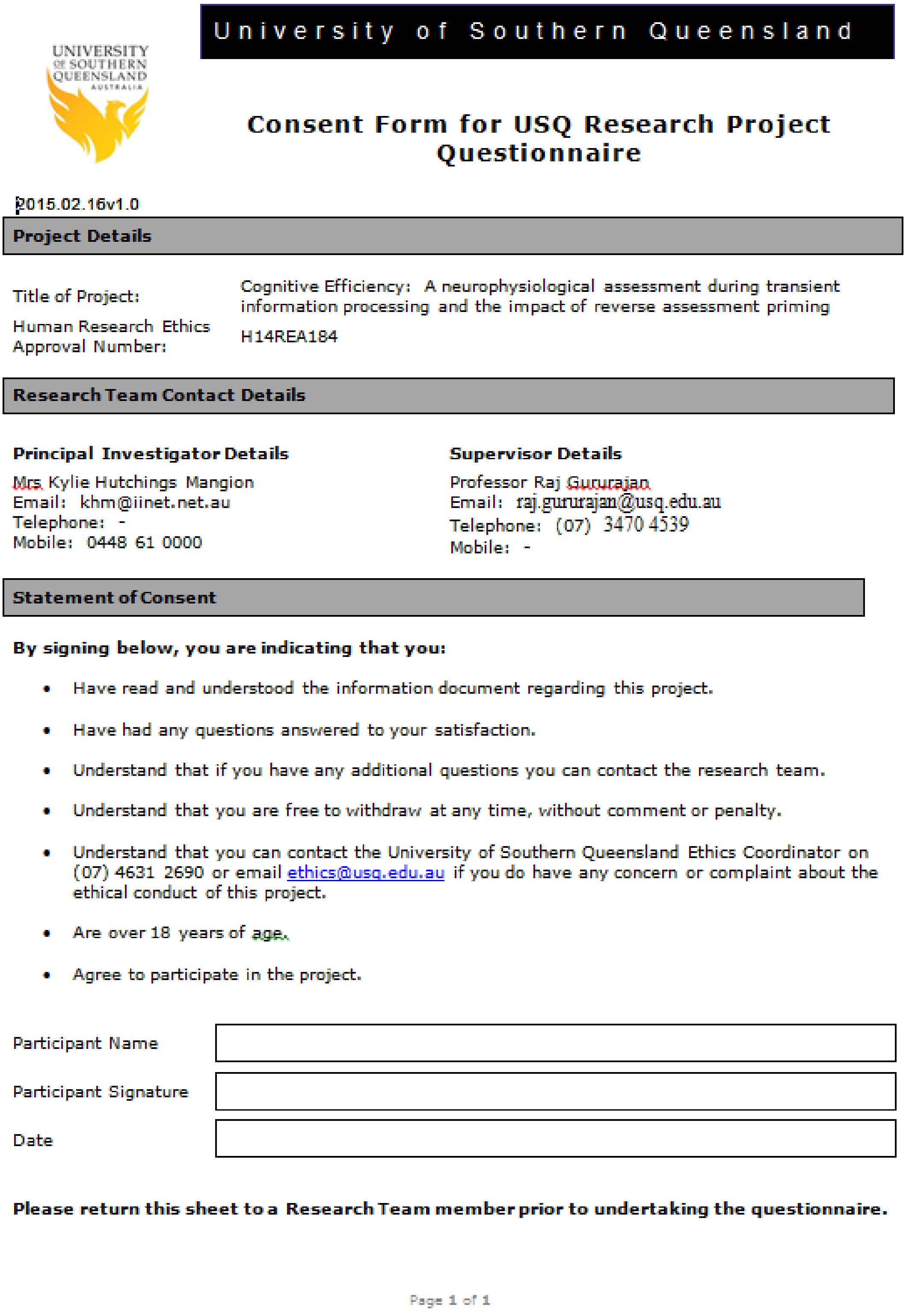
Please refer to the Research Team Contact Details at the top of the form to have any questions answered or to request further information about this project.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project you may contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au. The Ethics Coordinator is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

Thank you for taking the time to help with this research project. Please keep this sheet for your information.

Appendix E Consent form



University of Southern Queensland

Consent Form for USQ Research Project Questionnaire

2015.02.16v1.0

Project Details

Title of Project: Cognitive Efficiency: A neurophysiological assessment during transient information processing and the impact of reverse assessment priming

Human Research Ethics Approval Number: H14REA184

Research Team Contact Details

Principal Investigator Details
Mrs Kylie Hutchings Mangion
Email: khm@iinet.net.au
Telephone: -
Mobile: 0448 61 0000

Supervisor Details
Professor Raj Gururajan
Email: raj.gururajan@usq.edu.au
Telephone: (07) 3470 4539
Mobile: -

Statement of Consent

By signing below, you are indicating that you:

- Have read and understood the information document regarding this project.
- Have had any questions answered to your satisfaction.
- Understand that if you have any additional questions you can contact the research team.
- Understand that you are free to withdraw at any time, without comment or penalty.
- Understand that you can contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au if you do have any concern or complaint about the ethical conduct of this project.
- Are over 18 years of age.
- Agree to participate in the project.

Participant Name

Participant Signature

Date

Please return this sheet to a Research Team member prior to undertaking the questionnaire.

Page 1 of 1

Appendix F Transient nformation processing task (Audio scripts)

File Name	Script (to be 2 minutes in length please)
TIPT_Low_01	Not Selected for Study
TIPT_Low_02	Bhutan officially the Kingdom of Bhutan, is a landlocked country in South Asia located at the eastern end of the Himalayas. It is bordered to the north by China and to the south, east and west by India. To the west, it is separated from Nepal by the Indian state of Sikkim, while further south it is separated from Bangladesh by the Indian states of Assam and West Bengal. Bhutan's capital and largest city is Thimphu. Bhutan's landscape ranges from subtropical plains in the south to the sub-alpine Himalayan heights in the north, where some peaks exceed 7,000 metres (23,000 ft). Bhutan has diplomatic relations with 52 countries and the European Union and has missions in India, Bangladesh, Thailand and Kuwait. It has two UN missions, one in New York and one in Geneva. Only India and Bangladesh have residential embassies in Bhutan, while Thailand has a consulate office in Bhutan. Other countries maintain diplomatic informal contact via their embassies in New Delhi. By a long-standing agreement, Indian and Bhutanese citizens may travel to each other's countries without the need for a passport or visa but only their national identity cards. Bhutanese citizens may also work in India without legal restriction. Bhutan does not have formal diplomatic ties with its northern neighbour, the People's Republic of China, although exchanges of visits at various levels between the two have significantly increased in recent times. The first bilateral agreement between China and Bhutan was signed in 1998 and Bhutan has also set up honorary consulates in the Chinese dependent territories of Macao and Hong Kong. Bhutan's border with China is largely not demarcated and thus disputed in some places. Approximately 269 square kilometers remain under discussion between China and Bhutan.[45] Bhutanese people primarily consist of the Ngalops and Sharchops, called the Western Bhutanese and Eastern Bhutanese respectively.
TIPT_Low_03	Mongolia is a landlocked country in east-central Asia. It is bordered by Russia to the north and China to the south, east and west. Ulaanbaatar, the capital and also the largest city, is home to about 45% of the population. Mongolia's political system is a parliamentary republic. Mongolia is the 19th largest and the most sparsely populated independent country in the world, with a population of around 2.9 million people. It is also the world's second-largest landlocked country after Kazakhstan. The country contains very little arable land, as much of its area is covered by steppe, with mountains to the north and west and the Gobi Desert to the south. Approximately 30% of the population is nomadic or semi-nomadic. The predominant religion in Mongolia is Tibetan Buddhism. In 2002, about 30% of all households in Mongolia lived from breeding livestock.] Most herders in Mongolia follow a pattern of nomadic or semi-nomadic pastoralism. Due to the severe 2009–2010 winter, Mongolia lost 9.7 million animals, or 22% of total livestock. This immediately affected meat prices, which increased twofold; GDP dropped 1.6% in 2009. The Trans-Mongolian Railway is the main rail link between Mongolia and its neighbors. It begins at the Trans-Siberian Railway in Russia at the town of Ulan-Ude, crosses into Mongolia, runs through Ulaanbaatar, and then passes into China at Erenhot where it joins the Chinese railway system. Mongolia holds many traditional festivals throughout the year and are mostly celebrations of Mongolian culture. Naadam Festival is the largest festival, celebrated in every town and village across the country. It features three sporting events: wrestling, archery and horse racing, amongst other traditional games and exhibits. The Eagle Festival draws about 400 eagle hunters on horseback, including the traveler to compete with their birds. The Ice Festival and the Thousand Camel Festival are amongst many other traditional Mongolian festivals.
TIPT_Low_04	Not Selected for Study

File Name	Script (to be 2 minutes in length please)
TIPT_Low_05	Malta officially the Republic of Malta is a Southern European island country comprising an archipelago of seven islands in the Mediterranean Sea. It lies 80 km (50 mi) south of Sicily, 284 km (176 mi) east of Tunisia, and 333 km (207 mi) north of Libya. The country covers just over 316 km^2, making it one of the world's smallest and most densely populated countries. The capital of Malta is Valletta, which is also, at 0.8 km^2, the smallest capital in the European Union.[12] Malta has two official languages: Maltese and English. Malta's location has given it great strategic importance as a naval base throughout history, and a succession of powers, including the Phoenicians, Romans, Moorish, Normans, Sicilians, Habsburg Spain, Knights of St. John, French and the British, have ruled the islands. Malta gained independence from the United Kingdom in 1964 and became a republic in 1974. Malta was admitted to the United Nations in 1964 and to the European Union in 2004; in 2008, it became part of the Eurozone. Malta has a long Christian legacy and its Roman Catholic Archdiocese of Malta is sometimes traditionally claimed to be an Apostolic see because, according to the Acts of the Apostles,[13] Paul the Apostle was shipwrecked on Malta. Catholicism is the official religion in Malta. The average yearly temperature is around 23 °C (during the day and 16 °C (61 °F) at night. In the coldest month – January – the typically maximum temperature ranges from 12 to 20 °C during the day and minimum 7 to 12 °C at night. In the warmest month – August – the typically maximum temperature ranges from 28 to 34 °C during the day and minimum 20 to 24 °C at night.
TIPT_Low_06	Not Selected for Study
TIPT_Low_07	A dragonfly is an insect belonging to the order Odonata, the suborder Epiprocta or, in the strict sense, the infraorder Anisoptera (from Greek ανισος *anisos*, "uneven" + πτερος *pteros*, "wings", because the hindwing is broader than the forewing).[1] It is characterized by large multifaceted eyes, two pairs of strong transparent wings, and an elongated body. Dragonflies can sometimes be mistaken for damselflies, which are morphologically similar; however, adults can be differentiated by the fact that the wings of most dragonflies are held away from, and perpendicular to, the body when at rest. Dragonflies possess six legs (like any other insect), but most of them cannot walk well. Dragonflies are among the fastest flying insects in the world. Dragonflies can fly backwards, change direction in mid-air and hover for up to a minute[2] Dragonflies are major predators that eat mosquitoes, and other small insects like flies, bees, ants, wasps, and very rarely butterflies. They are usually found around marshes, lakes, ponds, streams, and wetlands because their larvae, known as "nymphs", are aquatic. About 5,900 different species of dragonflies (Odonata) are known in the world today of which about 3000 belong to the Anisoptera.]Though dragonflies are predators, they themselves are subject to being preyed upon by birds, lizards, frogs, spiders, fish, water bugs, and even other large dragonflies. Female dragonflies lay eggs in or near water, often on floating or emergent plants. When laying eggs, some species will submerge themselves completely in order to lay their eggs on a good surface. The eggs then hatch into naiads (nymphs). Most of a dragonfly's life is spent in the naiad form, beneath the water's surface, using extendable jaws to catch other invertebrates (often mosquito larvae) or even vertebrates such as tadpoles and fish.

File Name	Script (to be 2 minutes in length please)
TIPT_Low_08	The dugong is a large marine mammal. It is one of four living species of the order Sirenia, which also includes three species of manatees. It is the only living representative of the once-diverse family Dugongidae; its closest modern relative, Steller's sea cow , was hunted to extinction in the 18th century. It is also the only sirenian in its range, which spans the waters of at least 37 countries throughout the Indo-Pacific, though the majority of dugongs live in the northern waters of Australia between Shark Bay and Moreton Bay. The dugong is the only strictly marine herbivorous mammal, as all species of manatee use fresh water to some degree. Like all modern sirenians, the dugong has a fusiform body with no dorsal fin or hind limbs, instead possessing paddle-like forelimbs used to manoeuvre. It is easily distinguished from the manatees by its fluked, dolphin-like tail, but also possesses a unique skull and teeth. The dugong is heavily dependent on seagrasses for subsistence and is thus restricted to the coastal habitats where they grow, with the largest dugong concentrations typically occurring in wide, shallow, protected areas such as bays, mangrove channels and the lee sides of large inshore islands. Its snout is sharply. Dugongs, along with other sirenians, are referred to as "sea cows" because their diet consists mainly of sea-grass. When eating they ingest the whole plant, including the roots. although when this is impossible they will feed on just the leaves.[A wide variety of seagrass has been found in dugong stomach contents, and evidence exists they will eat algae when seagrass is scarce. Although almost completely herbivorous,[13] they will occasionally eat invertebrates such as jellyfish, sea squirts, and shellfish. Dugongs in Moreton Bay, Australia, are omnivorous, feeding on invertebrates such as polychaetes[or marine algae when the supply of their choice grasses decreases.
TIPT_Low_09	A goanna is any of several Australian monitor lizards of the genus *Varanus*, as well as to certain species from Southeast Asia. Around 30 species of goanna are known, 25 of which are found in Australia. Being predatory lizards, goannas are often quite large, or at least bulky, with sharp teeth and claws. The largest is the perentie which can grow over 2.5 m (8.2 ft) in length. Not all goannas are gargantuan. Pygmy goannas may be smaller than a man's arm. The smallest of these, the short-tailed monitor reaches only 20 cm in length. They survive on smaller prey, such as insects and mice. Goannas combine predatory and scavenging behaviours. A goanna will prey upon any animal it can catch and is small enough to eat whole. Goannas have been blamed for the death of sheep by farmers, though most likely erroneously, as goannas are also eaters of carrion and are attracted to rotting meat. Most goannas are dark in colouration, browns, blacks and greens featuring prominently. Many desert-dwelling species also feature yellow-red tones. Camouflage ranges from bands and stripes to splotches, speckles, and circles, and can change as the creature matures, with juveniles sometimes being brighter than adults. Like most lizards, goannas lay eggs. Most lay eggs in a nest or burrow, but some species lay their eggs inside termite mounds. This offers protection and incubation; additionally, the termites may provide a meal for the young as they hatch. Unlike some other species of lizards, goannas do not have the ability to regrow limbs or tails. The diets of goannas vary greatly depending on the species and the habitat. Prey can include all manner of small animals: insects, smaller lizards, snakes, mammals, birds, and eggs. Meals are often eaten whole, thus the size of their meals may depend on the size of the animals.
TIPT_Low_10	Not Selected for Study
4 minutes in length please	

File Name	Script (to be 2 minutes in length please)
TIPT_High_01	Japan is an island nation in East Asia. Located in the Pacific Ocean, it lies to the east of the Sea of Japan, China, North Korea, South Korea and Russia, stretching from the Sea of Okhotsk in the north to the East China Sea and Taiwan in the south. The characters that make up Japan's name mean "sun-origin", which is why Japan is often referred to as the "Land of the Rising Sun". Japan is a stratovolcanic archipelago of 6,852 islands. The four largest islands are Honshu, Hokkaido, Kyushu, and Shikoku, which together comprise about ninety-seven percent of Japan's land area. Japan has the world's tenth-largest population, with over 126 million people. Honshū's Greater Tokyo Area, which includes the *de facto* capital of Tokyo and several surrounding prefectures, is the largest metropolitan area in the world, with over 30 million residents. Japan has a total of 6,852 islands extending along the Pacific coast of East Asia. The country, including all of the islands it controls, lies between latitudes 24° and 46°N, and longitudes 122° and 146°E. The main islands, from north to south, are Hokkaido, Honshu, Shikoku and Kyushu. The Ryukyu Islands, which includes Okinawa, are a chain to the south of Kyushu. Together they are often known as the Japanese Archipelago. About 73 percent of Japan is forested, mountainous, and unsuitable for agricultural, industrial, or residential use.[2][75] As a result, the habitable zones, mainly located in coastal areas, have extremely high population densities. Japan is one of the most densely populated countries in the world. The islands of Japan are located in a volcanic zone on the Pacific Ring of Fire. Japan has 108 active volcanoes. Destructive earthquakes, often resulting in tsunami, occur several times each century.] The 1923 Tokyo earthquake killed over 140,000 people. More recent major quakes are the 1995 Great Hanshin earthquake and the 2011 Tōhoku earthquake, a 9.0-magnitude [quake which hit Japan on March 11, 2011, and triggered a large tsunami.[52] Due to its location in the Pacific Ring of Fire, Japan is substantially prone to earthquakes and tsunami, having the highest natural disaster risk in the developed world. Japan has nine forest ecoregions which reflect the climate and geography of the islands. They range from subtropical moist broadleaf forests in the Ryūkyū and Bonin Islands, to temperate broadleaf and mixed forests in the mild climate regions of the main islands, to temperate coniferous forests in the cold, winter portions of the northern islands.[Japan has over 90,000 species of wildlife, including the brown bear, the Japanese macaque, the Japanese raccoon dog, and the Japanese giant salamander. A large network of national parks has been established to protect important areas of flora and fauna as well as thirty-seven Ramsar wetland sites. Four sites have been inscribed on the UNESCO World Heritage List for their outstanding natural value.[90] Japan has a large industrial capacity, and is home to some of the largest and most technologically advanced producers of motor vehicles, electronics, machine tools, steel and nonferrous metals, ships, chemical substances, textiles, and processed foods. Agricultural businesses in Japan cultivate 13 percent of Japan's land, and Japan accounts for nearly 15 percent of the global fish catch, second only to China. In Japan, health care is provided by national and local governments. Payment for personal medical services is offered through a universal health insurance system that provides relative equality of access, with fees set by a government committee.

