THE IMPACT OF THE EDUBLOX ONLINE TUTOR (EOT) PROGRAMME ON THE COGNITIVE FUNCTIONING OF PRIMARY SCHOOL CHILDREN

By

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"We must find time to stop and thank the people who make a difference in our lives"

- *John F. Kennedy*

Thank you, God, for all the blessings that you have bestowed on me, for the strength that you give me each day, and for all the people around me who make life more meaningful:

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It is not where or what you have in your life, but it is who you have by your side that matters...

Thank you all for your part in my journey

DECLARATION

I, Naseehat Ebrahim Dawood, hereby declare that this dissertation titled "THE IMPACT OF THE EDUBLOX ONLINE TUTOR (EOT) PROGRAMME ON THE COGNITIVE FUNCTIONING OF PRIMARY SCHOOL CHILDREN" is my own work and that, where applicable, every effort has been made to correctly reference the work of other authors. Furthermore, I declare that this dissertation is to be submitted to the University of Pretoria and has not previously been submitted to this university or any other tertiary institution

ETHICS STATEMENT

The author, whose name appears above, has obtained, for the research described in this work, the applicable research ethics approval.

The author declares that she has observed the ethical standards required in terms of the University of Pretoria's Code of Ethics for Researchers and the policy guidelines for responsible research.

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ABSTRACT

Edublox is an educational training facility with headquarters in Pretoria, with branches nationally and their programme marketing internationally. Their latest development was the Edublox Online Tutor (EOT) programme that claims to enhance cognitive functioning in children. This retrospective study thus seeks to establish whether exposure to the EOT programme has an impact on the cognitive functioning (specifically working memory - comprising of visual working memory, auditory memory, and logical reasoning) of primary school children. The conceptual structure for this study was formed using The Cognitive Information Processing Theory and Vygotsky's Social Cognitive Theory. A convenience sampling method was chosen and comprised of grade 2 children (n=64) who formed 3 groups; 2 experimental groups (EOT and educational computer games) and a control group (usual schooling). A quantitative, experimental research design was adopted throughout the study and included pre-and post-assessments of cognitive performances. Varying data analysis techniques, such as mean plots, paired samples t-tests, and one-way repeated measures ANOVA tests were utilised. Overall, analyses revealed that exposure to the EOT programme significantly improved children's conceptual skills in one out of the 4 variables tested in cognitive performance. Other findings revealed that while there were overall improvements in mean post-test scores, there were no significant differences in mean post-test scores between the experimental groups and the control group. The differences in strength of changes between the pre-and post-test scores were influenced by the length of exposure, the type of intervention, the delivery environment, and the sample size, among other factors. It was recommended that the treatment period is lengthened, a multimodal approach is adopted, and the treatment environment is varied to investigate effect sizes and enhance the validity and comparability of this study.

Keywords: auditory memory, cognitive skills, Edublox, Edublox Online Tutor (EOT), visual working memory, working memory

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CHAPTER 1: INTRODUCTION

"Research is creating new knowledge"

- *Neil Armstrong*

1.1. Introduction

Cognitive skills, as defined by Mühlenweg (2012), are the skills that we employ for our thinking and learning processes. These skills are also referred to as the core skills of an individual's mental functioning, enabling us to remember things, make judgments, reason, and pay attention. Deficits with any of these cognitive skills are said to significantly affect the learning process (Mühlenweg, 2012). Concerning a child's learning and development, poor functioning of these key cognitive skills may hinder a child's understanding and ability to respond to situations in the manner in which other children usually do. As a result, a child finds it difficult to continue the learning processes as compared to a child who has these cognitive skills intact (Mühlenweg, 2012). It is thus imperative for educators and parents to understand this, to ensure the successful development of these skills, as well as to detect any irregularities in the cognitive development of children.

This chapter presents a general overview of the study by introducing the research context, addressing the problem statement, highlighting the research questions, stating the significance of the study, and providing the overall outline of the dissertation.

1.2. Background to the study

Across the globe, there are millions of children with Special Education Needs (SEN) or those classified as having a learning disability (Minou, 2011; Gafoor, 2015). Minou (2011) notes that often children with learning disabilities are subject to ridicule and discrimination in schools, leading to further decreases in performance. In a study conducted within 31 government and government-aided schools in the Kerala State of India, Gafoor (2015) found that nearly 5% of students at a school of a 850 students can be classified as belonging to the SEN category. The SEN category included learners who were classified as having a learning disability, who were suffering from visual impairement, who struggled with intellectual disability (formally known as mental retardation), or who have been diagnosed with autism and Attention Deficit Hyperactivity Disorder (ADHD).

In a related study, Padhy et al. (2015) found that through the use of the Specific Learning Disability-Screening Questionnaire (SLD-SQ) and the Brigance Diagnostic Inventory (BDI), 10% of grade 3 and 4 children were found to have learning disabilities. It is, however important to note that the actual rate of learning disabilites in children may be higher, since most research studies sample children in ordinary government schools, even though most children with learning disabilities attend special schools. Thus, using a cluster sampling technique, incorporating children from different school types, Mahin et al. (2014) found that learning disabilities were prevalent in up to 40.74% of children.

In addition, the intelligence, mathematics, reading, and writing tests of children found that learning disabilities tend to vary among disciplines, with writing disability resulting in 4.5%, mathematical disability ranging to around 13.1% and reading disability peaking at 36.9% (Mahin et al., 2014). Thus, the prevalence of learning disabilities among school-going children highlights the need for enhanced and lasting interventions to combat learning disabilities and improve cognitive performance. If left unchecked, learning disabilities tend to result in chronic scholastic backwardness, leading to school dropouts, emotional and behavioural problems among children (Basil, Fysal, Akhila, & Aswathy, 2019). Basil et al. (2019) found that despite having a basic knowledge of the existence of learning disabilities, the majority of teachers in their study lacked sufficient understanding of the causes, concepts, and identification of learning disabilities. Thus, they were unable to correctly identify children who required special attention and education. Similarly, in South Africa, Nel and Grosser (2016) note that except for those teaching in SEN schools, many teachers generally have a limited understanding of the learning disabilities and how they can be identified during the learning process.