File Name	Script (to be 2 minutes in length please)
TIPT_High_02	Liechtenstein is bordered by Switzerland to the west and south and Austria to the east and north. It has an area of just over 160 square kilometres (62 square miles) and an estimated population of 35,000. Liechtenstein is situated in the Upper Rhine valley of the European Alps and is bordered to the east by Austria and to the south and west by Switzerland. The entire western border of Liechtenstein is formed by the Rhine. Measured south to north the country is about 24 km (15 mi) long. Its highest point, the Grauspitz, is 2,599 m (8,527 ft). Despite its Alpine location, prevailing southerly winds make the climate of Liechtenstein comparatively mild. In winter, the mountain slopes are well suited to winter sports. New surveys using more accurate measurements of the country's borders in 2006 have set its area at 160 km^2 (61.776 sq mi), with borders of 77.9 km (48.4 mi).[27] Thus, Liechtenstein discovered in 2006 that its borders are 1.9 km (1.2 mi) longer than previously thought.[28] Liechtenstein is one of only two doubly landlocked countries in the world[29]—being a landlocked country wholly surrounded by other landlocked countries (the other is Uzbekistan). Liechtenstein is the sixth-smallest independent nation in the world by land area. Population-wise, Liechtenstein is the fourth smallest country of Europe, after Vatican City, San Marino, and Monaco. Its population is primarily Alemannic-speaking, although its resident population is approximately one third foreign-born, primarily German speakers from Germany, Austria, and Switzerland, other Swiss, Italians, and Turks. Foreign-born people make up two-thirds of the country's workforce.[*citation needed*] The official language is German There are about 250 kilometers (155 miles) of paved roadway within Liechtenstein, with 90 km (56 miles) of marked bicycle paths. A 9.5 km (5.9 mi) railway connects Austria and Switzerland through Liechtenstein. The literacy rate of Liechtenstein is 100%.[29] In 2006 Programme for International Student Assessment report, coordinated by the Organisation for Economic Co-operation and Development, ranked Liechtenstein's education as the 10th best in the world.[42] In Liechtenstein, there are four main centers for higher education: The University of Liechtenstein Private University in the Principality of Liechtenstein Liechtenstein Institute International Academy of Philosophy, Liechtenstein The Liechtenstein National Police is responsible for keeping order within the country. It consists of 87 field officers and 38 civilian staff, totaling 125 employees. All officers are equipped with small arms. The country has one of the world's lowest crime rates. Liechtenstein's prison holds few, if any, inmates, and those with sentences over two years are transferred to Austrian jurisdiction. The Liechtenstein National Police maintains a trilateral treaty with Austria and Switzerland that enables close cross-border cooperation among the police forces of the three countries.[48] Liechtenstein follows a policy of neutrality and is one of the few countries in the world that maintains no military. The army was abolished soon after the Austro-Prussian War of 1866, in which Liechtenstein fielded an army of 80 men, although they were not involved in any fighting. The demise of the German Confederation in that war freed Liechtenstein from its international obligation to maintain an army, and parliament seized this opportunity and refused to provide funding for one. The Prince objected, as such a move would leave the country defenceless, but relented on 12 February 1868 and disbanded the force.
TIPT_High_03	Not Selected for Study

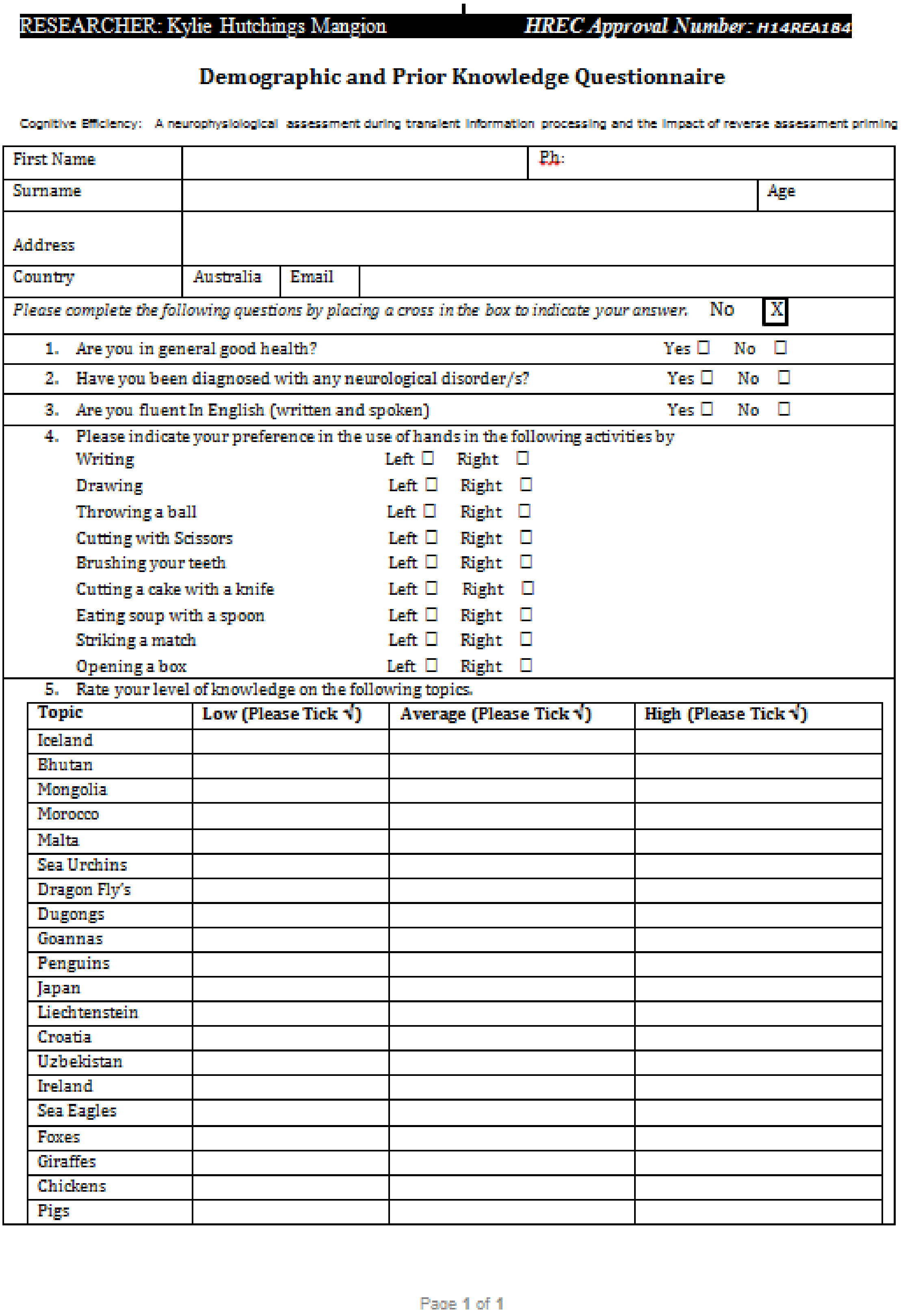
File Name	Script (to be 2 minutes in length please)
TIPT_High_04	Uzbekistan in Central Asia. It is a unitary, constitutional, presidential republic, comprising 12 provinces, 1 autonomous republic, and 1 independent city. Uzbekistan is bordered by five countries: Kazakhstan and the Aral Sea to the north; Tajikistan to the southeast; Kyrgyzstan to the northeast; Afghanistan to the south; and Turkmenistan to the southwest. Uzbekistan has an area of 447,400 square kilometres (172,700 sq mi). It is the 56th largest country in the world by area and the 42nd by population.[9] Among the CIS countries, it is the 5th largest by area and the 3rd largest by population.[10] Uzbekistan lies between latitudes 37° and 46° N, and longitudes 56° and 74° E. It stretches 1,425 kilometres (885 mi) from west to east and 930 kilometres (580 mi) from north to south. Bordering Kazakhstan and the Aral Sea to the north and northwest, Turkmenistan to the southwest, Tajikistan to the southeast, and Kyrgyzstan to the northeast, Uzbekistan is one of the largest Central Asian states and the only Central Asian state to border all the other four. Uzbekistan also shares a short border (less than 150 km or 93 mi) with Afghanistan to the south. Uzbekistan is a dry, landlocked country. It is one of two doubly landlocked countries in the world (that is, a country completely surrounded by landlocked countries), the other being Liechtenstein. In addition, due to its location within a series of endorheic basins, none of its rivers lead to the sea. Less than 10% of its territory is intensively cultivated irrigated land in river valleys and oases. The rest is vast desert (Kyzyl Kum) and mountains. When Uzbekistan gained independence in 1991, there was concern that Muslim fundamentalism would spread across the region. The expectation was that a country long denied freedom of religious practice would undergo a very rapid increase in the expression of its dominant faith. As of 1994, over half of Uzbekistan's population was said to be Muslim, though in an official survey few of that number had any real knowledge of the religion or knew how to practice it. However, Islamic observance is increasing in the region. Green tea is the national hot beverage taken throughout the day; teahouses (*Chaikhanas*) are of cultural importance. The more usual black tea is preferred in Tashkent, both green and black teas are taken daily without milk or sugar. Tea always accompanies a meal, but it is also a drink of hospitality,that is automatically offered: green or black to every guest. Ayran, a chilled yogurt drink, is popular in summer, but does not replace hot tea. Uzbekistan is home to former racing cyclist Djamolidine Abdoujaparov. Abdoujaparov has won the green jersey points contest in the Tour de France three times.[100] Abdoujaparov was a specialist at winning stages in tours or one-day races when the bunch or peloton would finish together. He would often 'sprint' in the final kilometer and had a reputation as being dangerous in these bunch sprints as he would weave from side to side. This reputation earned him the nickname 'The Terror of Tashkent'. Artur Taymazov won Uzbekistan's first wrestling medal at the 2000 Summer Olympic Games, as well as three gold medals at the 2004, 2008 Summer Olympic Games and 2012 Summer Olympic Games in Men's 120 kg. Uzbekistan has a wide mix of ethnic groups and cultures, with the Uzbek being the majority group. In 1995 about 71% of Uzbekistan's population was Uzbek.
TIPT_High_05	Not Selected for Study

File Name	Script (to be 2 minutes in length please)
TIPT_High_06	A sea eagle (also called erne or ern, mostly in reference to the white-tailed eagle) is any of the birds of prey in the genus *Haliaeetus*[1] in the bird of prey family Accipitridae. Sea eagles vary in size, from Sanford's sea eagle, averaging 2–2.7 kg, to the huge Steller's sea eagle, weighing up to 9 kg.[2] At up to 6.9 kg, the white-tailed eagle is the largest eagle in Europe. Bald eagles can weigh up to 6.3 kg, making them the largest eagle native to North America. The white-bellied sea eagle can weigh up to 3.4 kg.[2] Their diets consist mainly of fish and small mammals. There are eight living species:[2] White-bellied sea eagle Sanford's sea eagle African fish eagle Madagascan fish eagle Pallas's fish eagle White-tailed eagle Bald eagle Steller's sea eagle The white-bellied sea eagle (*Haliaeetus leucogaster*), also known as the white-breasted sea eagle, is a large diurnal bird of prey in the family Accipitridae. Originally described by Johann Friedrich Gmelin in 1788, it is closely related to Sanford's sea eagle of the Solomon Islands, and the two are considered a superspecies. A distinctive bird, the adult white-bellied sea eagle has a white head, breast, under-wing coverts and tail. The upper parts are grey and the black under-wing flight feathers contrast with the white coverts. The tail is short and wedge-shaped as in all *Haliaeetus* species. Like many raptors, the female is slightly larger than the male, and can measure up to 90 cm (35 in) long with a wingspan of up to 2.2 m (7 ft), and weigh 4.5 kg (10 lb). Immature birds have brown plumage, which is gradually replaced by white until the age of five or six years. The call is a loud goose-like honking. Resident from India and Sri Lanka through Southeast Asia to Australia on coasts and major waterways, the white-bellied sea eagle breeds and hunts near water, and fish form around half of its diet. Opportunistic, it consumes carrion and a wide variety of animals. Although rated of *Least Concern* globally, it has declined in parts of southeast Asia such as Thailand, and southeastern Australia. It is ranked as *Threatened* in Victoria and *Vulnerable* in South Australia and Tasmania. Human disturbance to its habitat is the main threat, both from direct human activity near nests which impacts on breeding success, and from removal of suitable trees for nesting. The white-bellied sea eagle is revered by indigenous people in many parts of Australia, and is the subject of various folk tales throughout its range. The Sanford's sea eagle was discovered by and named after Dr Leonard C. Sanford, a trustee for the American Museum of Natural History. The first description was by Ernst Mayr in 1935. It can reach a length between 70–90 cm (28–35 in) and a weight between 1.1–2.7 kg (2.4–6.0 lb.). The wingspan is between 165–185 cm (5.41–6.07 ft.). It is the only large predator on the Solomon Islands. The eagles inhabit coastal forests and lakes up to an altitude of about 1500 m asl.[3] The plumage is whitish brown to bright brown on the head and the neck. The underparts are brown to reddish brown and dark brown. The upperparts are darkish brown to gray-black. The eyes are bright brown. Uniquely among sea eagles, this species has an entirely dark tail throughout its life. The breeding season is from August to October. The nest consists of two eggs. The diet consists of mainly of tideline carrion, fish, mollusks, crabs, tortoises, and sea snakes, and more rarely birds and megabats snatched from the rainforest canopy

File Name	Script (to be 2 minutes in length please)
TIPT_High_07	Foxes are small-to-medium-sized, omnivorous and carnivorous mammals belonging to several genera of the Canidae family. Foxes are slightly smaller than a medium-size domestic dog, with a flattened skull, upright triangular ears, a pointed, slightly upturned snout, and a long bushy tail (or *brush*). Twelve species belong to the monophyletic group of *Vulpes* genus of "true foxes". Approximately another 25 current or extinct species are always or sometimes called foxes; these foxes are either part of the paraphyletic group of the South American foxes and the outlying group, which consists of Bat-eared fox, Gray fox, and Island fox.[1] Foxes are found on every continent except Antarctica. By far the most common and widespread species of fox is the red fox (*Vulpes vulpes*) with about 47 recognized sub-species In the wild, the typical lifespan of a fox is one to three years, although individuals may live up to ten years. Unlike many canids, foxes are not always pack animals. Typically, they live in small family groups, but some (arctic foxes) are known to be solitary.[2][6] Foxes are omnivores.[10][11] The diet of foxes is largely made up of invertebrates such as insects, and small vertebrates such as reptiles and birds, and also can include eggs and plants. Many species are generalist predators, but some (such as the crab-eating fox) have more specialized diets. Most species of fox consume around 1 kg (2.2 lb) of food every day. Foxes cache excess food, burying it for later consumption, usually under leaves, snow, or soil.[6][12] Foxes tend to use a pouncing technique where they crouch down to camouflage themselves in the terrain, then using their hind legs, leap up with great force to land on top of their targeted prey.[2] Using their pronounced canine teeth, foxes grip on to their prey's neck and either shake until the prey is dead, or until the animal can be disemboweled.[2] The gray fox is one of only two canine species known to climb trees; the other is the raccoon dog. The fox's vocal repertoire is vast: Whine- Made shortly after birth. Occurs at a high rate when cubs are hungry and when their body temperatures are low. Whining stimulates the mother to care for her young; it also has been known to stimulate the male fox into caring for his mate and cubs. Yelp- Made about 19 days later. The cubs' whining turns into infantile barks, yelps, which occur heavily during play. Explosive call- At about a month old, the cubs can emit an explosive call which is intended to be threatening to intruders or other cubs; a high pitch howl. Combative call- In adults, the explosive call becomes an open-mouthed combative call during any conflict; a sharper bark. Growl- An adult fox's indication to their cubs to feed or head to the adult's location. Bark- Adult foxes warn against intruders and in defense by barking.[2][17] In the case of domesticated foxes, the whining seems to remain in adult individuals as a sign of excitement and submission in the presence of their owners. Foxes are often considered pests or nuisance creatures for their opportunistic attacks on poultry and other small livestock. Fox attacks on humans are not common but have increased in frequency.[28] Many foxes adapt well to human environments, with several species classified as "resident urban carnivores" for their ability to sustain populations entirely within urban boundaries.[29] Foxes in urban areas can live longer and can have smaller litter sizes than foxes in non-urban areas.[29] Urban foxes are ubiquitous in Europe, where they show altered behaviors compared to non-urban foxes, including increased population density, smaller territory, and pack foraging.[30]

File Name	Script (to be 2 minutes in length please)
TIPT_High_08	The giraffe (*Giraffa camelopardalis*) is an African even-toed ungulate mammal, the tallest living terrestrial animal and the largest ruminant. Its species name refers to its camel-like appearance and the patches of color on its fur. Its chief distinguishing characteristics are its extremely long neck and legs, its horn-like ossicones, and its distinctive coat patterns. It is classified under the family Giraffidae, along with its closest extant relative, the okapi. The nine subspecies are distinguished by their coat patterns. The giraffe's scattered range extends from Chad in the north to South Africa in the south, and from Niger in the west to Somalia in the east. Giraffes usually inhabit savannas, grasslands, and open woodlands. Their primary food source is acacia leaves, which they browse at heights most other herbivores cannot reach. Giraffes are preyed on by lions; their calves are also targeted by leopards, spotted hyenas, and wild dogs. Adult giraffes do not have strong social bonds, though they do gather in loose aggregations if they happen to be moving in the same general direction. Males establish social hierarchies through "necking", which are combat bouts where the neck is used as a weapon. Dominant males gain mating access to females, which bear the sole responsibility for raising the young. A giraffe has only two gaits: walking and galloping. Walking is done by moving the legs on one side of the body at the same time, then doing the same on the other side.[25] When galloping, the hind legs move around the front legs before the latter move forward,[15] and the tail will curl up.[25] The animal relies on the forward and backward motions of its head and neck to maintain balance and the counter momentum while galloping.[10]:327–29 The giraffe can reach a sprint speed of up to 60 km/h (37 mph),[38] and can sustain 50 km/h (31 mph) for several kilometers.[39] A giraffe rests by lying with its body on top of its folded legs.[10]:329 To lie down, the animal kneels on its front legs and then lowers the rest of its body. To get back up, it first gets on its knees and spreads its hind legs to raise its hindquarters. It then straightens its front legs. With each step, the animal swings its head.[32]:31 In captivity, the giraffe sleeps intermittently around 4.6 hours per day, mostly at night.[40] It usually sleeps lying down; however, standing sleeps have been recorded, particularly in older individuals. Intermittent short "deep sleep" phases while lying are characterized by the giraffe bending its neck backwards and resting its head on the hip or thigh, a position believed to indicate paradoxical sleep.[40] If the giraffe wants to bend down to drink, it either spreads its front legs or bends its knees.[25] Giraffes would probably not be competent swimmers as their long legs would be highly cumbersome in the water,[41] although they could possibly float.[42] When swimming, the thorax would be weighed down by the front legs, making it difficult for the animal to move its neck and legs in harmony[41][42] or keep its head above the surface. Giraffe gestation lasts 400–460 days, after which a single calf is normally born, although twins occur on rare occasions.[63] The mother gives birth standing up. The calf emerges head and front legs first, having broken through the fetal membranes, and falls to the ground, severing the umbilical cord.[14] The mother then grooms the newborn and helps it stand up.[32]:40 A newborn giraffe is about 1.8 m (6 ft) tall. Within a few hours of birth, the calf can run around and is almost indistinguishable from a one-week-old. However, for the first 1–3 weeks, it spends most of its time hiding;[64] its coat pattern providing camouflage. The ossicones, which have lain flat while it was in the womb, become erect within a few days.[25]
TIPT_High_09	Not Selected for Study
TIPT_High_10	Not Selected for Study

Appendix G Demographic and prior knowledge questionnaire



RESEARCHER: Kylie Hutchings Mangion *HREC Approval Number:* **H14REA184**

Demographic and Prior Knowledge Questionnaire

Cognitive Efficiency: A neurophysiological assessment during transient information processing and the impact of reverse assessment priming

First Name		Ph:	
Surname		Age	
Address			
Country	Australia	Email	

Please complete the following questions by placing a cross in the box to indicate your answer. No ☒

1. Are you in general good health? Yes ☐ No ☐
2. Have you been diagnosed with any neurological disorder/s? Yes ☐ No ☐
3. Are you fluent In English (written and spoken) Yes ☐ No ☐
4. Please indicate your preference in the use of hands in the following activities by

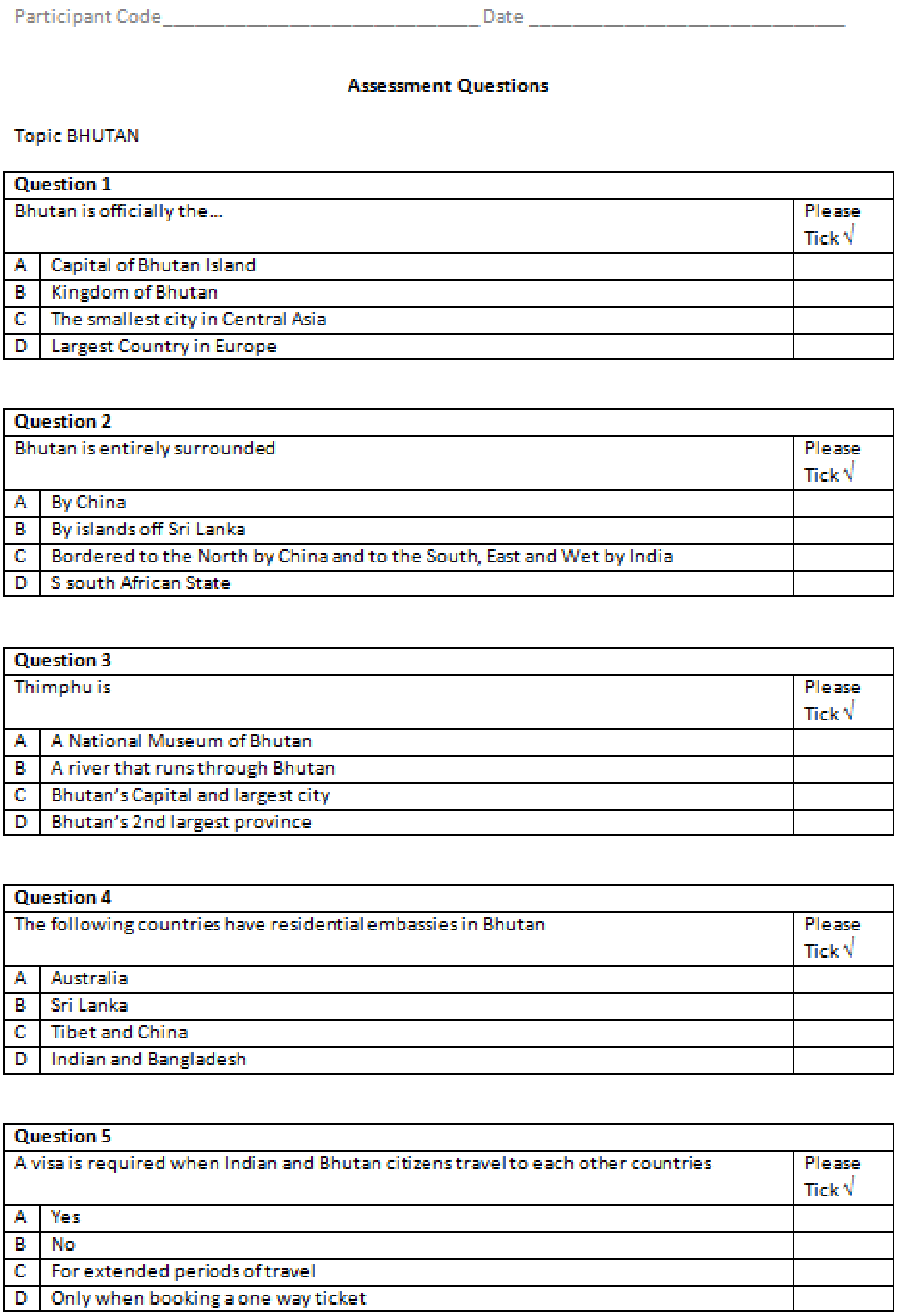
Writing	Left ☐	Right ☐
Drawing	Left ☐	Right ☐
Throwing a ball	Left ☐	Right ☐
Cutting with Scissors	Left ☐	Right ☐
Brushing your teeth	Left ☐	Right ☐
Cutting a cake with a knife	Left ☐	Right ☐
Eating soup with a spoon	Left ☐	Right ☐
Striking a match	Left ☐	Right ☐
Opening a box	Left ☐	Right ☐