With advancements in technology and digital functioning, it is notable that the educational sciences have achieved significant developments in initiating and designing useful ideas and processes that can improve the learning capability of a child (Nusir, 2011). These achievements are in the form of audio and visual aids that are focused on making the learning processes effective and efficient for the development of children (Nusir, 2011). The learning process has been revolutionised in a manner in which learners can significantly acquire the relevant knowledge and expertise through different online mediums depending on their interest and accessibility of such resources (McHaney, 2012).

One such online medium of interest is a development by Edublox- the Edublox Online Tutor (EOT) programme. Edublox aims to develop the foundational skills of children like reading spelling, writing, and mathematics skills. The most important feature which distinguishes Edublox and other online programmes is their claim for the effective development of cognitive skills in children (Edublox Online Tutor, 2018). Edublox further posits that various cognitive skills are improved through their online programmes (Edublox Online Tutor, 2018). It is thus imperative that novel programmes like the EOT be evaluated to examine the effectiveness of such learning interventions along with the comprehension of their limitations (Entwistle, 2015). In addition, the need arises to study whether Edublox is effective in the development of cognitive skills such as attention, concentration, processing, and other mental abilities in children.

Edublox is an educational training facility that specialises in developing the foundational skills of children – such as reading, spelling, comprehension, and mathematical enhancement (Edublox, 2014). Since its formation in 1979, Edublox has delivered self-help home-based online services to over 40 countries including South Africa. During this period, more than a 150 000 learners have made use of the Edublox reading and learning clinics and found positive changes in their learning (Edublox, 2017). Their latest development is the EOT programme, which comprises a set of exercises that claim to be responsible for directly improving learners' cognitive skills, by engaging them in meaningful and beneficial online activities. In addition, Edublox offers an interactive system of cognitive exercises that is meant to build a strong foundation for learning that varies depending on the individuals pace and grasp of concepts (Edublox, 2017).

The following key skills are primarily focused on by all Edublox programmes - including the EOT programme:

- Attention and concentration training
- Enhancement of accurate perception
- Visual discrimination of colour, foreground-background, form, size, and position
- Visual analysis and synthesis of position in space
- Auditory discrimination of foreground-background, and position in time and space
- Auditory analysis and synthesis of position in time and space
- Decoding and integration of information
- Visual closure
- Imagination
- Visual, auditory, sequential, iconic, short-term, long-term, and working memory
- Reasoning and logical thinking

For the purpose of this study, Edublox sought to investigate the effectiveness of the EOT programme on the cognitive functioning in primary school children. The study comprised of 3 groups – a *control group* and the *Edublox online training programme group.* The latter, should not be confused as being the EOT programme group – but rather, it *includes both* the EOT programme group *and* the educational computer games group. Although the primary focus was the EOT group, the educational computer games group was added to serve as the active control group for future research and will be discussed in Chapter 3 of this dissertation. In addition, empirical studies in Chapter 2 of this dissertation show that there are several methods of improving learners' cognitive functions - one of which includes cognitive training as provided by Edublox. Therefore, there is a need to assess the EOT programme to establish the extent to which such interventions have an impact (if any) on cognitive functioning – thus enabling one to prove or reject the claims made by Edublox.

1.3. Statement of the problem

Rutledge, Bos, McClure, and Schweitzer (2012) note that increasingly, ADHD has become one of the top public health concerns due to its prevalence in about 5% of children. In addition to ADHD, several other learning disabilities have been identified among school-going children - inclusive of visual impairment, intellectual disability, and autism (Padhy et al., 2015; Gafoor, 2015; Nel & Grosser, 2016). As a result, diverse interventions have been identified and suggested for the improvement of performance among children with learning disabilities. Although the most widely applied interventions currently are classroom-based, recent trends have seen the introduction of other interventions such as lunchrooms and playgrounds, especially in assisting children with ADHD (Tresco, Lefler, & Power, 2010). Jitendra et al. (2008) note that for children with ADHD, not much intervention beyond expert instruction is required. In addition, many studies support simple interventions such as teacher-mediated, peer-mediated, and Computer-Assisted Instruction (CAI) approaches (Jitendra, et al., 2008).

Edublox, as a programme falls under the broad category of classroom-based approaches, and similar programmes like the Edublox programme were found to be highly effective in improving academic performance among children with learning disabilities (Jitendra, et al., 2008). However, a review of studies such as Tresco et al. (2010) and Aikins (2011) show that the field of performance enhancement in children with learning disabilities, is constantly evolving, and consensus has not yet been reached on the most effective intervention(s). As a result, the aim of this study was to analyse the impact of the EOT programme on the cognitive functioning of primary school children, and add to the body of existing knowledge pertaining to this topic. Moreover, the broad objectives of the study were two-fold: the first one is to examine whether the EOT programme is indeed effective in the improvement of cognitive skills (specifically working memory - comprising of visual working memory, auditory memory, and logical reasoning) in children- thus validating or rejecting the claims made by Edublox- and secondly, to bridge the gap in the literature, especially in a South African context where online learning programmes like these are innovative and novel.

1.4. Research objectives

Primarily, this retrospective study sought to establish whether exposure to the EOT programme has an impact on the cognitive functioning of school children. Specifically, the study sought to achieve the following objectives:

1.4.1. To evaluate the effectiveness of the EOT programme in enhancing cognitive performance in areas of reading, writing, and spelling

1.4.2. To assess the effectiveness of the EOT programme on the enhancement of auditory processing and performance with reference to numbers, words, and sentences

1.4.3. To ascertain the effectiveness of the EOT programme in enhancing working memory

1.4.4. To determine the effectiveness of the EOT programme in enhancing processing speed

1.5. Research questions

Emanating from the research objectives, the following research questions formed the basis of this study:

1.5.1. How effective is the EOT programme in enhancing the cognitive performance in areas of reading, writing, and spelling?

1.5.2. How effective is the EOT programme on the enhancement of auditory performance with reference to numbers, words, and sentences?

1.5.3. How effective is the EOT programme in enhancing working memory?

1.5.4. How effective is the EOT programme in enhancing processing speed?

1.6. Research hypotheses

Data analysis for this study was based mainly on inferential statistics namely, a paired samples t-test and a one-way repeated measures ANOVA test with post-hoc testing. The statistical tests were therefore based on the following hypotheses, each of which were based on the study questions:

Research question	Hypotheses
How effective is the EOT programme in enhancing cognitive performance in areas of reading, writing, and spelling?	• **H1:** Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of reading, writing, and spelling • **H2:** There are no significant differences in mean cognitive score changes between the 3 groups (EOT, Educational Games, and Control Group)
How effective is the EOT programme in enhancing auditory performance with reference to numbers, words and sentences?	• **H1:** Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of numbers, words, and sentences • **H2:** There are no significant differences in mean auditory score changes between the 3 groups (EOT, Educational Games, and Control Group)
How effective is the EOT programme in enhancing working memory?	• **H1:** Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of working memory • **H2:** There are no significant differences in mean working memory score changes between the 3 groups (EOT, Educational Games, and Control Group)
How effective is the EOT programme in enhancing processing speed	• **H1:** Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of processing speed • **H2:** There are no significant differences in mean processing speed score changes between the 3 groups (EOT, Educational Games, and Control Group)

1.7. The rationale for the study

In fighting the prevalence of behavioural disorders such as ADHD, various interventions have been introduced and implemented across the world. A review of the literature found that despite there being numerous cognitive enhancement programmes and interventions across the world, there still appears to be limited consensus on which interventions are best suited for cognitive enhancement. In the process of implementation of any educational programme, it is important to ascertain the extent to which, upon completion, the programme has contributed to positive change. Through the analysis of the pre-and post-test data provided, this study will inform Edublox on the effectiveness of the programme in enhancing cognitive performance, auditory performance, working memory, and processing speed. Through a literature review, this study will expand the understanding of cognitive enhancement approaches by examining other interventions beyond the EOT programme. The study will hence provide an understanding of both the effectiveness of the EOT programme and the possible need for the implementation of other interventions to bring about greater cognitive conceptual skills enhancement among school-going children.

1.8. Dissertation outline

This dissertation is structured into 5 chapters which include the following:

Chapter One: Introduction and Background

The first chapter provided an overview of this research study, that is - an exploration of the effectiveness of the EOT programme in enhancing cognitive conceptual skills among school-going children. In addition, the research aim, objectives, and research questions were all discussed in this chapter. Lastly, the rationale for this research was also highlighted to explain how this research may help with the ongoing discussion of whether educational interventions, like that of the EOT programme, are effective as cognitive enhancement tools.

Chapter Two: Literature Review

The literature review chapter presents current and previous literature on the effectiveness of Edublox programmes, other educational programmes as well as pharmacological interventions in improving cognitive conceptual skills among school children. The review of the literature provided an in-depth analysis into not only the effectiveness of different interventions, but also how such effectiveness differs as a result of variations of the same programme and integration with other programmes.

Chapter 3: Research Methodology and Approach

This chapter discussed the chosen and justified research strategy that formed the basis of this study. The research philosophy influencing the methodology and design is explained. Furthermore, the sampling strategy, treatment approach, and data analysis techniques are all discussed in this chapter. Moreover, the chapter also offers insights into the ethical considerations employed in this study.

Chapter 4: Results and Analysis of Findings

Primary results gathered from empirical evidence from the Edublox administered programme were presented and discussed in line with the research objectives of the study. This chapter presents both the descriptive and inferential statistical techniques employed in the analysis and discussion of the results.

Chapter Five: Summary of Findings.

The analysed findings were reviewed in this last chapter in accordance with the key research questions guiding the study. Chapter 5 further locates the study in the context of literature and offers a discussion into the meaning of the study's findings. Research gaps for future research pertaining to the methods and approaches to the enhancement of cognitive conceptual skills among school-going children. The chapter also provides a conclusion to the study, limitations of the study as well as suggested recommendations, and areas of further research.

1.9. Chapter summary

This chapter introduced the research through a discussion of the study context and statement of the problem. The research objectives as well as research questions were also discussed. In addition, the significance and rationale for the study were also highlighted. The chapter further presents the organisation of subsequent chapters that will form the basis of this dissertation.

The next chapter presents a discussion on available empirical studies pertaining to the topic of cognitive enhancement techniques.

CHAPTER 2:
LITERATURE REVIEW

"Research is to see what everybody else has seen and to think what nobody else has thought"

- Albert Szent-Györgyi

2.1. Introduction

Feldman (2016) argues that a child's development can be affected in a manner in which they process and utilise sensory information and therefore, each child has a different development rate. Inevitably, this impacts how children learn, interact, and cater to developmental demands. From an evolutionary perspective, learning is an essential characteristic of human beings, though children tend to learn quickly in the initial stages of life by imitating adults or by their surroundings. The learning capabilities of a child vary from individual to individual and therefore, there has been a need to adopt such learning techniques and processes to deliver ultimate benefits in terms of easily understandable processes and techniques of learning (Seidman, 2013). Gathercole (2014) found that cognitive skills especially that of perception, attention, memory, and logical reasoning are developed during early childhood as these skills form the basic pillars of the human brain, enabling a person to perform various mental functions.

Notably, the education sciences have achieved significant developments in initiating and designing useful ideas and processes that can improve the learning capability of a child. These achievements focus on enhancing the effectiveness and efficiency of learning processes for the development of children. The learning process has been revolutionized in a manner in which learners can significantly acquire the relevant knowledge and expertise through different online mediums depending on their interest and accessibility (McHaney, 2012). However, it is imperative that these programmes are examined and evaluated to examine the effectiveness of such learning processes along with the comprehension of their limitations (Entwistle, 2015). In realising this, it becomes necessarily important to examine whether online programmes like the EOT, is effective in the development of cognitive skills such as attention, concentration, processing speed, and other mental abilities in children.

This chapter focuses on reviewing contextual, theoretical, and empirical literature on the effect of cognitive enhancement education on learner performance. Discussed in this chapter is an introduction to the EOT programme, a definition of key terms related to the study, a review of theoretical frameworks underpinning the study, and a review of the impact of cognitive enhancement tools on learner performance. To broaden the understanding on this research topic and to provide another angle of possible interventions of cognitive enhancement techniques, this chapter also assesses literature on the effectiveness of pharmacological and other interventions such as training and physical exercise on improving cognitive performance.