5. Rate your level of knowledge on the following topics.

Topic	Low (Please Tick √)	Average (Please Tick √)	High (Please Tick √)
Iceland			
Bhutan			
Mongolia			
Morocco			
Malta			
Sea Urchins			
Dragon Fly's			
Dugongs			
Goannas			
Penguins			
Japan			
Liechtenstein			
Croatia			
Uzbekistan			
Ireland			
Sea Eagles			
Foxes			
Giraffes			
Chickens			
Pigs			

Page 1 of 1

Appendix H Assessment questions sheet (all tasks x 20)



Participant Code_____________________________ Date _____________________________

Assessment Questions

Topic BHUTAN

Question 1		
Bhutan is officially the…		Please Tick √
A	Capital of Bhutan Island	
B	Kingdom of Bhutan	
C	The smallest city in Central Asia	
D	Largest Country in Europe	

Question 2		
Bhutan is entirely surrounded		Please Tick √
A	By China	
B	By islands off Sri Lanka	
C	Bordered to the North by China and to the South, East and Wet by India	
D	S south African State	

Question 3		
Thimphu is		Please Tick √
A	A National Museum of Bhutan	
B	A river that runs through Bhutan	
C	Bhutan's Capital and largest city	
D	Bhutan's 2nd largest province	

Question 4		
The following countries have residential embassies in Bhutan		Please Tick √
A	Australia	
B	Sri Lanka	
C	Tibet and China	
D	Indian and Bangladesh	

Question 5		
A visa is required when Indian and Bhutan citizens travel to each other countries		Please Tick √
A	Yes	
B	No	
C	For extended periods of travel	
D	Only when booking a one way ticket	

Participant Code______________________________ Date ______________________________

Assessment Questions

Topic MONGOLIA

Question 1		
Ulaan Battar, the capital city is home to about ______% of the population?		Please Tick √
A	45	
B	40	
C	60	
D	85	

Question 2		
Mongolia is the most sparsely populated county in _________		Please Tick √
A	Asia	
B	The world, 2nd to Tibet	
C	The world	
D	Asia except Tibet	

Question 3		
Mongolia is the worlds		Please Tick √
A	2nd largest landlocked county of Kazakhstan	
B	2nd largest landlocked county	
C	Smallest Asian country	
D	None of the above	

Question 4		
Mongolia lost		Please Tick √
A	All its sheep and goats in an extreme summer	
B	Animals due to a drought that lasted 4 years	
C	The election to host the Olympics in 1942 due to weather	
D	9.7 million animals in 2009/10 winter	

Question 5		
Naadam festival is celebrated		Please Tick √
A	In every town and village	
B	By the farmers of Mongolia	
C	With building structures	
D	None of the above	

Participant Code ______________________________ Date ______________________________

Assessment Questions

Topic MALTA

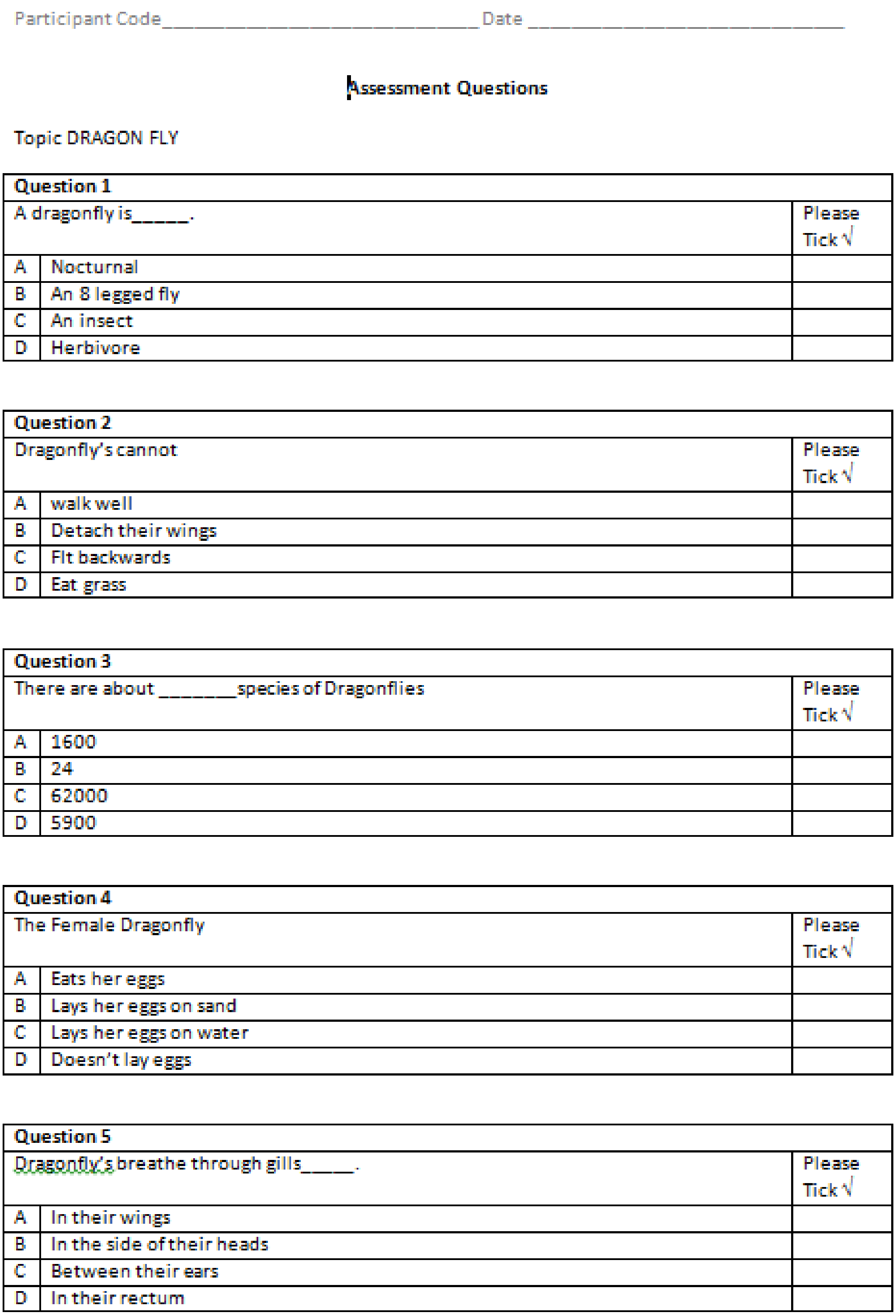
Question 1		
Malta is an Island Country comprising of an Archipelago of ___ Islands		Please Tick √
A	7	
B	6	
C	5	
D	13	

Question 2		
Malta is surrounded by the ______sea		Please Tick √
A	Dead	
B	Black	
C	Mediterranean	
D	Red	

Question 3		
Malta covers just over____Km2		Please Tick √
A	316	
B	290	
C	400	
D	700	

Question 4		
Malta has two official languages they are __________ & ___________		Please Tick √
A	Maltese and Arabic	
B	English and French	
C	Maltese and English	
D	Arabic and English	

Question 5		
Paul the Apostle was...		Please Tick √
A	Anointed in Malta	
B	Not known of in Malta	
C	Was the only religious icon in Malta	
D	Shipwrecked on Malta	



Participant Code_____________________________ Date _____________________________

Assessment Questions

Topic DRAGON FLY

Question 1		
A dragonfly is_____.		Please Tick √
A	Nocturnal	
B	An 8 legged fly	
C	An insect	
D	Herbivore	

Question 2		
Dragonfly's cannot		Please Tick √
A	walk well	
B	Detach their wings	
C	Flt backwards	
D	Eat grass	

Question 3		
There are about _______species of Dragonflies		Please Tick √
A	1600	
B	24	
C	62000	
D	5900	

Question 4		
The Female Dragonfly		Please Tick √
A	Eats her eggs	
B	Lays her eggs on sand	
C	Lays her eggs on water	
D	Doesn't lay eggs	

Question 5		
Dragonfly's breathe through gills_____.		Please Tick √
A	In their wings	
B	In the side of their heads	
C	Between their ears	
D	In their rectum	

Participant Code_______________________________ Date _______________________________

Assessment Questions

Topic DUGONG

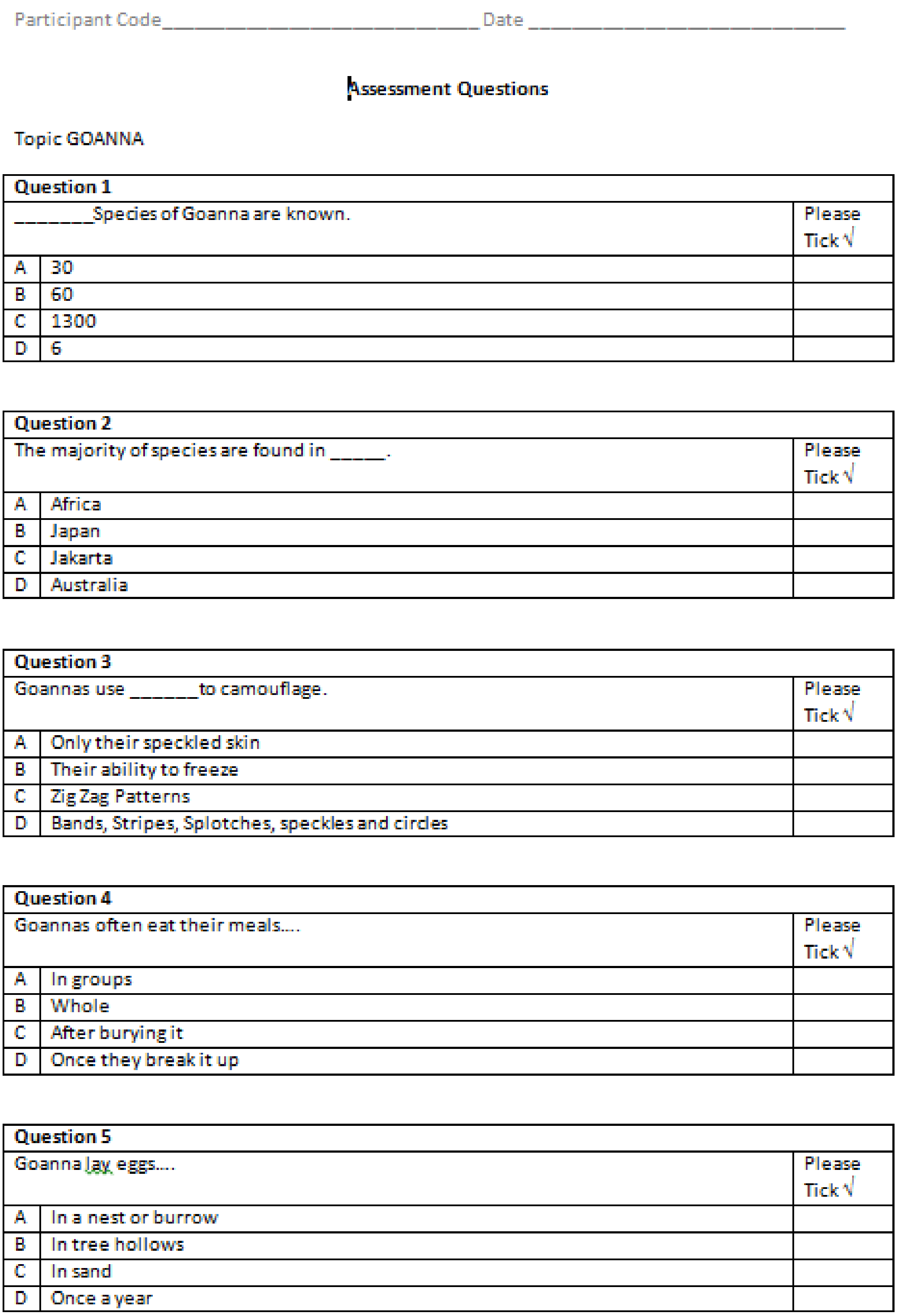
Question 1		
The Dugong is a large marine _____.		Please Tick √
A	Reptile	
B	Fish	
C	Mammal	
D	Herbivore	

Question 2		
Its closest modern relative, Stellar's Sea cow_____.		Please Tick √
A	Was hunted to extinction in the 18the century.	
B	Is near extinction	
C	Was extinct earlier this century	
D	Still exists in small numbers off the coast of Japan.	

Question 3		
The majority of Dugong live I the____.		Please Tick √
A	North Waters of New Zealand	
B	North Waters of Ireland	
C	North Waters of Australia near Shark Bay and Moreton Bay.	
D	Northern Waters of Australia near PNG	

Question 4		
The Dugong uses it's ________ to manoeuvre.		Please Tick √
A	Fins	
B	Forelimbs	
C	Tail	
D	Legs	

Question 5		
Dugongs are referred to as a "Sea Cows" because of...		Please Tick √
A	Their shape	
B	The noise they make	
C	Of their diet consisting of mainly sea grass	
D	Their habits	



Participant Code_____________________________ Date _____________________________

Assessment Questions

Topic GOANNA

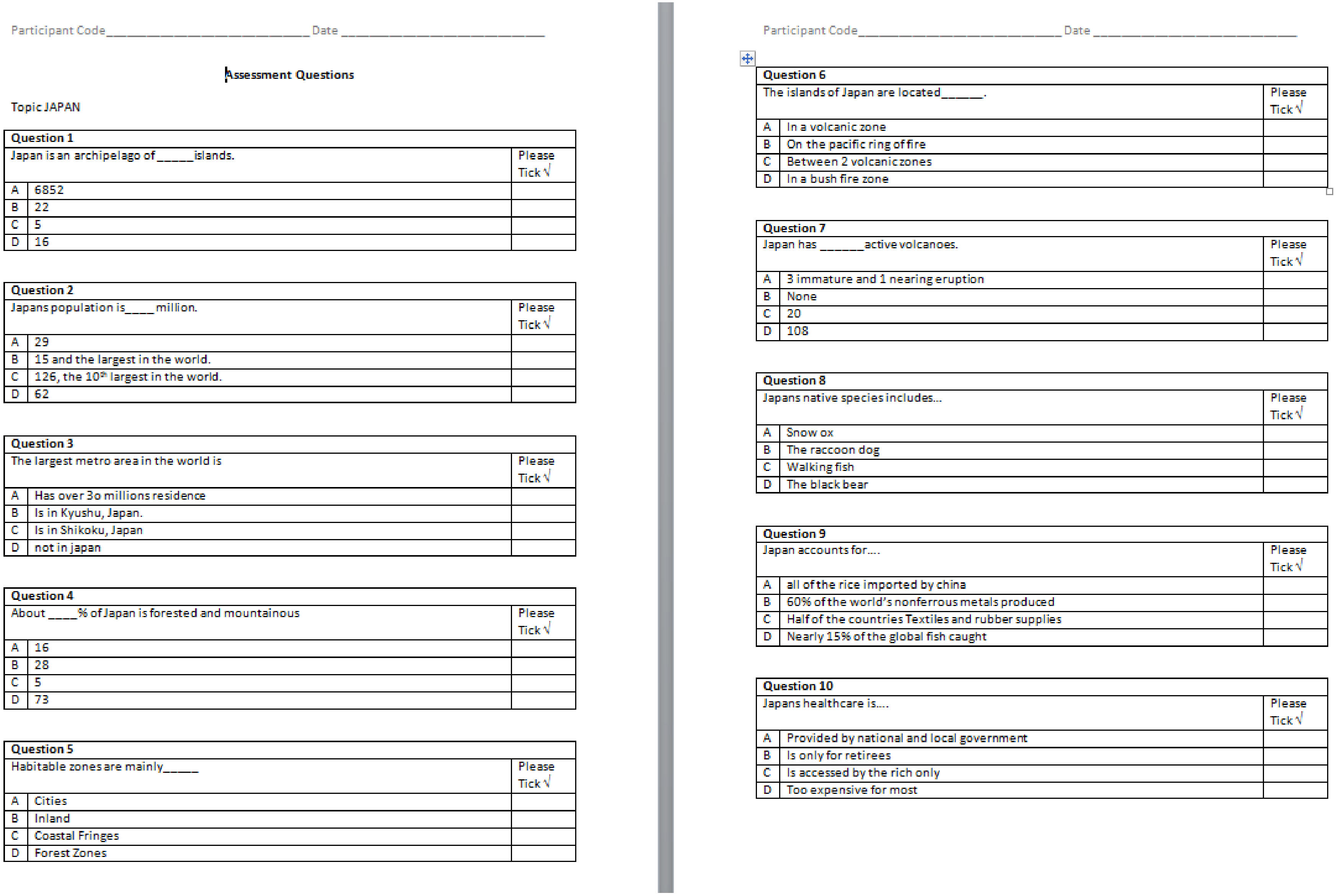
Question 1		
_______Species of Goanna are known.		Please Tick √
A	30	
B	60	
C	1300	
D	6	

Question 2		
The majority of species are found in _____.		Please Tick √
A	Africa	
B	Japan	
C	Jakarta	
D	Australia	

Question 3		
Goannas use ______to camouflage.		Please Tick √
A	Only their speckled skin	
B	Their ability to freeze	
C	Zig Zag Patterns	
D	Bands, Stripes, Splotches, speckles and circles	

Question 4		
Goannas often eat their meals….		Please Tick √
A	In groups	
B	Whole	
C	After burying it	
D	Once they break it up	

Question 5		
Goanna lay eggs….		Please Tick √
A	In a nest or burrow	
B	In tree hollows	
C	In sand	
D	Once a year	



Participant Code___________________________ Date ___________________________

Assessment Questions

Topic JAPAN

Question 1		
Japan is an archipelago of _____islands.		Please Tick √
A	6852	
B	22	
C	5	
D	16	

Question 2		
Japans population is____ million.		Please Tick √
A	29	
B	15 and the largest in the world.	
C	126, the 10th largest in the world.	
D	62	

Question 3		
The largest metro area in the world is		Please Tick √
A	Has over 3o millions residence	
B	Is in Kyushu, Japan.	
C	Is in Shikoku, Japan	
D	not in japan	

Question 4		
About ____% of Japan is forested and mountainous		Please Tick √
A	16	
B	28	
C	5	
D	73	

Question 5		
Habitable zones are mainly_____		Please Tick √
A	Cities	
B	Inland	
C	Coastal Fringes	
D	Forest Zones	