2.2. Definition of key terms

Several key terms were identified as forming the structure of this study. For the purpose of this study, a distinction is drawn between *cognitive skills* and *conceptual skills.*
While the definition of *cognitive skills* in section 2.2.1 is retained, the term *conceptual skills* can be defined as the combination of *cognitive skills, working memory, visual memory, auditory memory, logical reasoning* and *processing speed.*

2.2.1. Cognitive skills

As discussed in the previous chapter, cognitive skills are the core skills that individuals utilise for their thinking and learning processes (Mühlenweg, 2012). Since these skills form the basis of an individual's mental functioning, Mühlenweg (2012) posits that any irregularities in these skills can significantly affect a person's thinking and learning processes. In the context of this study, this suggest that the functioning of these cognitive skills play a pivotal role in a child's learning and development. In their study, Helou and Newsome (2018) found that should there be irregularities with these key cognitive skills, a child may find it a bit more difficult to continue the learning processes as effectively as compared to a child who has these cognitive skills intact. As a result, it is important for educators and parents to understand these key cognitive skills and their importance thereof, in order to ensure the successful development as well as to detect any irregularities in the cognitive development of children (Helou & Newsome, 2018).

2.2.2. Working Memory

Working memory (WM) is defined as the process executed by the human brain to store and manage temporary information (Meltzer, 2012). This process is important for all cognitive tasks especially in learning, reading, and reasoning applications (Meltzer, 2012; Alloway & Passolunghi, 2011). Baddeley and Hitch (1974) suggest that a model for WM consists of 4 components which are the phonological loop, the visuospatial sketchpad, a central executive system, and an episodic buffer. WM consists of two brief stores, a visual component and an auditory component. Visual working memory is an iconic memory while audio short term memory as echoic memory. In this study, working memory capacity (WMC) refers to audio and visual memory, enabling a learner to retain visual and audio information provided in the classroom as well as for cognitive activities such as reading, doing arithmetic, and language learning (Weiten & Hassim, 2018). Thus, should there be irregularities or deficits in the functioning of WMC, it would be difficult for a child to effectively execute a task during the learning stage (Alloway & Passolunghi, 2011).

For the purpose of this study, the focus is on visual and auditory memory as components of WM and WMC. These components will be discussed below:

2.2.3. Visual memory

Visual memory is regarded as a key component of visual perception and literacy (Kulp et al., 2004). Studies show that visual memory relates to skills such as learning mathematics and performing arithmetic functions. However, for the purpose of this study, the focus is more on assessing visual sequential memory, which is the memory for sequentially presented stimuli (Giles & Terrell, 1997). While earlier research found a significant relationship between visual sequential memory and paragraph comprehension, oral reading, and word recognition (Guthrie & Goldberg, 1972), other studies found a significant relationship between visual sequential memory scores with their numeracy scores but not with reading, writing, and spelling (Wood, Black, Hopkins, & White, 2018). Therefore, the difference in the above findings necessitates further research on educational programmes like the EOT programme that aim to improve visual sequential memory.

2.2.4. Auditory Memory

Auditory memory can be defined as the sensory memory which enables an individual to register information that is presented orally, and thus is an essential cognitive skill in information processing and memory (Kraus, Strait and Parbery-Clark, 2012). According to Sacks (2013), it is evident that children who experience difficulties with auditory memory find it challenging to remember a lot of the information that is taught in the classroom and educational settings. Therefore, it becomes a learning challenge for these children and many struggle to reach the required academic developmental areas with ease (Kraus, Strait and Parbery-Clark, 2012). Moreover, research has confirmed that auditory memory plays a crucial role in literacy as it directly impacts reading, spelling, writing, and maths skills (Kurdek & Sinclair, 2001). In addition, it should be noted that problems with auditory memory relate to the difficulty in remembering words, understanding words, and remembering oral information (Kurdek & Sinclair, 2001). While some studies demonstrated the relationship between auditory short-term memory and academic achievement, others have found the relationship to be inconclusive (Abraham, George, & Kunnath, 2016; Riccio, Cash, & Cohen, 2007). Thus, the difference in the aforementioned findings resulted in one of the objectives of this study - to determine whether the EOT programme had any impact on auditory memory.

2.2.5. Logical reasoning

Logical reasoning can be defined as a cognitive process that involves a systematic series of steps that is used to arrive at a conclusion (Buckley, Seery, Canty, & Gumaelius, 2018). Logical reasoning comprises of two main components i.e. *deductive reasoning* and *inductive reasoning*. Deductive reasoning is defined as reasoning from the general to the specific and thus, only one valid conclusion is possible. Whereas, induction reasoning is the reasoning from specifics to the general, thus based on various patterns of how a conclusion is derived. Inductive reasoning appears to form part of fluid intelligence and therefore is not based on previously obtained knowledge and experience (Buckley et al., 2018). Studies indicate that fluid intelligence is an important predictor of mathematic achievement and verbal performance. Furthermore, inductive reasoning and fluid intelligence is a key ingredient in learning novel aspects and making correct inferences (Primi, Ferrão, & Almeida, 2010).

The above constructs form the basis of this study. As noted in the beginning of the chapter, the term "conceptual skills" will be used to encapsulate the aforementioned cognitive constructs into one coherent term. The next section focuses on the theoretical framework underpinning the study.

2.3. Theoretical framework

Two main theories were identified as key in providing a conceptual structure to this study, namely *Vygotsky's Sociocultural Theory* and the *Cognitive Information Processing Theory*.

2.3.1. Vygotsky's Sociocultural Theory

Since the early 1930's, Vygostsky's work has formed a solid foundation in the understanding of cognitive development through his Social Development Theory (McLeod, 2018). Vygotsky's sociocultural perspective on cognitive development justifies assisted and guided learning; and can be profitably applied in current online teaching and guided learning contexts (Dalgarno, 2001; McKendree, Stenning, Mayes, Lee, & Cox, 1998; McLoughlin & Oliver, 1998; Stahl, 2005).

According to Vygotsky (1986), human activities take place in cultural settings and cannot be understood apart from these settings (Gredler, 2012). One of his key ideas was that people's specific mental structures and processes can be traced to their interactions with others. These social interactions are more than simple influences on cognitive development. Rather, they are creating individuals' cognitive structures and thinking processes (Palincsar, 1998). Regarding higher cognitive processes, Vygotsky believed that a child can direct his/her attention and thinking through solving problems guided and assisted by others. This is first co-constructed during shared activities between the child and another person. Thereafter, these co-constructed processes are internalised by the child and become part of his/her cognition (Mercer, 2013). Figure 1 illustrates Vygotsky's ideas which emphasize the importance of social interactions in cognitive development.