Participant Code___________________________ Date ___________________________

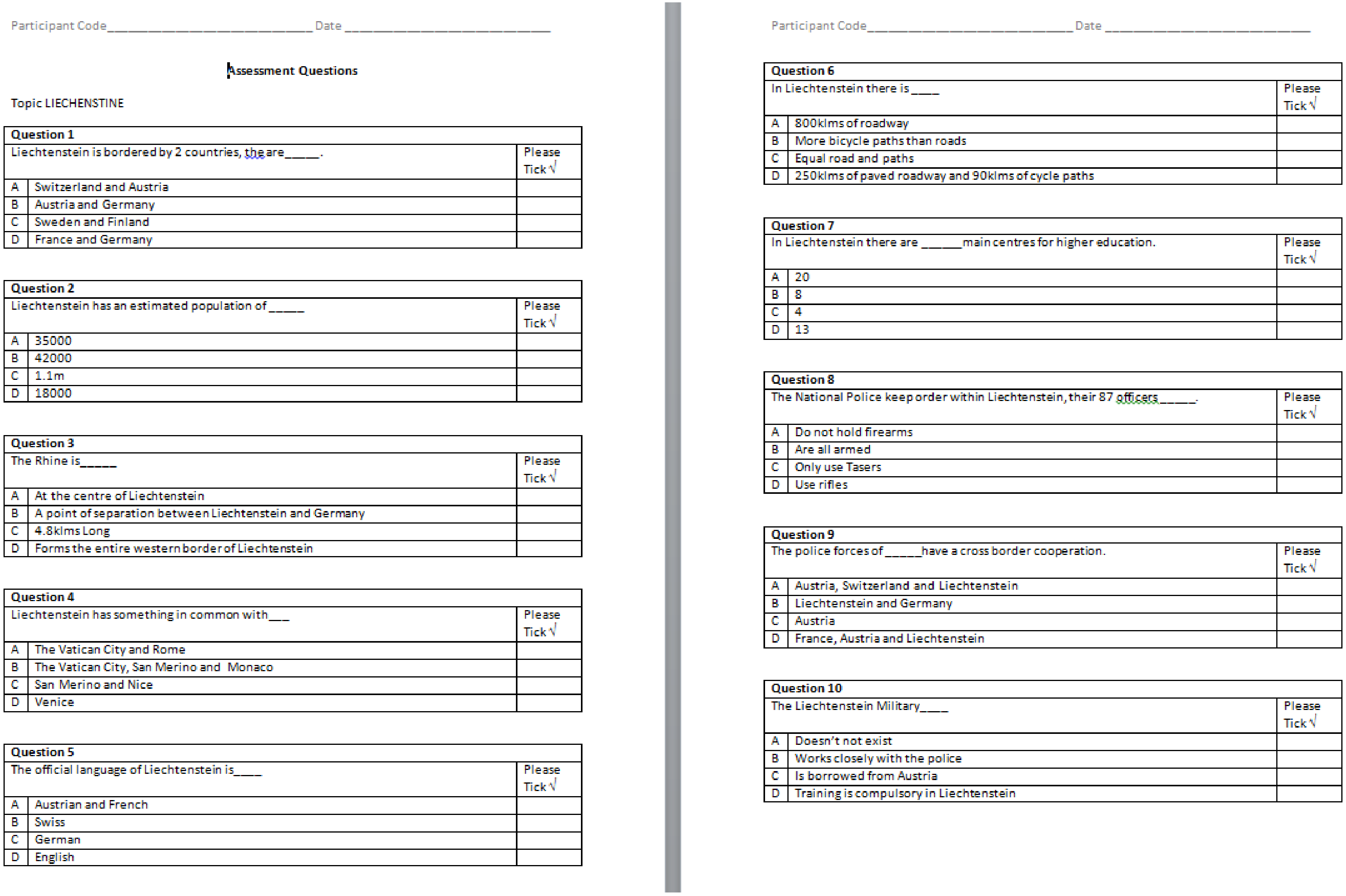
Question 6		
The islands of Japan are located______.		Please Tick √
A	In a volcanic zone	
B	On the pacific ring of fire	
C	Between 2 volcanic zones	
D	In a bush fire zone	

Question 7		
Japan has ______active volcanoes.		Please Tick √
A	3 immature and 1 nearing eruption	
B	None	
C	20	
D	108	

Question 8		
Japans native species includes…		Please Tick √
A	Snow ox	
B	The raccoon dog	
C	Walking fish	
D	The black bear	

Question 9		
Japan accounts for….		Please Tick √
A	all of the rice imported by china	
B	60% of the world's nonferrous metals produced	
C	Half of the countries Textiles and rubber supplies	
D	Nearly 15% of the global fish caught	

Question 10		
Japans healthcare is….		Please Tick √
A	Provided by national and local government	
B	Is only for retirees	
C	Is accessed by the rich only	
D	Too expensive for most	



Participant Code_____________________________ Date _____________________________

Assessment Questions

Topic LIECHENSTINE

Question 1		
Liechtenstein is bordered by 2 countries, the are_____.		Please Tick √
A	Switzerland and Austria	
B	Austria and Germany	
C	Sweden and Finland	
D	France and Germany	

Question 2		
Liechtenstein has an estimated population of _____		Please Tick √
A	35000	
B	42000	
C	1.1m	
D	18000	

Question 3		
The Rhine is_____		Please Tick √
A	At the centre of Liechtenstein	
B	A point of separation between Liechtenstein and Germany	
C	4.8klms Long	
D	Forms the entire western border of Liechtenstein	

Question 4		
Liechtenstein has something in common with___		Please Tick √
A	The Vatican City and Rome	
B	The Vatican City, San Merino and Monaco	
C	San Merino and Nice	
D	Venice	

Question 5		
The official language of Liechtenstein is____		Please Tick √
A	Austrian and French	
B	Swiss	
C	German	
D	English	

Participant Code_____________________________ Date _____________________________

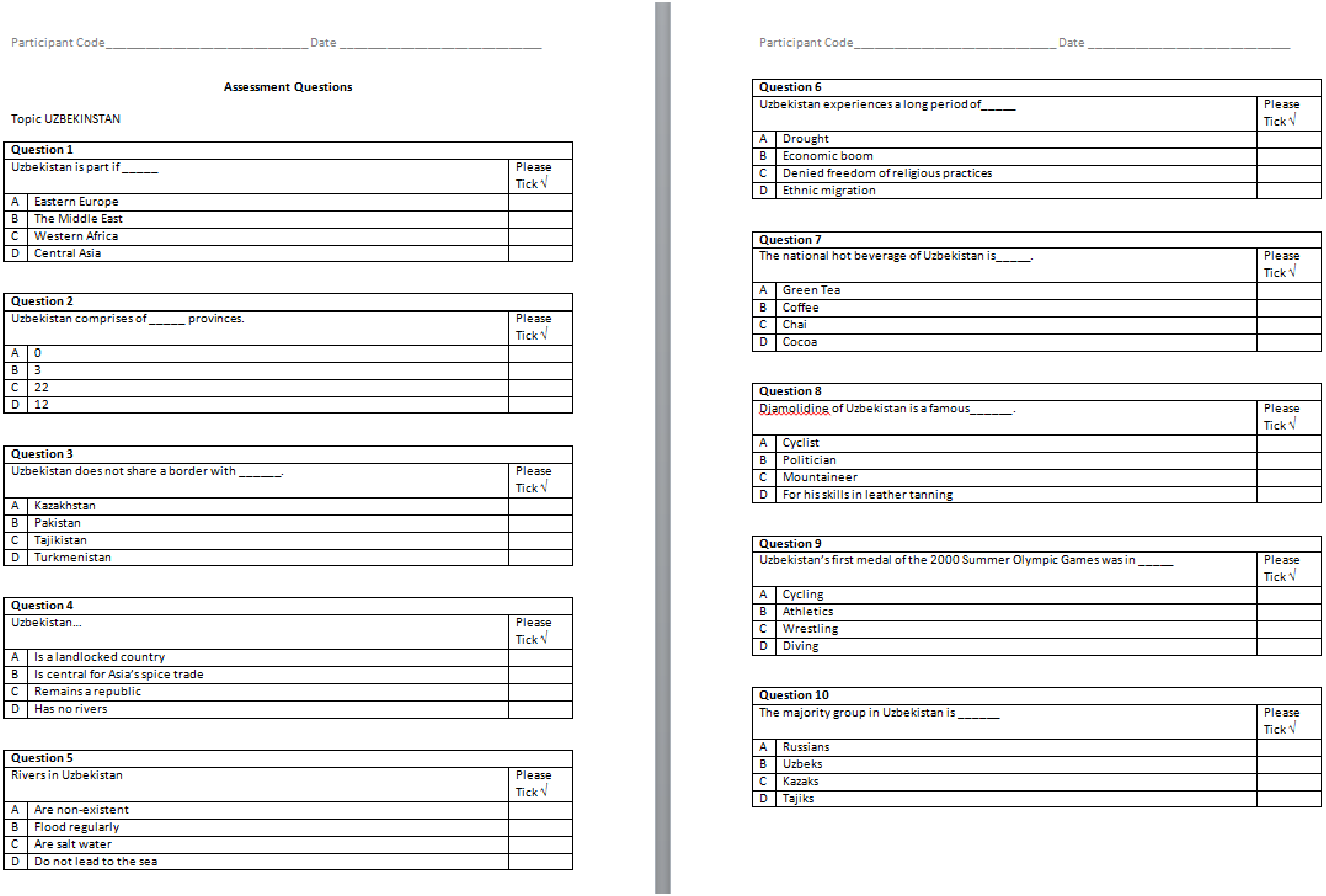
Question 6		
In Liechtenstein there is ____		Please Tick √
A	800klms of roadway	
B	More bicycle paths than roads	
C	Equal road and paths	
D	250klms of paved roadway and 90klms of cycle paths	

Question 7		
In Liechtenstein there are ______main centres for higher education.		Please Tick √
A	20	
B	8	
C	4	
D	13	

Question 8		
The National Police keep order within Liechtenstein, their 87 officers_____.		Please Tick √
A	Do not hold firearms	
B	Are all armed	
C	Only use Tasers	
D	Use rifles	

Question 9		
The police forces of _____have a cross border cooperation.		Please Tick √
A	Austria, Switzerland and Liechtenstein	
B	Liechtenstein and Germany	
C	Austria	
D	France, Austria and Liechtenstein	

Question 10		
The Liechtenstein Military____		Please Tick √
A	Doesn't not exist	
B	Works closely with the police	
C	Is borrowed from Austria	
D	Training is compulsory in Liechtenstein	



Participant Code___________________________ Date ___________________________

Assessment Questions

Topic UZBEKISTAN

Question 1		
Uzbekistan is part if _____		Please Tick √
A	Eastern Europe	
B	The Middle East	
C	Western Africa	
D	Central Asia	

Question 2		
Uzbekistan comprises of _____ provinces.		Please Tick √
A	0	
B	3	
C	22	
D	12	

Question 3		
Uzbekistan does not share a border with ______.		Please Tick √
A	Kazakhstan	
B	Pakistan	
C	Tajikistan	
D	Turkmenistan	

Question 4		
Uzbekistan…		Please Tick √
A	Is a landlocked country	
B	Is central for Asia's spice trade	
C	Remains a republic	
D	Has no rivers	

Question 5		
Rivers in Uzbekistan		Please Tick √
A	Are non-existent	
B	Flood regularly	
C	Are salt water	
D	Do not lead to the sea	

Participant Code___________________________ Date ___________________________

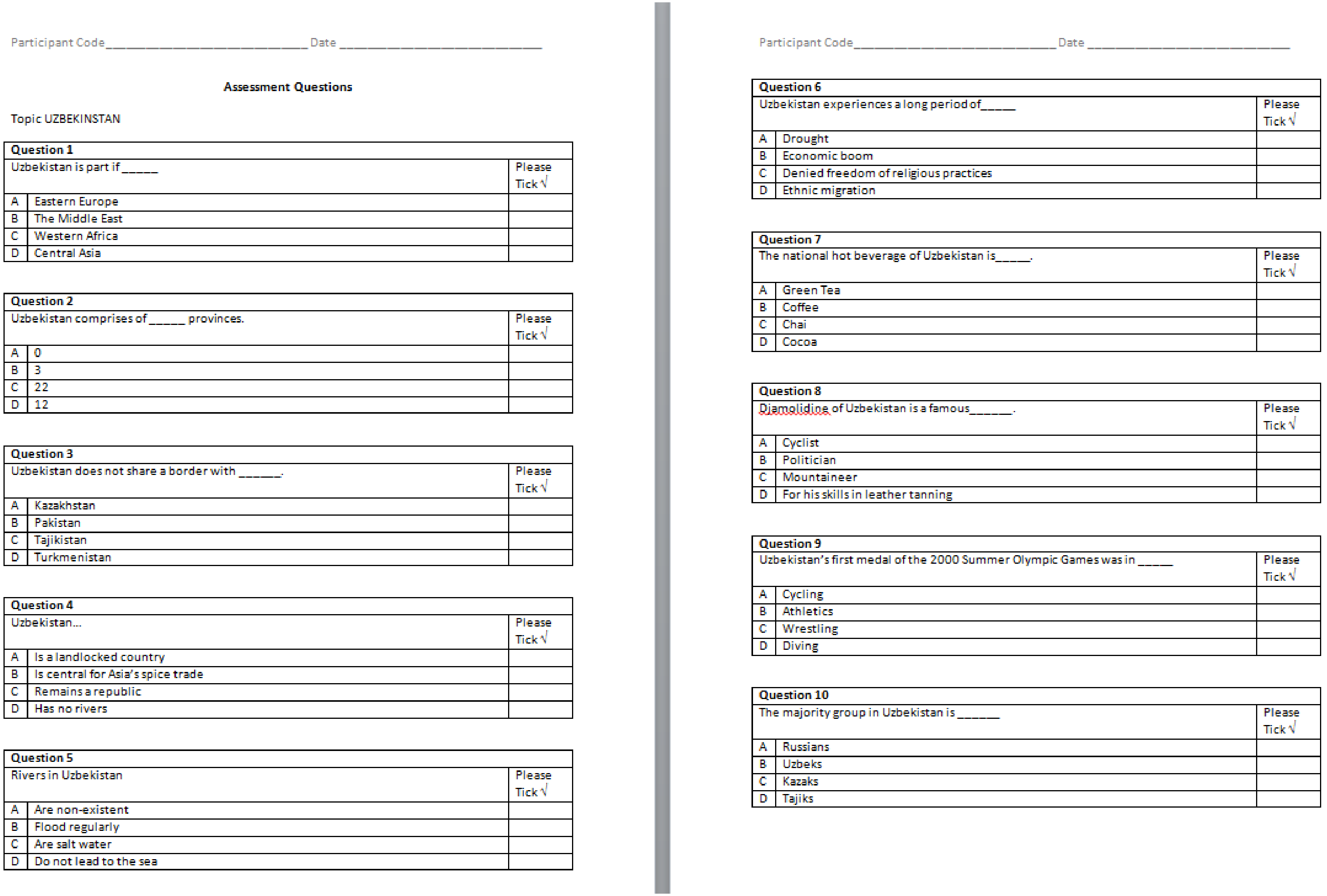
Question 6		
Uzbekistan experiences a long period of_____		Please Tick √
A	Drought	
B	Economic boom	
C	Denied freedom of religious practices	
D	Ethnic migration	

Question 7		
The national hot beverage of Uzbekistan is_____.		Please Tick √
A	Green Tea	
B	Coffee	
C	Chai	
D	Cocoa	

Question 8		
Djamolidine of Uzbekistan is a famous______.		Please Tick √
A	Cyclist	
B	Politician	
C	Mountaineer	
D	For his skills in leather tanning	

Question 9		
Uzbekistan's first medal of the 2000 Summer Olympic Games was in _____		Please Tick √
A	Cycling	
B	Athletics	
C	Wrestling	
D	Diving	

Question 10		
The majority group in Uzbekistan is ______		Please Tick √
A	Russians	
B	Uzbeks	
C	Kazaks	
D	Tajiks	



Participant Code_____________________________ Date _____________________________

Assessment Questions

Topic UZBEKINSTAN

Question 1		
Uzbekistan is part if_____		Please Tick √
A	Eastern Europe	
B	The Middle East	
C	Western Africa	
D	Central Asia	

Question 2		
Uzbekistan comprises of _____ provinces.		Please Tick √
A	0	
B	3	
C	22	
D	12	

Question 3		
Uzbekistan does not share a border with ______.		Please Tick √
A	Kazakhstan	
B	Pakistan	
C	Tajikistan	
D	Turkmenistan	

Question 4		
Uzbekistan…		Please Tick √
A	Is a landlocked country	
B	Is central for Asia's spice trade	
C	Remains a republic	
D	Has no rivers	

Question 5		
Rivers in Uzbekistan		Please Tick √
A	Are non-existent	
B	Flood regularly	
C	Are salt water	
D	Do not lead to the sea	

Participant Code_____________________________ Date _____________________________

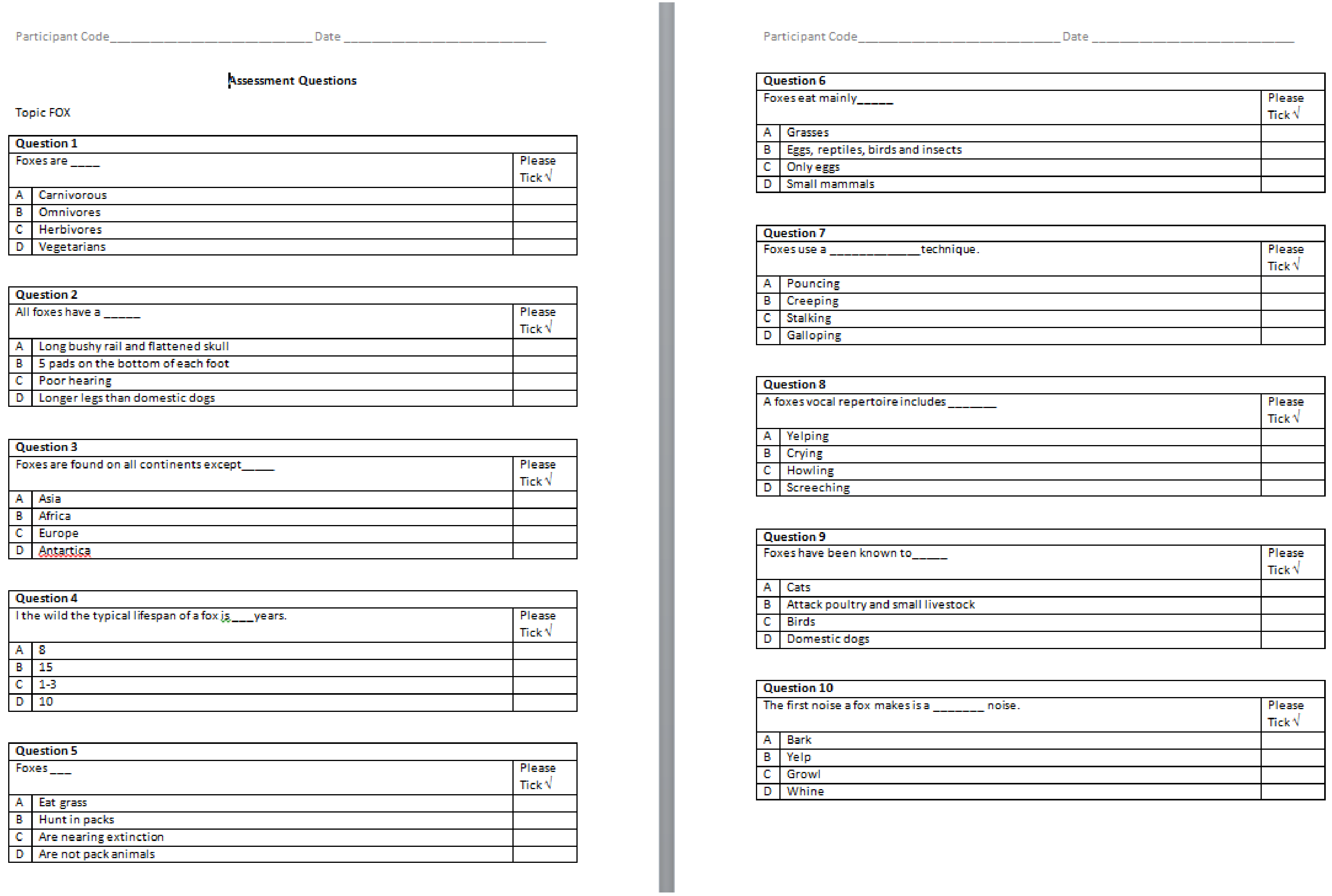
Question 6		
Uzbekistan experiences a long period of_____		Please Tick √
A	Drought	
B	Economic boom	
C	Denied freedom of religious practices	
D	Ethnic migration	

Question 7		
The national hot beverage of Uzbekistan is_____.		Please Tick √
A	Green Tea	
B	Coffee	
C	Chai	
D	Cocoa	

Question 8		
Djamolidine of Uzbekistan is a famous______.		Please Tick √
A	Cyclist	
B	Politician	
C	Mountaineer	
D	For his skills in leather tanning	

Question 9		
Uzbekistan's first medal of the 2000 Summer Olympic Games was in _____		Please Tick √
A	Cycling	
B	Athletics	
C	Wrestling	
D	Diving	

Question 10		
The majority group in Uzbekistan is ______		Please Tick √
A	Russians	
B	Uzbeks	
C	Kazaks	
D	Tajiks	



Participant Code____________________________ Date ____________________________

Assessment Questions

Topic FOX

Question 1		
Foxes are ____		Please Tick √
A	Carnivorous	
B	Omnivores	
C	Herbivores	
D	Vegetarians	

Question 2		
All foxes have a _____		Please Tick √
A	Long bushy rail and flattened skull	
B	5 pads on the bottom of each foot	
C	Poor hearing	
D	Longer legs than domestic dogs	

Question 3		
Foxes are found on all continents except_____		Please Tick √
A	Asia	
B	Africa	
C	Europe	
D	Antartica	

Question 4		
I the wild the typical lifespan of a fox is___years.		Please Tick √
A	8	
B	15	
C	1-3	
D	10	

Question 5		
Foxes ___		Please Tick √
A	Eat grass	
B	Hunt in packs	
C	Are nearing extinction	
D	Are not pack animals	

Participant Code____________________________ Date ____________________________

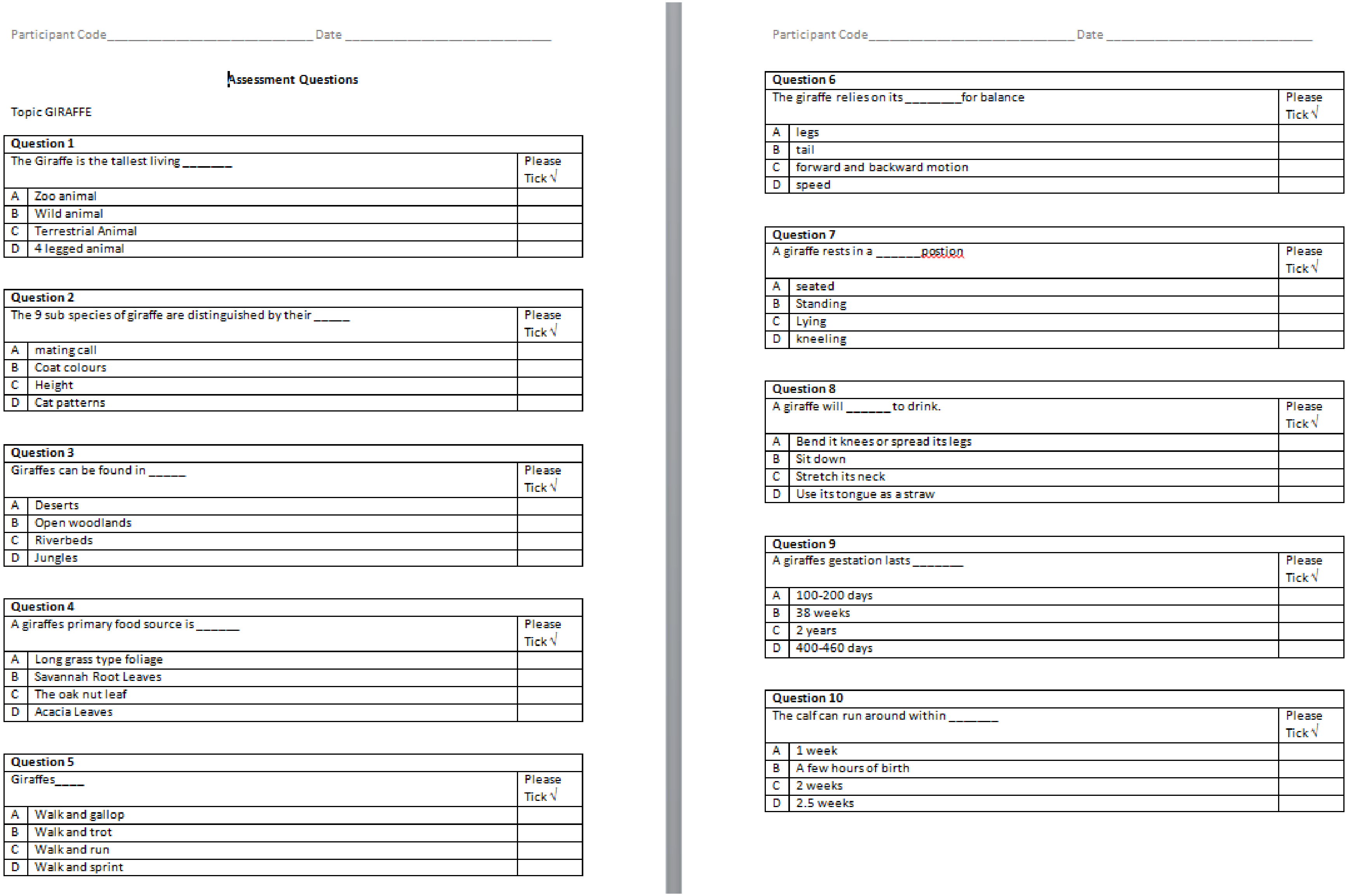
Question 6		
Foxes eat mainly_____		Please Tick √
A	Grasses	
B	Eggs, reptiles, birds and insects	
C	Only eggs	
D	Small mammals	

Question 7		
Foxes use a ____________technique.		Please Tick √
A	Pouncing	
B	Creeping	
C	Stalking	
D	Galloping	

Question 8		
A foxes vocal repertoire includes _______		Please Tick √
A	Yelping	
B	Crying	
C	Howling	
D	Screeching	

Question 9		
Foxes have been known to_____		Please Tick √
A	Cats	
B	Attack poultry and small livestock	
C	Birds	
D	Domestic dogs	

Question 10		
The first noise a fox makes is a _______ noise.		Please Tick √
A	Bark	
B	Yelp	
C	Growl	
D	Whine	



Participant Code____________________________ Date ____________________________

Assessment Questions

Topic GIRAFFE

Question 1		
The Giraffe is the tallest living _______		Please Tick √
A	Zoo animal	
B	Wild animal	
C	Terrestrial Animal	
D	4 legged animal	

Question 2		
The 9 sub species of giraffe are distinguished by their _____		Please Tick √
A	mating call	
B	Coat colours	
C	Height	
D	Cat patterns	

Question 3		
Giraffes can be found in _____		Please Tick √
A	Deserts	
B	Open woodlands	
C	Riverbeds	
D	Jungles	

Question 4		
A giraffes primary food source is ______		Please Tick √
A	Long grass type foliage	
B	Savannah Root Leaves	
C	The oak nut leaf	
D	Acacia Leaves	

Question 5		
Giraffes____		Please Tick √
A	Walk and gallop	
B	Walk and trot	
C	Walk and run	
D	Walk and sprint	

Participant Code____________________________ Date ____________________________

Question 6		
The giraffe relies on its ________for balance		Please Tick √
A	legs	
B	tail	
C	forward and backward motion	
D	speed	

Question 7		
A giraffe rests in a ______postion		Please Tick √
A	seated	
B	Standing	
C	Lying	
D	kneeling	

Question 8		
A giraffe will ______to drink.		Please Tick √
A	Bend it knees or spread its legs	
B	Sit down	
C	Stretch its neck	
D	Use its tongue as a straw	

Question 9		
A giraffes gestation lasts _______		Please Tick √
A	100-200 days	
B	38 weeks	
C	2 years	
D	400-460 days	

Question 10		
The calf can run around within _______		Please Tick √
A	1 week	
B	A few hours of birth	
C	2 weeks	
D	2.5 weeks	

APPENDIX I Reverse assessment priming stimuli (x6)

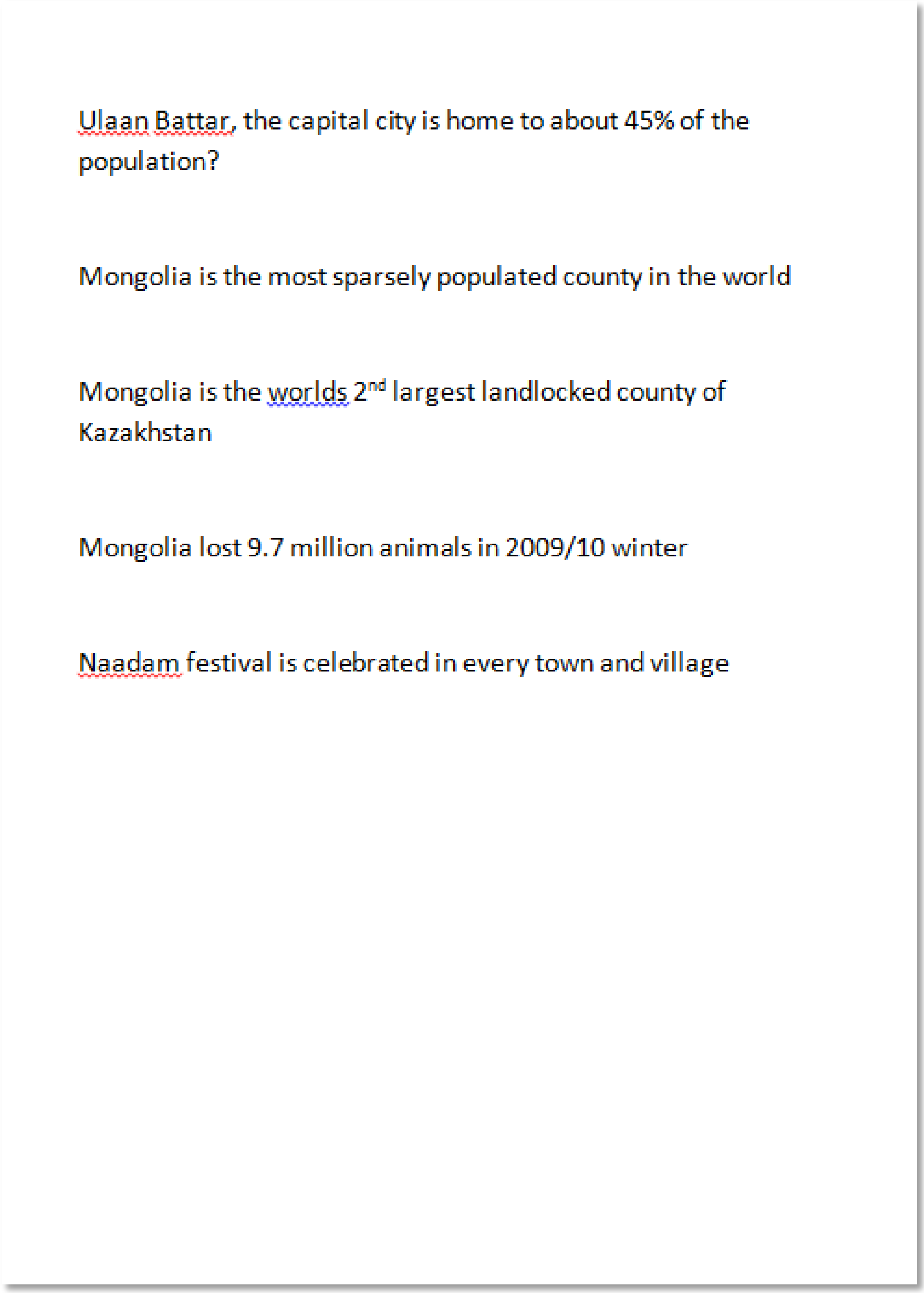
Bhutan is officially the Kingdom of Bhutan

Bhutan is entirely surrounded Bordered to the North by China and to the South, East and Wet by India

Thimphu is Bhutan's Capital and largest city

The following countries have residential embassies in Bhutan Indian and Bangladesh

A visa is required when Indian and Bhutan citizens travel to each other countries - No



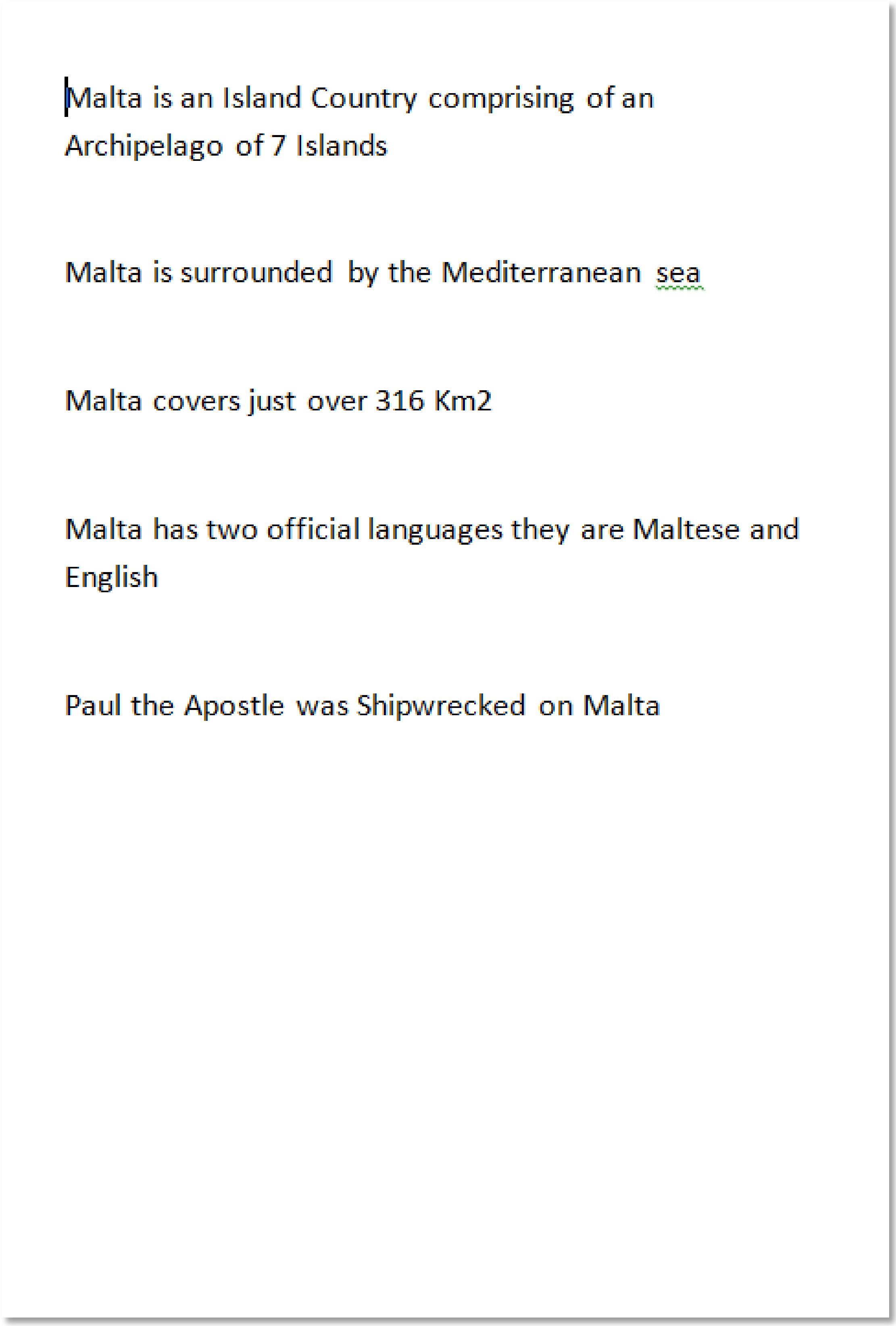
Ulaan Battar, the capital city is home to about 45% of the population?

Mongolia is the most sparsely populated county in the world

Mongolia is the worlds 2nd largest landlocked county of Kazakhstan

Mongolia lost 9.7 million animals in 2009/10 winter

Naadam festival is celebrated in every town and village



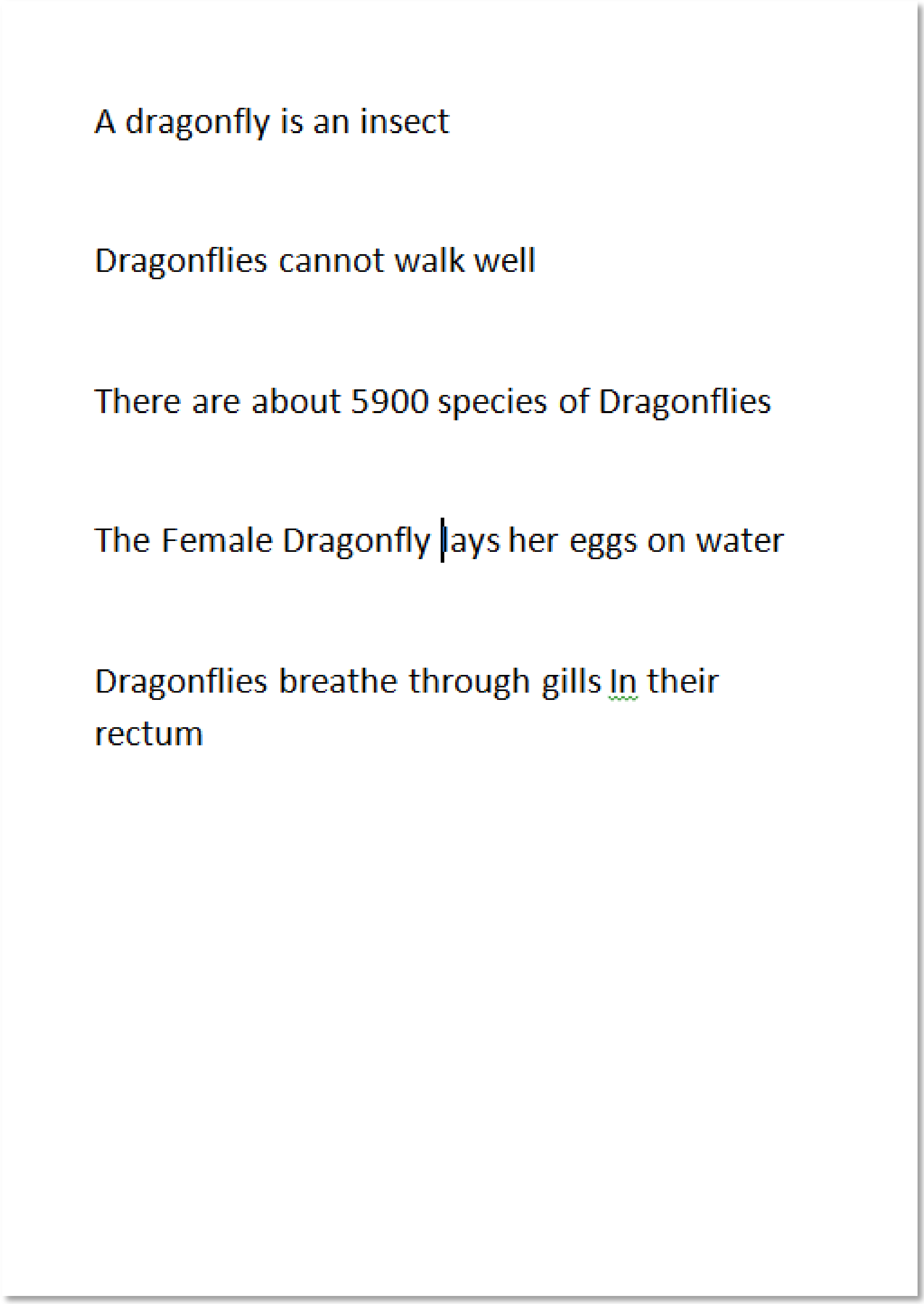
Malta is an Island Country comprising of an Archipelago of 7 Islands