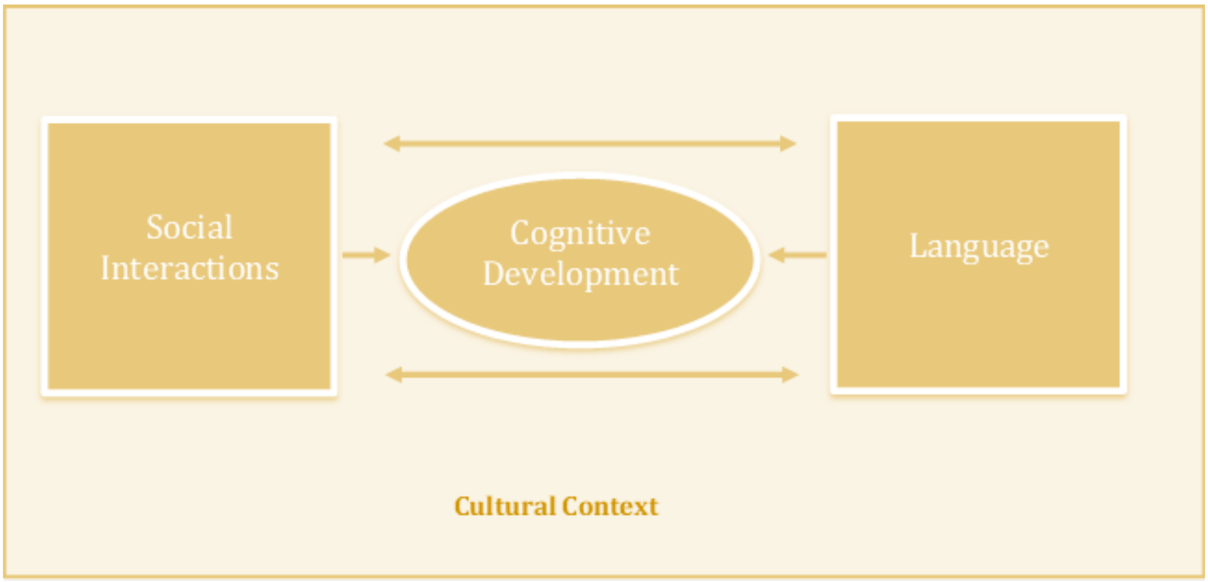

Figure 1: Cognitive development in individuals
Source: Vygotsky (1986)

In Figure 1, Vygotsky (1986) suggests that social interactions and the cultural context within which an individual is raised, determine his/her cognitive development. In addition, Vygotsky (1986) proposed that regarding child development, the "zone of proximal development" (i.e. the zone of the most immediate psychological development which shows the difference between what a learner can do without help and what he/she can do with adult support) can be extended outwards if a child is raised in a favourable environment. In their study, Helou and Newsome (2018) found that Vygotsky's theory applied well in peer learning scenarios, leading to greater cognitive performance. In addition, Vygotsky (1986) suggests that learning is bolstered when a learner can "internalise" the tools that are being provided in the culture itself (Helou & Newsome, 2018). This is because when the tools of culture evolve and emerge, the learners' ability to grow as individuals and increase their knowledge base is broadened (Gredler, 2012). As such, according to the Sociocultural Learning Theory, it is important for instructors to use constantly evolving tools to understand the human mind from a cultural point, and thus the EOT programme warrants evaluation to determine its effectiveness on cognitive performance.

2.3.2. Cognitive Information Processing Theory

The field of cognitive psychology views an individual as a computer that requires input information to be provided for it to process the information and produce an output (McLeod, 2008). The theory is mainly attributed to John William Atkinson and Richard Shiffrin who developed a multi-stage theory of memory in the year 1968. The theory is based on the following types of memory: *sensory memory, short-term memory*, and *long-term memory*. In addition, Atkinson and Shiffrin (1968) made the following assumptions regarding the human mind and its cognitive processes:

- A series of processing systems (such as attention, perception, and short-term memory) are used to process information provided by the environment
- Processing systems alter the information in systematic forms
- Research is conducted to outline processes underlying cognitive performance
- Human beings process information just as computers

In exploring attention in humans, the cognitive information processing theory seeks to explain how information processing relates to attention. To do this, McLeod (2008) notes that the theory conceptualises humans as processors who can only process a limited amount of information at a given time – just like a computer of technological system. Figure 2 shows the basic flow of information as hypothesised by Atkinson and Shiffrin (1968), from the realisation of a stimulus to the processing of information, storage, and retrieval of information. It should be noted that Figure 2 provides a basic flow of information as proposed by Atkinson and Shiffrin (1968), but the actual cognitive process is more complex and intricate.

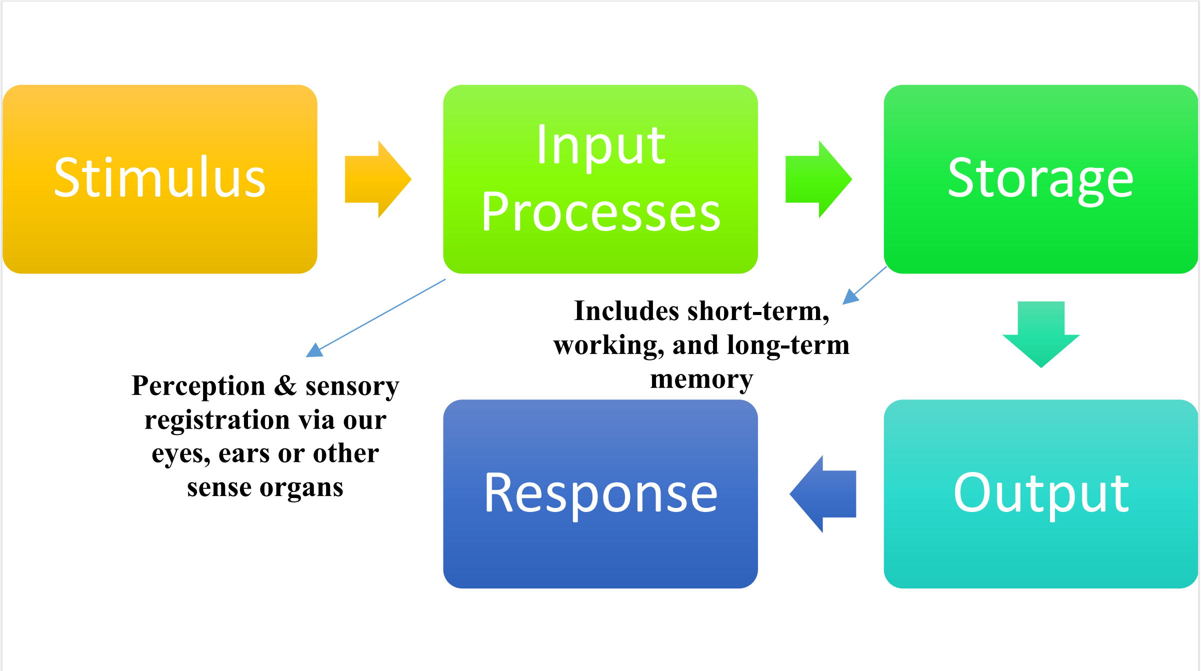

Figure 2: Flow of information processing systems in humans

Source: Atkinson and Shiffrin (1968)

Lutz and Huitt (2003) note that the information processing theory is significant in educational contexts especially in early child development. In that regard, the theory helps in the understanding of how children process information provided to them and how educators and parents can best intervene to ensure healthy results in cognition and learning. Lutz and Huitt (2003) further postulate that learners will require exercises and examinations for periodic measurement to demonstrate their elaborative skills. This not only assists with problem diagnosis, but with assistance from the information processing theory, it helps determine possible interventions or children depending on which stage of the information process is affected.

The theories discussed in this subsection have direct implications on the cognitive learning abilities of children. A review of the theoretical foundations show that a learner's cognitive functions is highly affected by the environment, as argued by Vygotsky's Sociocultural Theory (social interactions) and the Cognitive Information Processing Theory (stimulus). These theories hence support the need for interventions to enhance learner's cognitive abilities (Hummel & Huit, 1994; Helou & Newsome, 2018). For example, based on Vygotsky's Sociocultural Theory, teachers and parents of under-performing learners can adjust their teaching approaches and environment to enhance a child's learning performance.

The next section explores the empirical literature on the impact of Edublox programmes and other cognitive enhancement tools in improving cognitive performance.

2.4. The impact of Edublox in shaping cognitive skills of learners

For over 20 years, Edublox has been working with children to explore possible methods of improving the learning process (Udoh, 2013). The online programme initiated by Edublox has focused on making the learning process faster, better, and easier (Gelderblom, 2017). Blablová (2015) suggests that the role of Edublox is instrumental in improving the processing speed, working memory, auditory memory, and other cognitive skills and behaviour if children. Notably, it is evident that the development of the aforementioned key cognitive skills is essential for the learning capability and mental understanding of a child (Wiegand, 2013), and thus the role of the EOT programme necessitates evaluation to determine the effectiveness of this intervention on learning and cognitive development.

While several empirical studies have been conducted specifically to measure the impact of the Edublox learning clinics in improving children's cognitive abilities, a review of the studies shows that they were conducted or funded by Edublox itself - thus making it difficult to ascertain whether the results and conclusions were fully independent of the company's interest in the field of cognitive enhancement education. Nevertheless, a review of available Edublox studies will be presented in the discussion below.

In 2014, Edublox hosted a study in Singapore called the 'FUNtastic Brain Clinic' in partnership with Mind Edge, a training company in Asia. The study sought to establish the extent of improvements in concentration among 27 learners between 10 and 12 years old. The programme was administered over 5 days with up to 8 half an hour sessions. To assess the changes in memory function, concentration, and general reasoning, both pre and post-testing were conducted; and data was analysed by the University of Pretoria. According to Edublox (2014), the results of the pre and post-tests show that cognitive enhancement education is capable of improving the concentration of children in just 5 days. Through training, children were reportedly higher focused attention – where they were able to ignore other things while concentrating on one aspect (Edublox, 2014). Through the use of Feature Match, a Cambridge Brain Sciences online test, Edublox observed statistically significant improvements between pre and post-tests, thus testifying to the effectiveness of cognitive enhancement education (Edublox, 2014).

However, conclusions and assertions by Steeger et al. (2016) dispute such findings. Rather, Steeger et al. (2016) found that the improvement in working memory and cognitive enhancement among participants was gradual, and greater improvements were witnessed over a longer period - thus contradicting the possible cognitive enhancement that was found by Edublox (2014) after just 5 days.

Two other studies were conducted on the impact of cognitive enhancement education in enhancing literacy and learning among children who were hearing impaired. Both studies were conducted as academic studies in partnership with Edublox. On the first study, De Wet (1989) observed an increase of 11.625 in non-verbal IQ scores in participants who were tutored through Edublox (then called Audioblox) between April and August of that year. Whereas, participants who were not tutored through Edublox showed an increase of only 4.625 on their non-verbal IQ scores. The second study conducted by Van Staden, Badenhorst and Esterhuyse (2008) (as quoted by Edublox, 2015) combined sign language teaching with Edublox programmes on visual processing, visual imaging, and visual memory enhancement among 60 hearing impaired learners from grade 1 to grade 3. Results showed significant differences in performance between the experimental and control groups in the pre and post-tests, thus demonstrating the effectiveness of cognitive enhancement education in hearing impaired learners.

In another Edublox funded study, chiropractor Mays (2012) sought to establish the comparative effect of Edublox training versus Edublox training coupled with cervical spinal manipulative therapy (Edublox, n.d.) on visual memory and visual sequential memory. The study included 34 children from an inner-city school in South Africa that were placed into two groups which were trained by an Edublox tutor for up to 22.5 hours over 5 days. The second group received further cervical adjustment therapy each morning over the 5 days. Results of the study showed that contrary to the null hypothesis, although Visual Memory Skills Test scores increased for both groups post-training, the first group that received only the Edublox training, performed better than the group that received the Edublox training and the cervical adjustment therapy. From the results, it can be concluded that the Edublox programme alone is already enough to enhance cognitive abilities, and perhaps a combination of the Edublox training with other programmes may lead to reduced impact.