Malta is surrounded by the Mediterranean sea

Malta covers just over 316 Km2

Malta has two official languages they are Maltese and English

Paul the Apostle was Shipwrecked on Malta



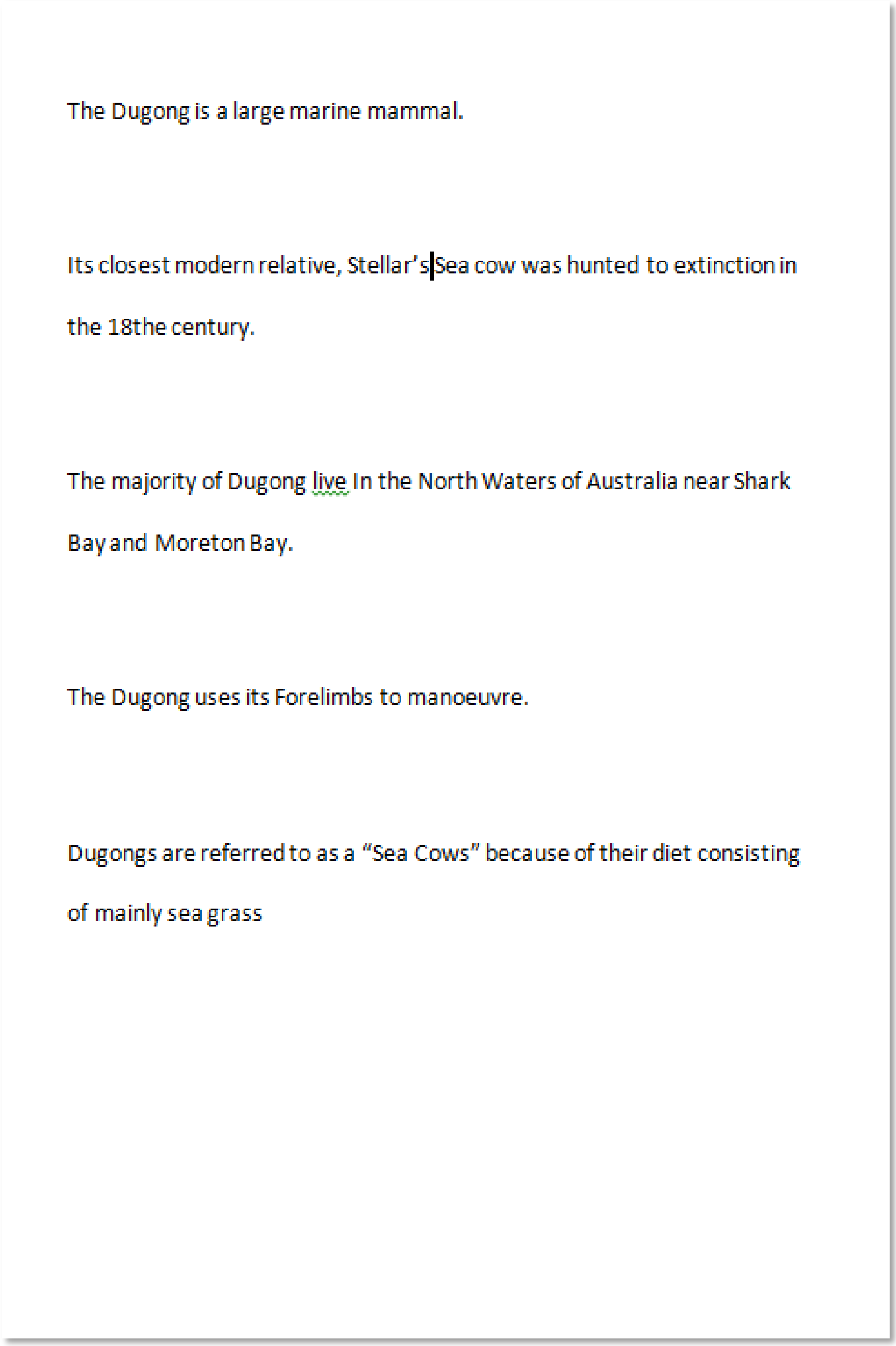
A dragonfly is an insect

Dragonflies cannot walk well

There are about 5900 species of Dragonflies

The Female Dragonfly lays her eggs on water

Dragonflies breathe through gills In their rectum



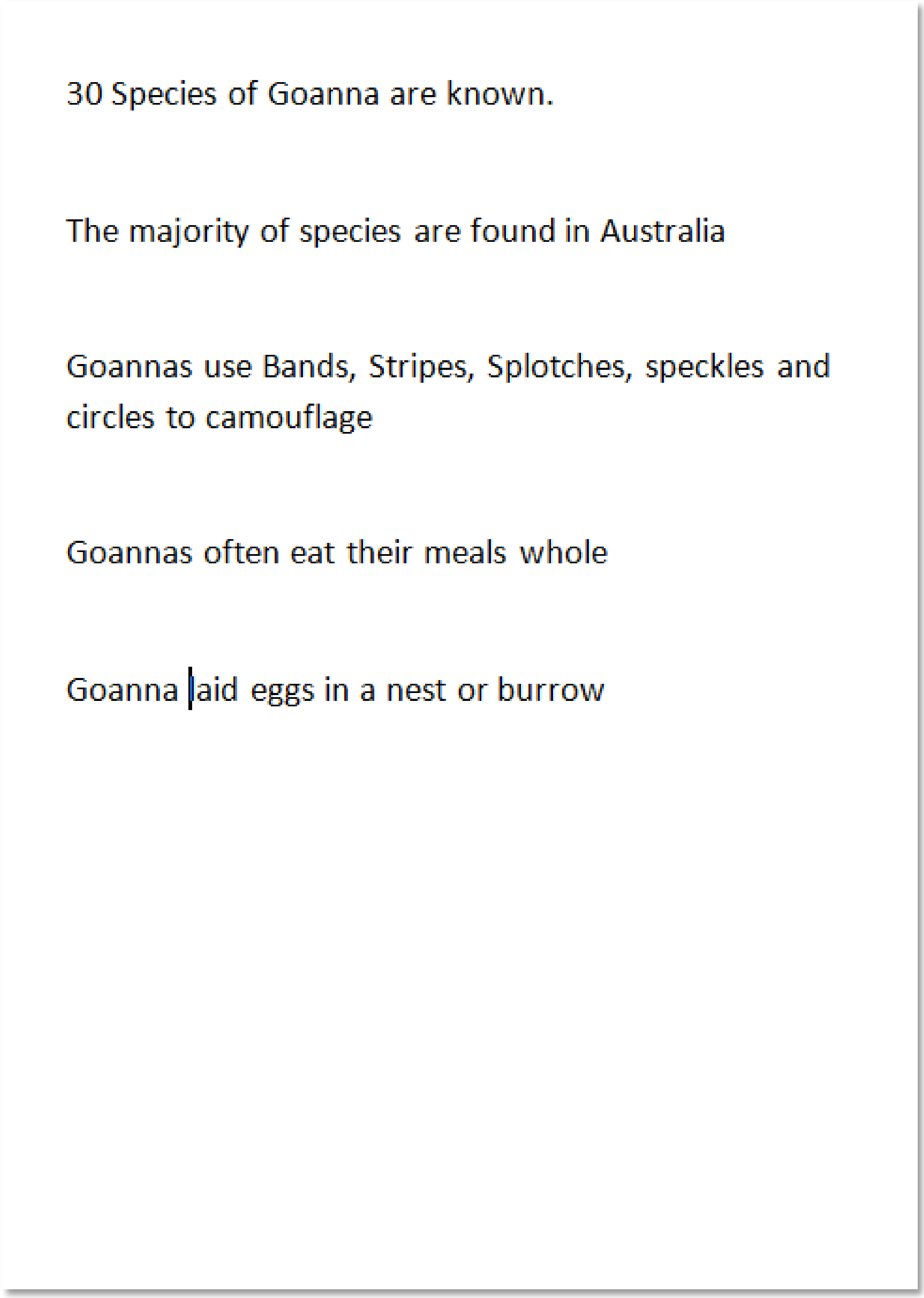
The Dugong is a large marine mammal.

Its closest modern relative, Stellar’s Sea cow was hunted to extinction in the 18the century.

The majority of Dugong live In the North Waters of Australia near Shark Bay and Moreton Bay.

The Dugong uses its Forelimbs to manoeuvre.

Dugongs are referred to as a “Sea Cows” because of their diet consisting of mainly sea grass



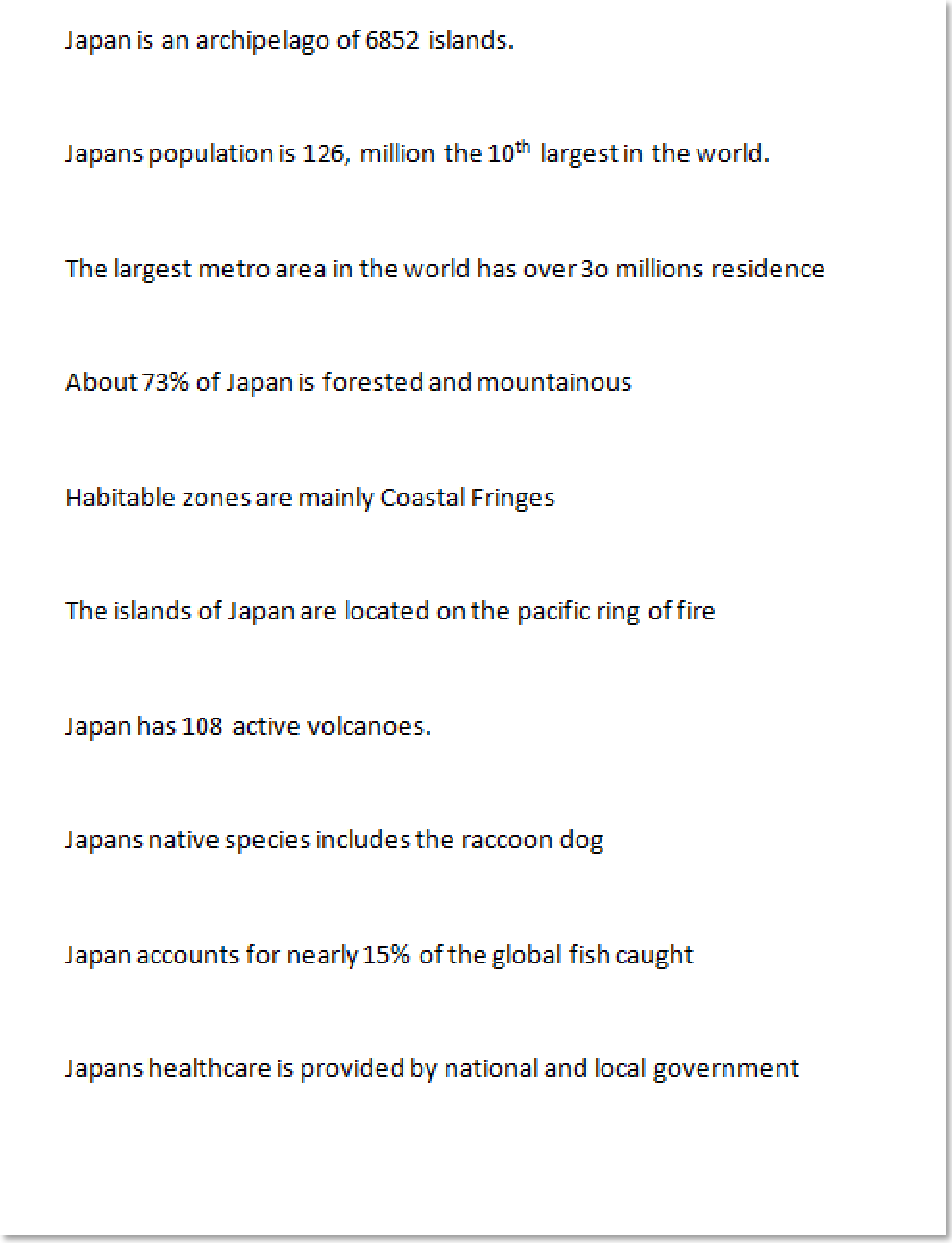
30 Species of Goanna are known.

The majority of species are found in Australia

Goannas use Bands, Stripes, Splotches, speckles and circles to camouflage

Goannas often eat their meals whole

Goanna laid eggs in a nest or burrow



Japan is an archipelago of 6852 islands.

Japans population is 126, million the 10th largest in the world.

The largest metro area in the world has over 3o millions residence

About 73% of Japan is forested and mountainous

Habitable zones are mainly Coastal Fringes

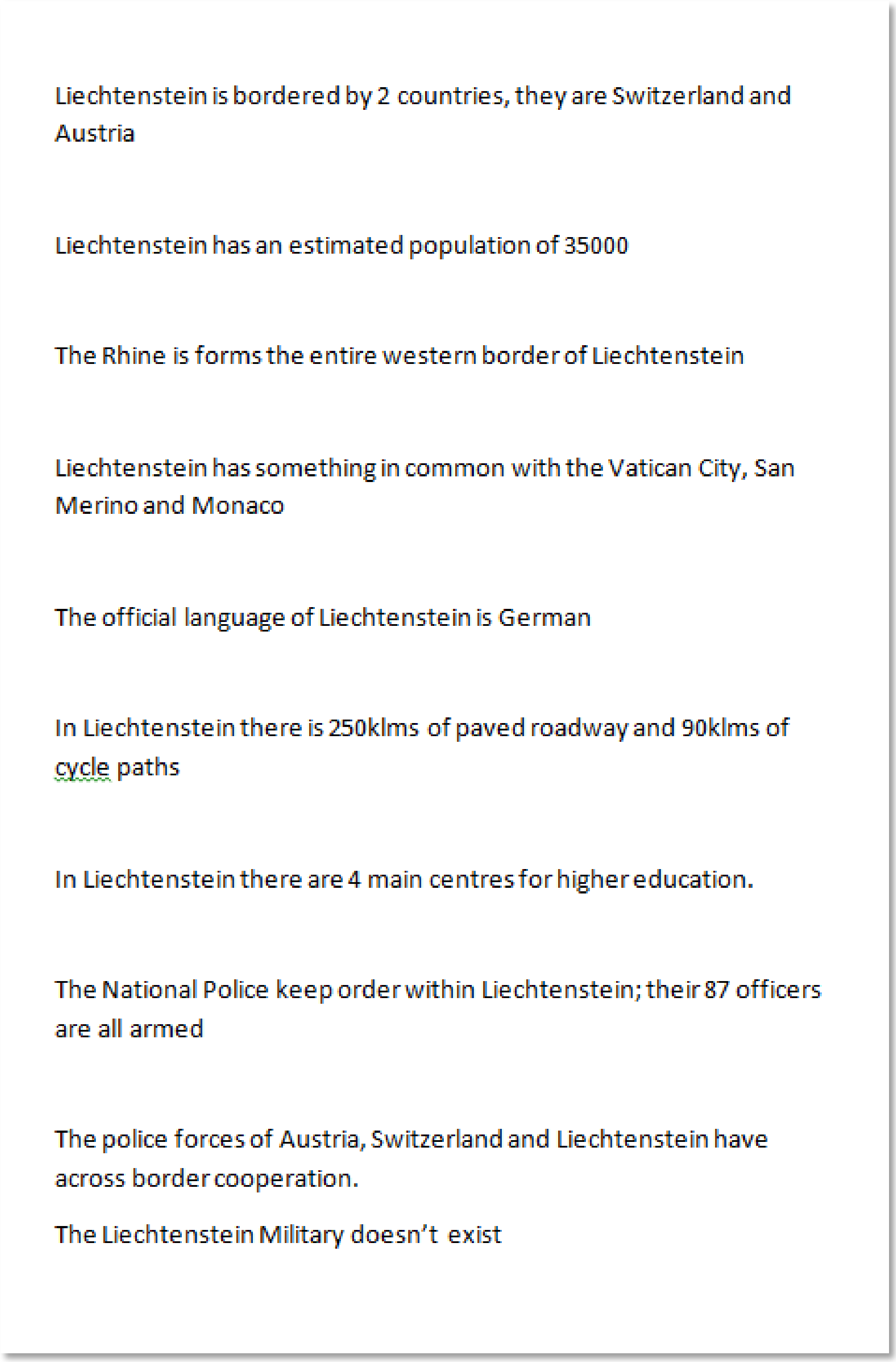
The islands of Japan are located on the pacific ring of fire

Japan has 108 active volcanoes.

Japans native species includes the raccoon dog

Japan accounts for nearly 15% of the global fish caught

Japans healthcare is provided by national and local government



Liechtenstein is bordered by 2 countries, they are Switzerland and Austria

Liechtenstein has an estimated population of 35000

The Rhine is forms the entire western border of Liechtenstein

Liechtenstein has something in common with the Vatican City, San Merino and Monaco

The official language of Liechtenstein is German

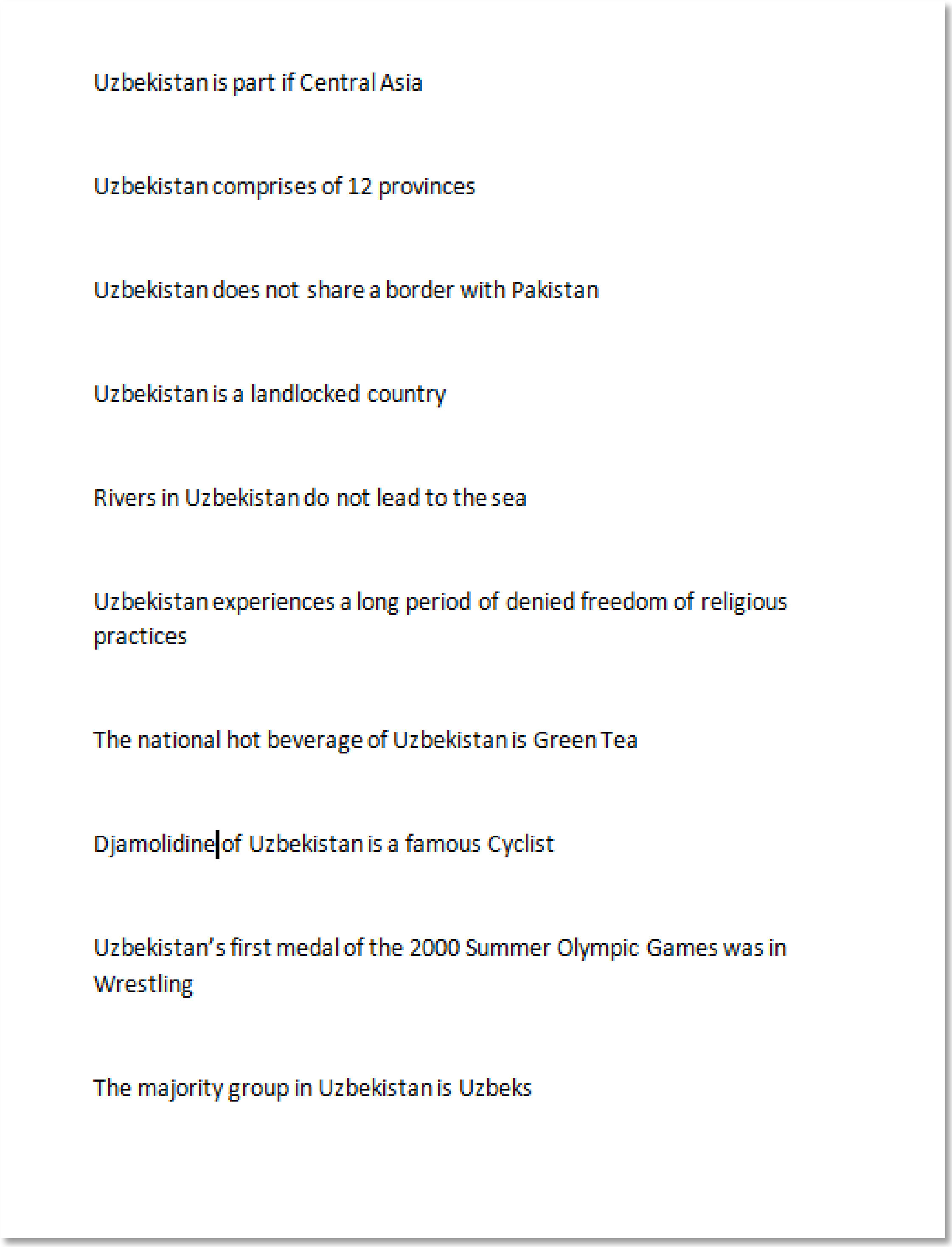
In Liechtenstein there is 250klms of paved roadway and 90klms of cycle paths

In Liechtenstein there are 4 main centres for higher education.

The National Police keep order within Liechtenstein; their 87 officers are all armed

The police forces of Austria, Switzerland and Liechtenstein have across border cooperation.