From the aforementioned reviewed empirical studies, the impact of the Edublox programmes was seen to positively enhance children's cognitive abilities. However, since they were all conducted using Edublox funding, it is difficult to rule out the possible conflict of interest and its implications on the reported results. In addition, the results of the Edublox studies were provided with no mention of the reliability coefficients or validity processes employed, making it difficult to validate these findings. However, regardless of the limitations, these findings reinforce the idea that cognitive performance may be improved through the use of cognitive enhancement education programmes such as Edublox.

The following subsections will discuss empirical findings from studies on other cognitive enhancement education programmes as well as other available interventions meant to improve a child's performance in school.

2.5. Impact of cognitive education on learner performance

Like Edublox, there are several other cognitive enhancement clinics over the world, specifically focusing on treating complications such as Attention-Deficit Hyperactivity Disorder (ADHD) and working memory (Aikins, 2011; Aleven & Koedinger, 2002). Using varied methodologies and approaches, researchers often aim to understand how effective a single intervention or a combination of interventions can be, in enhancing cognitive functions.

Steeger, Gondoli, Gibson and Morrissey (2016) combined cognitive training for 91 adolescents with ADHD and included their mothers to establish the impact of parent-pupil training in enhancing cognitive functions. Over a course of 5 weeks, pupils received cognitive working memory training while their mothers received behavioural parental training. Results of the study showed drastic improvements in pupil's working memory (Steeger et al., 2016). These results are in line with Vygotsky's Sociocultural Theory which states that interventions such as parental guidance, can greatly enhance a child's cognitive performance (Vygotsky, 1986).

In a more recent study, Adubasim (2018) used an experimental research design to investigate the effectiveness of the Brainfeed intervention programme on 24727 high school students living with dyslexia in Nigeria.

The Brainfeed programme was put together by Adubasim (2018) as a tool to target cognitive skill impairments in children with dyslexia. The programme involves several exercises built to challenge children's attention, concentration, logic and reasoning, memory, speed, and accuracy. Brainfeed is similar to the EOT programme due to its use of various educational games and digital applications in teaching. In the study, participants were subjected to both pre-and post-tests before and after receiving a training intervention course. Adubasim's (2018) results showed an improvement in both working memory and processing speed in children who received the Brainfeed intervention programme. This was shown through the improvement in absolute mean figures as well as significant p-values established from independent samples t-tests. In addition, the total treatment phase applied in Adubasim's (2018) study was 1 month, which is similar to the average treatment period also employed by Edublox. Results of this study were generally found to be reliable - with a healthy score of the Spearman-Brown coefficient of 0.94. The study was also found to be valid - with contents of the dyslexia questionnaire being subjected to the criteria for dyslexia diagnosis and the Gibson Test of Cognitive Skills being aligned to the factors for intelligence as identified by the Cattell-Horn-Carroll (CHC) theory of cognitive abilities.

In another study, Rosa et al. (2017) focused on exploring the impact of non-pharmacological approaches to cognitive enhancement. Over the course of 12 weeks, the researchers placed 6 ADHD patients under cognitive training as well as placebo training. The pre and post-tests were conducted using the Swanson, Nolan and Pelham Questionnaire (SNAP-IV scale) to measure ADHD symptoms. Their findings showed a decrease in ADHD symptoms reported between both the experimental and placebo group (Rosa et al., 2017). In addition, neuropsychological tests conducted revealed that for trained tasks, there were improvements in both the treatment and placebo groups. While the findings appear to dispute the positive impact of cognitive training on cognitive performance, Rosa et al. (2017) argue that there is rather a need for new strategies used in assessing cognitive training that focus on improving external validity (such as the use of a classroom environment) that has larger sample sizes.

Similarly, Rutledge, Bos, McClure and Schweitzer (2012) also suggest the need for new strategies and larger sample sizes. Furthermore, they argue that more effective and adjunctive interventions for ADHD are needed to improve cognitive performance. For instance, current interventions do not seem to possess a potential for sustained positive effects once discontinued and show limited evidence of growth in behaviour (Rutledge et al., 2012).

Several other studies report generally similar trends on the impact of cognitive training interventions (Sellah, Jacinta and Helen, 2017; Dunlosky et al. 2013). Key variables to the studies are often the combination of more than one intervention programme or the variation in training times and sample sizes. For instance, Du Plessis and Maree (2019) emphasise the importance of a child's environmental surroundings on auditory short-term memory and visual sequential memory performance. The applicability and effectiveness of such an intervention may hence depend on the processes followed throughout its implementation, the combination or mixture with other interventions as well as the sample size. In addition, Chacko et al. (2013) found that variations in control conditions and individual differences of participants often lead to mixed findings on the benefit of cognitive education. This suggests that conflicting findings are thus likely to persist in this field unless the research conditions are more similar across empirical cases.

The next section explores pharmacological interventions that are also used either in isolation or in combination with cognitive training in improving cognitive performance.

2.6. Pharmacological interventions for enhancing learner performance

While most recent studies in the field of cognitive enhancement have become more focused on the use of non-pharmacological interventions, the preceding trend has been the use of medication - as parents and teachers attempted to find the quickest methods of enhancing their children's cognitive functions (Aikins, 2011). This section explores the literature on the effectiveness of pharmacological interventions in enhancing cognitive school performance, in comparison to non-pharmacological interventions such as the EOT programme. Reviewing alternate methods to cognitive development assists educational facilities, the public, and future research in identifying which interventions best bring out a sustained positive impact with minimum expense and minimum side effects.

Aikins (2011) used a qualitative methodology to review the developmental implications of cognitive enhancement medication on college students. The study surveyed students who took both licit and illicit stimulants to enhance their cognitive performance. Based on self-reported opinions, Aikins (2011) found that both takers of legitimate and illicit stimulants felt that cognitive enhancement medication was instrumental in their academic performance. In line with the literature, participants reported improved focus, faster task completion, mental stamina and endurance, calming feelings, greater concentration, and overall improved time management (Aikins, 2011). However, these stimulants also resulted in several reported side-effects such as loss of appetite, mood swings, sleep disruption, jitteriness, loss of sociability during usage times, and fatigue. Findings by Aikins (2011) show that while medication may achieve instant results – the positive effects are usually temporary (resulting in the need for individuals to have a constant supply). In addition, the side-effects of these drugs usually diminish its positive effects. Thus, Aikins (2011) favoured the use of non-pharmacological methods or at least, a hybrid combination that involves medical treatment and cognitive training to create lasting effects.