The Liechtenstein Military doesn’t exist



Uzbekistan is part if Central Asia

Uzbekistan comprises of 12 provinces

Uzbekistan does not share a border with Pakistan

Uzbekistan is a landlocked country

Rivers in Uzbekistan do not lead to the sea

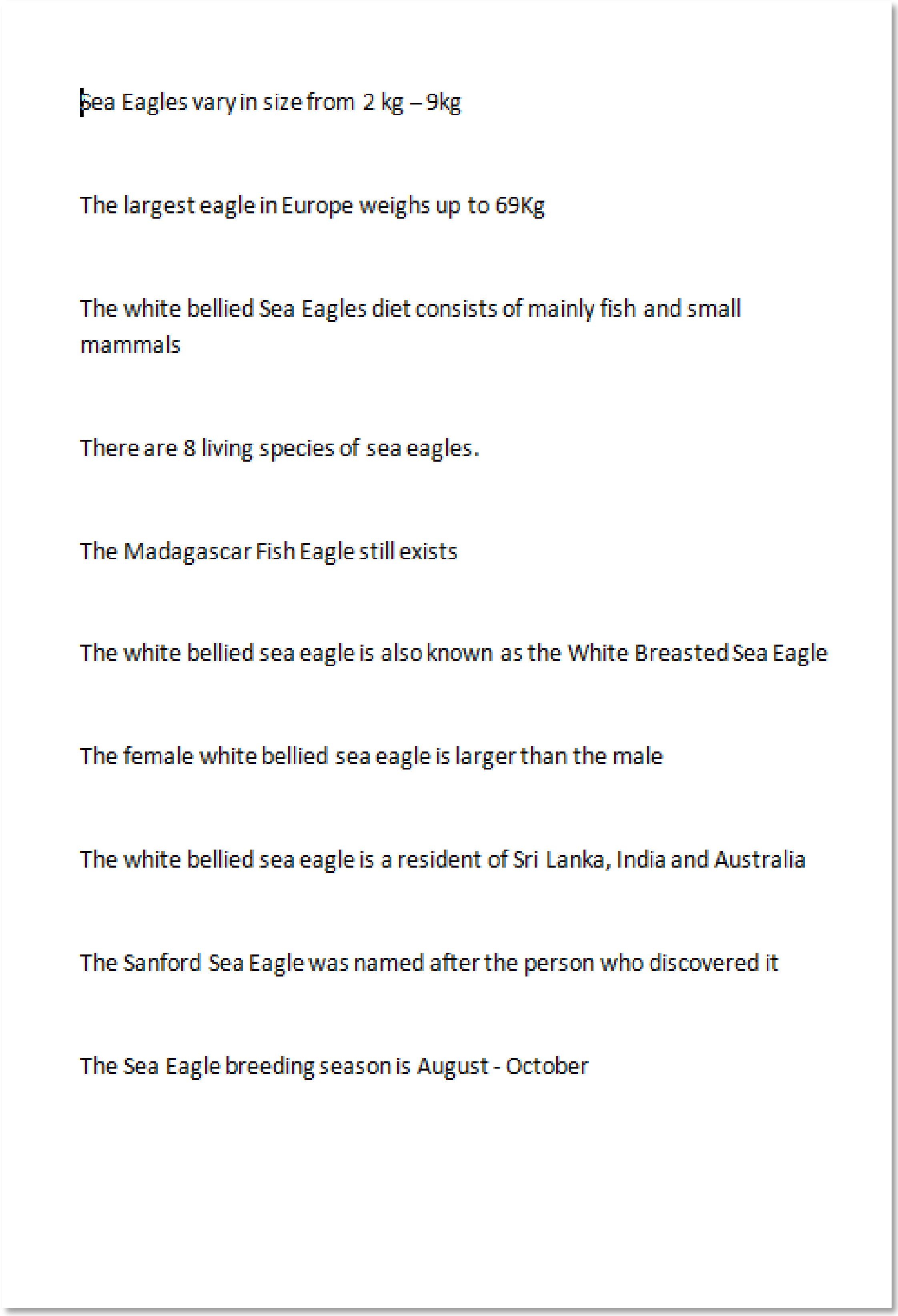
Uzbekistan experiences a long period of denied freedom of religious practices

The national hot beverage of Uzbekistan is Green Tea

Djamolidine of Uzbekistan is a famous Cyclist

Uzbekistan's first medal of the 2000 Summer Olympic Games was in Wrestling

The majority group in Uzbekistan is Uzbeks



Sea Eagles vary in size from 2 kg – 9kg

The largest eagle in Europe weighs up to 69Kg

The white bellied Sea Eagles diet consists of mainly fish and small mammals

There are 8 living species of sea eagles.

The Madagascar Fish Eagle still exists

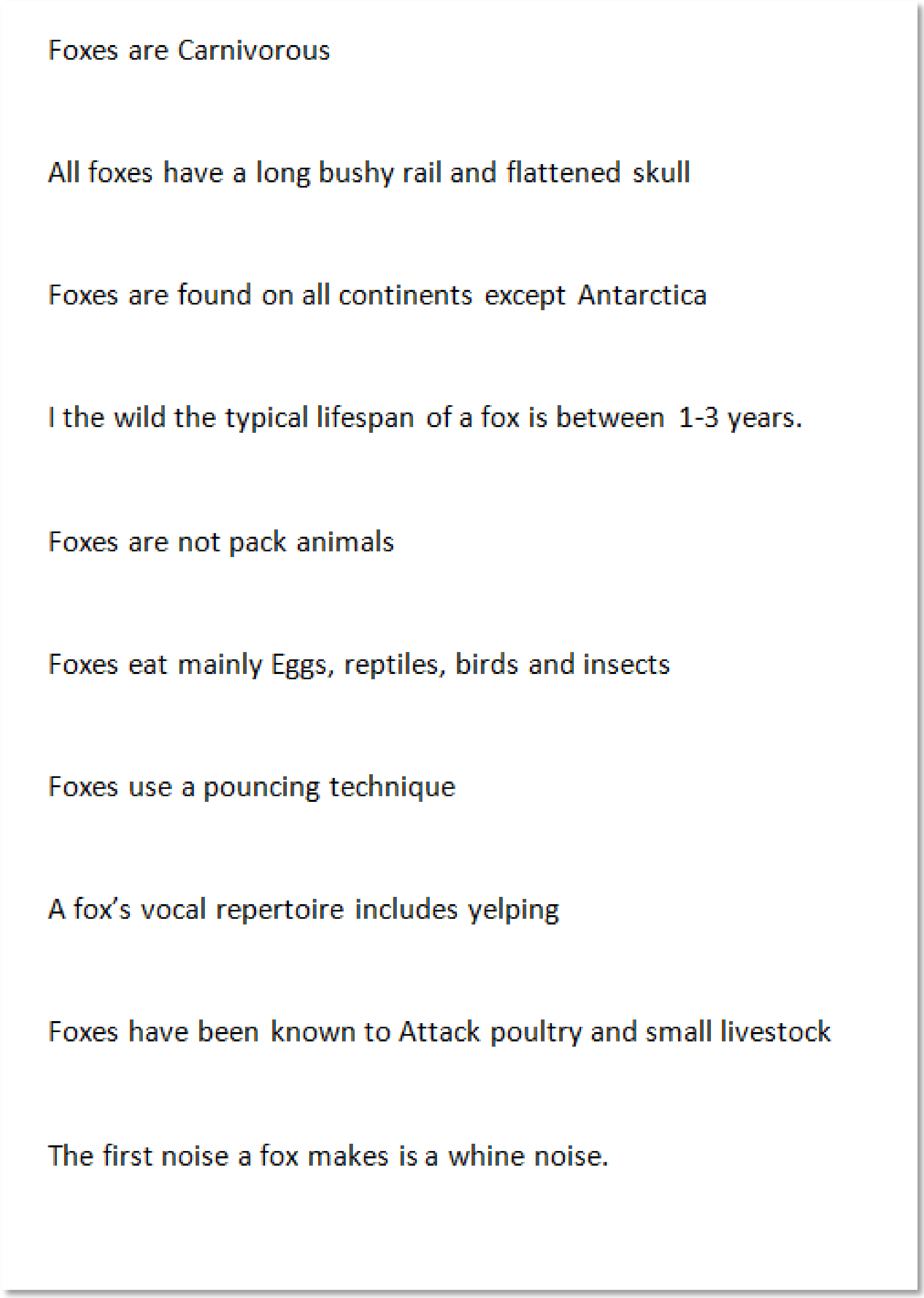
The white bellied sea eagle is also known as the White Breasted Sea Eagle

The female white bellied sea eagle is larger than the male

The white bellied sea eagle is a resident of Sri Lanka, India and Australia

The Sanford Sea Eagle was named after the person who discovered it

The Sea Eagle breeding season is August - October



Foxes are Carnivorous

All foxes have a long bushy rail and flattened skull

Foxes are found on all continents except Antarctica

I the wild the typical lifespan of a fox is between 1-3 years.

Foxes are not pack animals

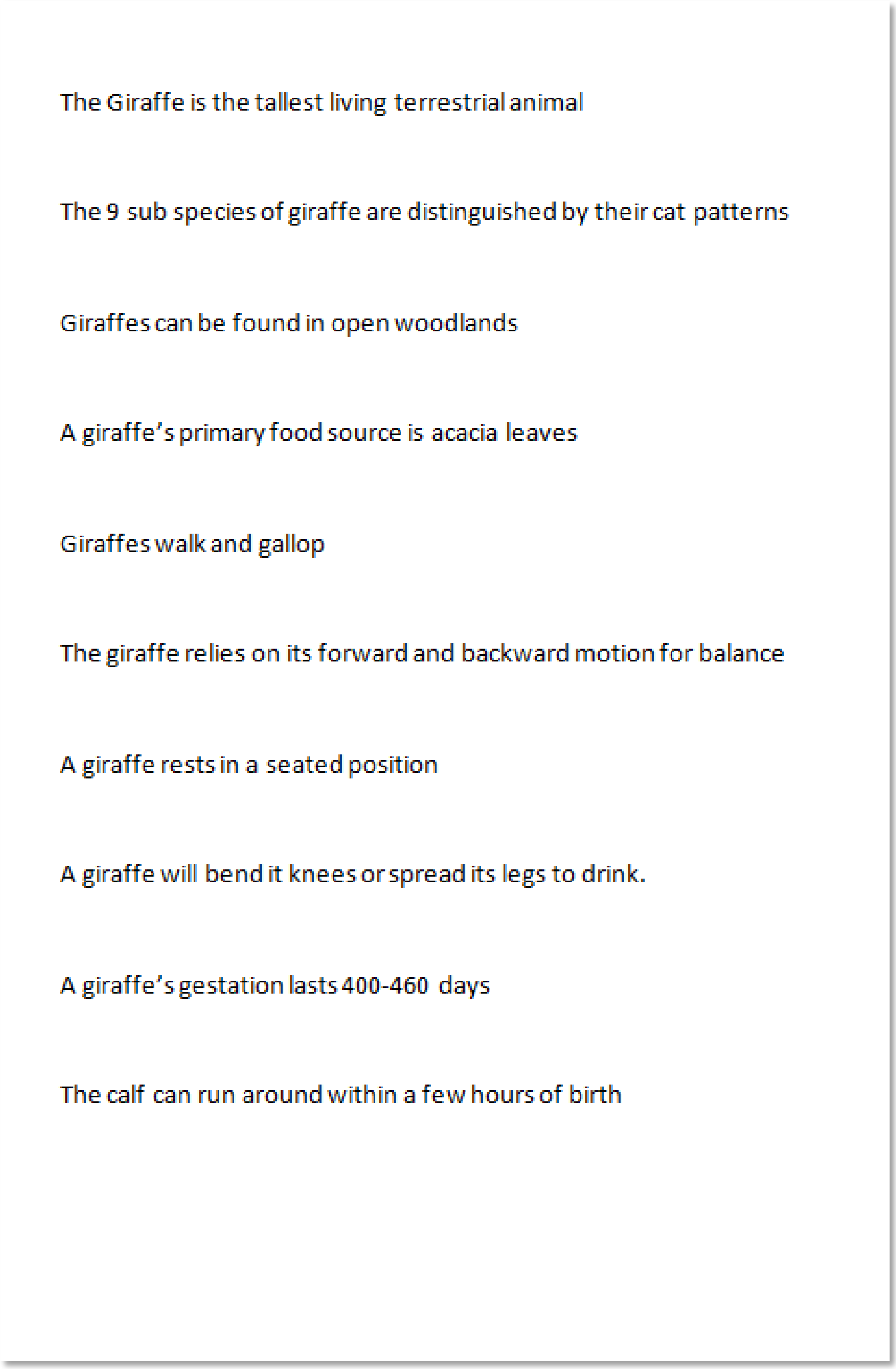
Foxes eat mainly Eggs, reptiles, birds and insects

Foxes use a pouncing technique

A fox's vocal repertoire includes yelping

Foxes have been known to Attack poultry and small livestock

The first noise a fox makes is a whine noise.



The Giraffe is the tallest living terrestrial animal

The 9 sub species of giraffe are distinguished by their cat patterns

Giraffes can be found in open woodlands

A giraffe’s primary food source is acacia leaves

Giraffes walk and gallop

The giraffe relies on its forward and backward motion for balance

A giraffe rests in a seated position

A giraffe will bend it knees or spread its legs to drink.

A giraffe’s gestation lasts 400-460 days

The calf can run around within a few hours of birth

APPENDIX J Self-reported levels of prior knowledge

Self-Reported Level of Prior Knowledge				
Topic	**Low**	**Average**	**High**	**Total**
Iceland	12	1	0	13
Bhutan	9	4	0	13
Mongolia	11	2	0	13
Morocco	8	4	1	13
Malta	12	1	0	13
Sea Urchins	11	2	0	13
Dragon Fly's	10	3	0	13
Dugongs	9	4	0	13
Goannas	10	3	0	13
Penguins	8	5	0	13
Japan	7	6	0	13
Liechtenstein	11	2	0	13
Croatia	11	2	0	13
Uzbekistan	12	1	0	13
Ireland	6	7	0	13
Sea Eagles	10	3	0	13
Foxes	8	5	0	13
Giraffes	7	6	0	13
Chickens	3	9	1	13
Pigs	5	7	1	13
Total	182	76	3	

APPENDIX K Transient information processing assessment task performance scores raw data

Performance Scores Low Transient Information Processing Task												
	Low TIPT Control Intervals (per event)			Total (Low) Control Performance		Low TIPT Test Intervals (RAPS) (per event)			Total Low (Test) Performance		Difference between Low Control & Low Test Performance Scores	
Subject	**#02**	**#03**	**#05**	**LC Control /15**	**%**	**#07**	**#08**	**#09**	**LT Test /15**	**%**	**Value**	**%**
A	5	3	4	12	80	5	5	5	15	100	3	20
B	5	3	5	13	87	5	5	5	15	100	2	13
C	4	4	3	11	73	5	5	5	15	100	4	27
D	4	4	3	11	73	4	5	5	14	93	3	20
F	5	3	3	11	73	5	5	5	15	100	4	27
G	5	2	5	12	80	5	5	5	15	100	3	20
H	3	3	4	10	67	5	5	5	15	100	5	33
I	5	3	5	13	87	5	5	5	15	100	2	13
J	4	2	3	9	60	5	5	5	15	100	6	40
K	5	3	4	12	80	4	4	5	13	87	1	7
L	4	3	2	9	60	4	5	5	14	93	5	33
M	3	3	3	9	60	5	4	5	14	93	5	33
N	3	3	4	10	67	5	5	5	15	100	5	33
Mean Low TIPT (Control) Performance Score												**10.92**
Mean Low TIPT (Test) Performance Score												**14.61**
Average increase in performance scores Low TIPT (Control) vs Low TIPT (Test) Intervals %												**33.79**

Performance Scores High Transient Information Processing Task

Subject	High TIPT Control Intervals (per event)			Total High (Control) Performance		High TIPT Test Intervals (RAPS) (per event)			Total High (Test) Performance		Difference in High (Control) & High (Test) Performance	
	#01	#02	#04	HC Score/30	%	#06	#07	#08	HT Score/30	%	Score	%
A	9	6	5	20	67	10	10	9	29	97	9	30
B	10	10	10	30	100	10	10	9	29	97	-1	-3
C	1	4	1	6	20	10	10	10	30	100	24	80
D	4	5	7	16	53	10	9	9	28	93	12	40
F	9	7	9	25	83	10	10	9	29	97	4	13
G	10	10	10	30	100	10	10	10	30	100	0	0
H	8	7	8	23	77	10	10	9	29	97	6	20
I	10	10	10	30	100	10	10	10	30	100	0	0
J	8	8	6	22	73	10	8	9	27	90	5	17
K	5	5	7	17	57	9	9	8	26	87	9	30
L	6	5	8	19	63	10	8	10	28	93	9	30
M	6	5	7	18	60	9	10	9	28	93	10	33
N	3	7	3	13	43	10	9	9	28	93	15	50
Mean High TIPT (Control) Performance Score												**20.75**
Mean High TIPT (Test) Performance Score												**28.5**
Average increase in performance scores High TIPT (Control) vs High TIPT (Test) Intervals %												**26**

APPENDIX L EEG raw data

MWL (Neural Baseline)												
MWL Baseline - Sum of the average α(8-12Hz) band power value µV												
Subject	A	B	C	D	G	H	I	J	K	L	M	N
Fp1-avg	0.346	0.771	0.584	1.01	0.308	0.368	0.767	1.007	0.864	0.539	0.453	0.907
Fp2-avg	0.337	0	0.598	1.007	0.28	0.373	0.905	0.233	0.724	0.463	0.461	0.887
F7 - avg	0.329	0.655	0.543	0.944	0.231	0.291	0.256	0.279	0.332	0.288	0.22	0.773
F3 - avg	0.31	0.654	0.644	1.011	0.213	0.344	0.181	0.223	0.297	0.276	0.227	0.865
Fz - avg	0.322	0.67	0.712	1.071	0.22	0.387	0.234	0.233	0.331	0.314	0.26	0.909
F4 - avg	0.295	0.607	0.661	1.008	0.202	0.35	0.209	0.093	0.295	0.276	0.253	0.802
F8 - avg	0.311	0.644	0.593	0.861	0.223	0.373	0.249	0.259	0.261	0.314	0.236	0.759
T3 - avg	0.293	0.6	0.534	0.755	0.278	0.281	0.302	0.193	0.447	0.294	0.26	0.617
C3 - avg	0.24	0.617	0.556	0.691	0.145	0.295	0.23	0.122	0.224	0.285	0.185	0.576
Cz - avg	0.296	0	0.615	1.009	0.193	0.387	0.182	0.127	0.383	0.296	0.237	0.8
C4 - avg	0.239	0.455	0.538	0.65	0.162	0.399	0.188	0.104	0.284	0.287	0.24	0.519
T4 - avg	0.29	0.538	0.578	0.908	0.214	0.275	0.308	0.225	0.348	0.328	0.286	0.461
A1 - avg	0.362	0.759	0.633	0.845	0.261	0.617	0.291	0.274	0.518	0.367	0.278	0.894
T5 - avg	0.463	0.58	0.886	0.907	0.252	0.367	0.308	0.211	0.478	0.322	0.296	1.004
P3 - avg	0.417	0.668	0.831	1.108	0.257	0.378	0.282	0.193	0.342	0.366	0.341	0.623
Pz - avg	0.406	0.869	0.626	1.311	0.234	0.443	0.22	0.175	0.401	0.317	0.242	0.767
P4 - avg	0.392	0.86	0.688	1.25	0.247	0.432	0.239	0.179	0.343	0.401	0.188	0.875
T6 - avg	0.558	0.823	0.766	1.886	0.264	0.501	0.281	0.238	0.406	0.432	0.228	1.511
A2 - avg	0.418	0.91	0.691	0.989	0.238	0.647	0.266	0.293	0.357	0	0.26	0.854
O1 - avg	0.872	1.356	1.39	1.863	0.286	0.772	0.293	0.29	0.485	0.406	0.313	2.466
O2 - avg	0.907	1.514	1.33	2.845	0.242	0.917	0.268	0.309	0.461	0.563	0.261	2.395
Sum	**8.403**	**14.55**	**14.997**	**23.929**	**4.95**	**9.197**	**6.459**	**5.26**	**8.581**	**7.134**	**5.725**	**20.264**

MWL Low TIPT (control) - Sum of the average α(8-12Hz) band power value µV												
Subject	A	B	C	D	G	H	I	J	K	L	M	N
Fp1-avg	0.365	0.735	0.645	1.048	0.353	0.458	0.353	0.321	1.059	0.806	0.715	0.989
Fp2-avg	0.37	0.803	0.647	1.051	0.351	0.457	0.349	0.28	1.049	0.823	0.709	0.945
F7 - avg	0.331	0.568	0.592	0.94	0.289	0.397	0.374	0.308	0.826	0.659	0.618	0.811
F3 - avg	0.316	0.545	0.66	1.006	0.266	0.409	0.351	0.275	0.981	0.767	0.71	0.939
Fz - avg	0.349	0.584	0.688	1.083	0.286	0.425	0.372	0.278	1.119	0.828	0.744	0.979
F4 - avg	0.33	0.557	0.634	1.019	0.258	0.313	0.341	0.214	1.014	0.78	0.699	0.84
F8 - avg	0.344	0.596	0.595	0.914	0.296	0.392	0.34	0.272	0.838	0.69	0.624	0.758
T3 - avg	0.268	0.426	0.548	0.698	0.3	0.355	0.377	0.273	0.575	0.527	0.446	0.591
C3 - avg	0.194	0.489	0.509	0.616	0.187	0.343	0.331	0.217	0.748	0.635	0.449	0.632
Cz - avg	0.288	0.563	0.583	0.876	0.223	0.39	0.338	0.243	1.147	0.648	0.54	0.904
C4 - avg	0.242	0.423	0.49	0.581	0.214	0.359	0.333	0.182	1.077	0.618	1.004	0.551
T4 - avg	0.283	0.5	0.552	0.711	0.274	0.344	0.407	0.26	0.534	0.463	0.417	0.407
A1 - avg	0.343	0.654	0.677	0.849	0.324	0.629	0.429	0.3	1.224	0.572	0.496	0.802
T5 - avg	0.456	0.484	0.873	0.996	0.316	0.385	0.47	0.281	1.691	0.916	0.896	1.159
P3 - avg	0.418	0.716	0.895	1.254	0.317	0.439	0.371	0.252	1.289	0.819	0.835	0.61
Pz - avg	0.424	0.795	0.75	1.297	0.296	0.553	0.376	0.249	1.486	0.735	0.982	0.709
P4 - avg	0.398	0.786	0.661	1.39	0.271	0.504	0.48	0.267	1.293	0.81	0.475	0.874
T6 - avg	0.53	0.752	0.729	1.757	0.299	0.613	0.677	0.45	1.596	1.106	0.954	1.63
A2 - avg	0.354	0.835	0.714	0.908	0.291	0.688	0.469	0.391	1.185	0	0.48	0.779
O1 - avg	0.861	1.452	1.543	2.126	0.34	0.945	0.64	0.601	2.022	2.155	1.382	2.624
O2 - avg	0.958	1.549	1.536	2.912	0.283	1.086	0.84	0.723	1.901	2.129	1.613	2.524
Sum	**8.422**	**14.812**	**15.521**	**24.032**	**6.034**	**10.484**	**9.018**	**6.637**	**24.654**	**17.486**	**15.788**	**21.057**

MWL Low TIPT RAPS (test)- Sum of the average α(8-12Hz) band power value μV												
Subject	A	B	C	D	G	H	I	J	K	L	M	N
Fp1-avg	0.292	0.72	0.703	1.081	0.358	0.414	0.41	0.326	1.013	0.972	0.774	0.996
Fp2-avg	0.298	0.757	0.699	1.085	0.352	0.405	0.404	0.284	1.037	0.999	0.764	0.987
F7 - avg	0.272	0.607	0.619	0.972	0.298	0.349	0.433	0.308	0.809	0.806	0.666	0.816
F3 - avg	0.255	0.558	0.73	1.053	0.272	0.378	0.413	0.273	0.969	0.985	0.725	0.943
Fz - avg	0.274	0.583	0.767	1.158	0.292	0.411	0.444	0.279	1.124	1.072	0.753	0.998
F4 - avg	0.259	0.566	0.699	1.079	0.265	0.313	0.404	0.22	1.031	0.999	0.72	0.886
F8 - avg	0.275	0.631	0.603	0.926	0.307	0.374	0.398	0.291	0.858	0.839	0.666	0.818
T3 - avg	0.247	0.463	0.553	0.752	0.258	0.305	0.411	0.25	0.677	0.609	0.458	0.63
C3 - avg	0.175	0.469	0.552	0.705	0.205	0.302	0.377	0.211	0.819	0.746	0.446	0.641
Cz - avg	0.258	0.577	0.633	0.992	0.232	0.41	0.412	0.236	1.217	0.817	0.541	0.912
C4 - avg	0.221	0.431	0.518	0.689	0.204	0.376	0.373	0.185	1.134	0.747	0.997	0.578
T4 - avg	0.259	0.52	0.524	0.844	0.274	0.309	0.44	0.245	0.641	0.53	0.497	0.462
A1 - avg	0.341	0.709	0.697	0.875	0.336	0.625	0.495	0.436	1.364	0.658	0.477	0.879
T5 - avg	0.401	0.523	0.877	1.01	0.327	0.363	0.555	0.285	1.717	1.079	0.86	1.289
P3 - avg	0.35	0.703	0.898	1.328	0.335	0.409	0.482	0.242	1.532	0.944	0.916	0.695
Pz - avg	0.382	0.847	0.774	1.366	0.33	0.52	0.458	0.242	1.664	0.866	1.137	0.769
P4 - avg	0.351	0.85	0.793	1.372	0.311	0.476	0.576	0.263	1.319	0.886	0.484	0.918
T6 - avg	0.448	0.729	0.848	1.851	0.295	0.55	0.74	0.435	1.526	1.309	0.924	1.744
A2 - avg	0.402	0.836	0.743	0.914	0.286	0.733	0.52	0.324	1.262	0	0.564	0.815
O1 - avg	0.694	1.419	1.519	2.154	0.364	0.836	0.798	0.605	2.077	2.699	1.343	2.697
O2 - avg	0.756	1.51	1.67	2.943	0.288	0.973	0.947	0.724	1.859	2.642	1.562	2.569
Sum	**7.21**	**15.008**	**16.419**	**25.149**	**6.189**	**9.831**	**10.49**	**6.664**	**25.649**	**21.204**	**16.274**	**22.042**

MWL High TIPT (control) - Sum of the average α(8-12Hz) band power value μV

Subject	A	B	C	D	G	H	I	J	K	L	M	N
Fp1-avg	0.398	0.699	0.81	0.951	0.37	0.484	0.457	0.369	1.143	0.931	1.006	1.157
Fp2-avg	0.39	0.737	0.793	0.953	0.388	0.484	0.456	0.354	1.165	0.966	0.992	1.132
F7 - avg	0.359	0.573	0.744	0.881	0.319	0.413	0.498	0.347	0.937	0.721	0.846	0.979
F3 - avg	0.355	0.553	0.837	0.916	0.263	0.451	0.45	0.317	1.077	0.842	0.949	1.133
Fz - avg	0.389	0.611	0.891	0.988	0.298	0.491	0.48	0.335	1.232	0.935	1	1.19
F4 - avg	0.364	0.584	0.808	0.93	0.277	0.377	0.442	0.279	1.109	0.873	0.947	1.044
F8 - avg	0.36	0.636	0.706	0.85	0.326	0.45	0.474	0.351	0.98	0.753	0.863	0.947
T3 - avg	0.302	0.474	0.722	0.704	0.33	0.36	0.44	0.318	0.682	0.556	0.584	0.73
C3 - avg	0.242	0.471	0.662	0.595	0.253	0.367	0.425	0.231	0.897	0.677	0.578	0.768
Cz - avg	0.357	0.61	0.747	0.859	0.244	0.481	0.424	0.279	1.29	0.747	0.674	1.11
C4 - avg	0.307	0.419	0.615	0.583	0.223	0.449	0.421	0.238	1.231	0.686	1.223	0.697
T4 - avg	0.311	0.537	0.645	0.89	0.291	0.358	0.494	0.354	0.696	0.487	0.665	0.541
A1 - avg	0.421	0.749	0.822	0.833	0.384	0.702	0.569	0.433	1.399	0.743	0.683	1.01
T5 - avg	0.524	0.529	1.044	0.969	0.345	0.474	0.613	0.343	1.754	1.068	1.201	1.444
P3 - avg	0.478	0.719	1.03	1.213	0.397	0.496	0.544	0.298	1.552	0.86	1.162	0.787
Pz - avg	0.501	0.9	0.904	1.334	0.395	0.633	0.479	0.304	1.805	0.778	1.349	0.898
P4 - avg	0.436	0.861	0.878	1.215	0.359	0.589	0.638	0.321	1.498	0.81	0.643	1.059
T6 - avg	0.656	0.755	0.953	1.644	0.321	0.649	0.803	0.498	1.657	1.153	1.32	2.005
A2 - avg	0.444	0.903	0.826	0.859	0.303	0.754	0.607	0.407	1.401	0	0.831	1.007
O1 - avg	1.116	1.52	1.828	1.831	0.427	1.017	0.867	0.764	2.273	2.437	1.79	3.282
O2 - avg	1.103	1.641	1.869	2.499	0.339	1.195	1.03	0.878	2.107	2.176	2.018	2.977
Sum	**9.813**	**15.481**	**19.134**	**22.497**	**6.852**	**11.674**	**11.611**	**8.018**	**27.885**	**19.199**	**21.324**	**25.897**

MWL High TIPT RAPS (test) - Sum of the average α(8-12Hz) band power value µV												
Subject	A	B	C	D	G	H	I	J	K	L	M	N
Fp1-avg	0.346	0.821	0.736	0.658	0.326	0.372	0.442	0.367	1.196	1.015	0.776	0.961
Fp2-avg	0.337	0	0.739	0.634	0.335	0.374	0.436	0.347	1.243	1.057	0.776	0.943
F7 - avg	0.329	0.682	0.638	0.593	0.291	0.327	0.443	0.348	0.974	0.821	0.656	0.815
F3 - avg	0.31	0.66	0.76	0.63	0.273	0.345	0.446	0.325	1.131	1.03	0.751	0.908
Fz - avg	0.322	0.723	0.81	0.667	0.303	0.375	0.488	0.344	1.331	1.146	0.797	0.94
F4 - avg	0.295	0.692	0.738	0.608	0.273	0.325	0.44	0.278	1.212	1.055	0.756	0.831
F8 - avg	0.311	0.706	0.648	0.549	0.319	0.352	0.425	0.348	1.076	0.873	0.68	0.793
T3 - avg	0.293	0.522	0.564	0.515	0.274	0.3	0.375	0.3	0.719	0.6	0.434	0.576
C3 - avg	0.24	0.515	0.576	0.477	0.211	0.329	0.373	0.25	0.967	0.75	0.419	0.613
Cz - avg	0.296	0	0.65	0.684	0.261	0.403	0.425	0.294	1.326	0.868	0.544	0.838
C4 - avg	0.239	0.506	0.544	0.488	0.232	0.4	0.376	0.242	1.345	0.781	0.954	0.527
T4 - avg	0.29	0.548	0.554	0.464	0.346	0.331	0.419	0.312	0.745	0.565	0.464	0.445
A1 - avg	0.362	0.757	0.689	0.565	0.38	0.55	0.499	0.528	1.448	0.674	0.498	0.743
T5 - avg	0.463	0.548	0.963	0.76	0.337	0.394	0.56	0.352	1.864	1.228	0.915	1.171
P3 - avg	0.417	0.72	0.968	0.82	0.365	0.445	0.442	0.319	1.767	1.119	0.875	0.651
Pz - avg	0.406	0.945	0.772	0.843	0.389	0.505	0.458	0.313	1.951	0.955	1.049	0.668
P4 - avg	0.392	0.902	0.785	0.818	0.347	0.48	0.587	0.328	1.57	0.93	0.458	0.857
T6 - avg	0.558	0.714	0.879	0.969	0.347	0.545	0.757	0.522	1.627	1.287	0.983	1.655
A2 - avg	0.418	0.877	0.769	0.537	0.363	0.63	0.527	0.418	1.43	0	0.573	0.763
O1 - avg	0.872	1.602	1.651	1.089	0.419	0.77	0.886	0.777	2.353	2.81	1.462	2.703
O2 - avg	0.907	1.737	1.667	1.356	0.346	0.915	1.025	0.912	2.111	2.481	1.585	2.397
Sum	**8.403**	**15.177**	**17.1**	**14.724**	**6.737**	**9.467**	**10.829**	**8.224**	**29.386**	**22.045**	**16.405**	**20.798**

MWL Low TIPT Task (Control) vs High TIPT (Control) - Sum of the average α(8-12Hz) band power value µV				
Subject	Low TIPT (control) µV	High TIPT (control) µV	Difference µV	Difference %
A	8.42	9.81	1.39	16.51
B	14.18	15.48	1.3	9.17
C	15.52	19.13	3.61	23.26
D	24.03	22.49	-1.54	-6.41
G	6.03	6.85	0.82	13.60
H	10.48	11.67	1.19	11.35
I	9.01	11.61	2.6	28.86
J	6.63	8.01	1.38	20.81
K	24.65	27.88	3.23	13.10
L	17.48	19.19	1.71	9.78
M	15.78	21.32	5.54	35.11
N	21.05	25.89	4.84	22.99
Mean Low TIPT (control) µV				**14.48**
Mean High TIPT (control) µV				**16.62**
Average Difference µV				**16.51**

MWL Low TIPT (Control) vs Low RAPS TIPT (Test) - Sum of the average α(8-12Hz) band power value µV				
Subject	Low TIPT (control) µV	Low TIPT RAPS (test) µV	Difference µV	Difference %
A	8.42	7.21	-1.21	-14.37
B	14.18	15.08	0.9	6.35
C	15.52	16.41	0.89	5.73
D	24.03	25.14	1.11	4.62
G	6.03	6.18	0.15	2.49
H	10.48	9.83	-0.65	-6.20
I	9.01	10.49	1.48	16.43
J	6.63	6.66	0.03	0.45
K	24.65	25.64	0.99	4.02
L	17.48	21.2	3.72	21.28
M	15.78	16.27	0.49	3.11
N	21.05	22.04	0.99	4.70
Mean Low TIPT (control) µV				**14.43**
Mean Low TIPT RAPS (test) µV				**15.17**
Average Difference µV				**4.05**

MWL High TIPT (Control) vs High RAPS TIPT (Test) - Sum of the average α(8-12Hz) band power value µV				
Subject	High TIPT (control) µV	High TIPT RAPS (test) µV	Difference µV	Difference %
A	9.81	8.4	-1.41	-14.37
B	15.48	15.1	-0.38	-2.45
C	19.13	17.1	-2.03	-10.61
D	22.49	14.7	-7.79	-34.64
G	6.85	6.7	-0.15	-2.19
H	11.67	9.4	-2.27	-19.45
I	11.61	10.8	-0.81	-6.98
J	8.01	8.2	0.19	2.37
K	27.88	29.3	1.42	5.09
L	19.19	22.04	2.85	14.85
M	21.32	16.4	-4.92	-23.08
N	25.89	20.7	-5.19	-20.05
Mean High TIPT (control) µV				**16.61**
Mean High TIPT RAPS (test) µV				**14.09**
Average Difference µV				**-9.29**

UHCI Measure - MWL variances between baseline and control & test tasks - Sum of the average α(8-12Hz) band power value μV

Subject	Baseline	MWL Low TIPT (control)	UHCI Low TIPT (control)	MWL Low TIPT RAPS (Test)	UHCI Low TIPT RAPS (test)	MWL High TIPT (control)	UHCI High TIPT (control)	MWL High TIPT RAPS (Test)	UHCI High TIPT RAPS (test)
A	8.40	8.42	0.20	7.21	-14.20	9.81	16.74	8.4	-0.04
B	14.55	14.18	-2.54	15.08	3.64	15.48	6.39	15.1	3.78
C	14.99	15.52	3.54	16.41	9.47	19.13	27.62	17.1	14.08
D	23.92	24.03	0.46	25.14	5.10	22.49	-5.98	14.7	-38.55
G	4.95	6.03	21.82	6.18	24.85	6.85	38.38	6.7	35.35
H	9.19	10.48	14.04	9.83	6.96	11.67	26.99	9.4	2.29
I	6.45	9.01	39.69	10.49	62.64	11.61	80.00	10.8	67.44
J	5.26	6.63	26.05	6.66	26.62	8.01	52.28	8.2	55.89
K	8.58	24.65	187.30	25.64	198.83	27.88	224.94	29.3	241.49
L	7.13	17.48	145.02	21.2	197.17	19.19	168.99	22.04	208.94
M	5.73	15.78	175.63	16.27	184.19	21.32	272.40	16.4	186.46
N	20.26	21.05	3.90	22.04	8.79	25.89	27.79	20.7	2.17

APPENDIX M CE data

CE Low (Control vs Test) TIPT												
Subject	UHCI - LC	z 4-UHCI - LC	Performance Score	**Z pscore**	**z UHCI - Z performance**	CE Score Low (Control) TIPT	UHCI - LT	zUHCI - LT	Performance Score	**Z pscore**	**z UHCI - Z perforamnce**	CE Score Low (Test) TIPT
A	0.20	-0.70	12	0.72	1.42	1.00	-14.20	-0.89	15	0.62	1.51	1.07
B	-2.54	-0.74	13	1.38	2.12	1.50	3.64	-0.67	15	0.62	1.30	0.92
C	3.54	-0.66	11	0.06	0.71	0.50	9.47	-0.60	15	0.62	1.23	0.87
D	0.46	-0.70	11	0.06	0.75	0.53	5.10	-0.66	14	-0.87	-0.22	-0.15
G	21.82	-0.40	12	0.72	1.12	0.79	24.85	-0.42	15	0.62	1.04	0.74
H	14.04	-0.51	10	-0.61	-0.10	-0.07	6.96	-0.63	15	0.62	1.26	0.89
I	39.69	-0.16	13	1.38	1.54	1.09	62.64	0.04	15	0.62	0.59	0.41
J	26.05	-0.35	9	-1.27	-0.93	-0.66	26.62	-0.40	15	0.62	1.02	0.72
K	187.30	1.87	12	0.72	-1.15	-0.81	198.83	1.68	13	-2.37	-4.05	-2.86
L	145.02	1.29	9	-1.27	-2.56	-1.81	197.17	1.66	14	-0.87	-2.53	-1.79
M	175.63	1.71	9	-1.27	-2.98	-2.11	184.19	1.50	14	-0.87	-2.38	-1.68
N	3.90	-0.65	10	-0.61	0.04	0.03	8.79	-0.61	15	0.62	1.24	0.87

CE High (Control vs Test) TIPT

Subject	UHCI-HC	Z - UHCI - HC	Performance Score	Z pscore	Efficiency z UHCI - Z performance	CE Score	UHCI - HT	Z - UHCI - HT	Performance Score	Z pscore	Efficiency z UHCI - Z performance	CE Score
A	16.74	-0.66	20	-0.05	0.62	0.44	-0.04	-0.69	29	0.40	1.10	0.77
B	6.39	-0.78	30	1.32	2.10	1.49	3.78	-0.65	29	0.40	1.05	0.75
C	27.62	-0.55	6	-1.96	-1.42	-1.00	14.08	-0.54	30	1.21	1.75	1.24
D	-5.98	-0.91	16	-0.59	0.32	0.22	-38.55	-1.10	28	-0.40	0.70	0.50
G	38.38	-0.43	30	1.32	1.75	1.24	35.35	-0.32	30	1.21	1.52	1.08
H	26.99	-0.55	23	0.37	0.92	0.65	2.29	-0.67	29	0.40	1.07	0.76
I	80.00	0.02	30	1.32	1.30	0.92	67.44	0.03	30	1.21	1.18	0.83
J	52.28	-0.28	22	0.23	0.51	0.36	55.89	-0.10	27	-1.21	-1.11	-0.78
K	224.94	1.59	17	-0.46	-2.05	-1.45	241.49	1.88	26	-2.01	-3.89	-2.75
L	168.99	0.99	19	-0.18	-1.17	-0.83	208.94	1.54	28	-0.40	-1.94	-1.37
M	272.40	2.11	18	-0.32	-2.43	-1.72	186.46	1.30	28	-0.40	-1.70	-1.20
N	27.79	-0.55	13	-1.00	-0.46	-0.32	2.17	-0.67	28	-0.40	0.27	0.19

APPENDIX N Data equations

The following equation was used to calculate the UHCI EEG from the EEG data

Equation 1 ***UHCI***

$$UHCI\% = \frac{Band\ Power\ Baseline\ \ Interval - \ Band\ Power\ Test\ Interval}{Band\ Power\ Baseline\ Interval}$$

Equation 2 ***MWL***

$$Sum\ of\ \ Averaged\ Bandpower\ values\ (Alpha\ 8 - 12Hz)$$

Equation used to calculate to the CE for TIPT

Equation 3 ***Individual CE Score***

$$\boldsymbol{\frac{Z\ performance\ score - \ Z\ UHCI}{sqrt(2)} = CE}$$