In their study, Hinshaw and Arnold (2015) attempted to capture the differential impact of medication versus the psychosocial and behavioural interventions in cognitive enhancement. Their study was based on a multimodal treatment study in children with ADHD which was conducted over 14 months. The initial results from their study indicated that medical interventions were more superior in combating ADHD symptoms among participants (Hinshaw & Arnold, 2015). However, repeated testing over the study period revealed that results shifted towards the superiority of combined methods especially in instances where family discipline and parental styles evolved over the period. However, over the longer term, Hinshaw and Arnold (2015) found that evidence of the impact of both medical and psychosocial interventions was inconclusive. Regardless, Hinshaw and Arnold's (2015) study points to the importance of combining medical interventions with behavioural training to enhance cognitive performance. While the effects of medication are likely immediate, lasting effects arise from social and behavioural adjustments for building children’s cognitive performance.

The next section explores other existing cognitive enhancement approaches that are neither necessarily similar to Edublox nor to the pharmacological methods.

2.7. Other methods of improving learner cognitive performance

Besides medication and non-pharmacological methods, some empirical studies also point to the effect of other cognitive enhancement interventions for adolescents. For instance, studies such as Singh, Saliasi, Van den-Berg, and Uijtdewilligen (2018) point to the impact of physical training whilst Yıldırım and Akamca (2017) point to general outdoor activities, as alternate methods that could impact an individual's cognitive performance. This section explores existing literature on any other cognitive enhancement tools that can be applied to improve cognitive performance. This review helps to broaden the field of cognitive enhancement, and possibly help build a hybrid approach that provides sustained positive effects.

In their study, Van den-Berg, Saliasi, Groot, Chinapaw and Singh (2019) sought to investigate the notion that exercise has a positive impact on cognitive performance. The study comprised of 512 school children between the ages of 9–12 years. The research included a 9 week programme which constituted daily exercise. The following pre-and post-tests were utilised: Attention Network Test, Stroop test, and the d2 test of attention and fluency test. The findings showed no improvements or decline in cognitive performance in the experimental group (Van den Berg et al., 2019). However, Christiansen et al. (2019) found that existing positive correlations between physical exercise and the reduction of ADHD symptoms among adolescents exist – with the largest effect sizes identified in exercises that were conducted for a period of 10-20 minutes and in exercises of moderate intensity. In support of the aforementioned findings, a meta-analysis of over 58 research articles by Bidzan-Bluma and Lipowska (2018) also found a positive effect of physical exercise on the cognitive functioning of individuals in late childhood. In addition, another empirical study conducted on 35 pre-school children in Turkey by Yıldırım and Akamca (2017) found that engaging in outdoor activities enhanced learner's cognitive, linguistic, social-emotional, and motor skills. Their study sample sizes and approach were found to be generally similar to studies measuring the impact of specific cognitive enhancement tools such as Edublox. Moreover, the use of quasi-experimental approaches in their measurement which included pre and post-testing with the inclusion of control groups, suggests that results were found to be generally comparable between the studies.

While empirical evidence showed generally varied findings, the existence of studies showing positive impacts of exercise on cognitive performance is undeniable. Hence, exercise and engagement in other outdoor activities are clear contributors and contenders in enhancing the cognitive performance of learners.

A review of the literature showed that for each intervention targeted towards enhancing a child's cognitive performance, there exist several limitations. These limitations point to the need for either different approaches to cognitive enhancement, a modification of existing approaches, or a combination of several approaches utilised together. In the case of the EOT programme, there is possibly a need for further research, preferably by independent researchers - on the EOT programme itself, as well as to establish the effect sizes of interventions such as the educational computer games in the short and long term. Due to the possibility that the EOT programme and educational games alone may not be sufficient to provide sustained positive effects, the Edublox programme could be combined with other proven techniques such as physical exercises and medication to optimise cognitive functioning.

2.8. Summary

This chapter focused on reviewing theoretical and empirical literature relating to the impact of cognitive enhancement education as well as other interventions on improving cognitive performance. To build the research context, the chapter began by reviewing the definitions and meanings of key terms involved in the study. The discussion progressed to a review of the theoretical foundations of the study by reviewing Vygotsky's Sociocultural Theory and the Cognitive Information Processing Theory and their applications in explaining the need for cognitive enhancement. An empirical review then commenced with the discussion on the impact of the EOT programme, the impact of other cognitive education programmes, pharmacological, and non-pharmacological interventions. From the literature, it can be concluded that currently, there is no consensus on the best approaches for cognitive enhancement. However, evidence suggests that pharmacological interventions are more effective in the short term; and require combination with non-pharmacological interventions to build lasting effect.

Moreover, due to the dearth of research on online programmes like Edublox in South Africa- this study becomes necessarily important to bridge the gap in the literature as well as to harbour further research on the many online learning programmes that exist today, especially since we are moving towards hybrid and blended learning.

The next chapter discusses the research methodology that was employed in this study.

CHAPTER 3:
RESEARCH METHODOLOGY

"It is important to get results from an experiment, but the most important is the process of getting the results"

- Dr. Nik Ahmad Nizam

3.1. Introduction

The research method, according to Creswell (2012) is a means of gaining knowledge through the use of an instrument to collect data for a research study. Academics use the research methodology chapter to measure the relevance of sampling processes, data collection techniques, and data analysis procedures to highlight their study. Contained in this chapter are the discussions of the research approach and strategy, population characteristics, sampling approaches, data collection processes, and the analysis processes that were employed in this research study.

Furthermore, the research methodology in this chapter was chosen in accordance to best pursue the following research objectives:

- To investigate whether the effect of the EOT programme can be observed in the classroom in the areas of reading, writing, and spelling
- To investigate the effectiveness of EOT programme as a tool for auditory memory enhancement in numbers, words, and sentences
- To determine the effectiveness of the EOT programme in enhancing working memory
- To determine the effectiveness of the EOT programme in enhancing processing speed

3.2. Research philosophy

A research philosophy explains the beliefs that guide research in establishing its empirical evidence, and the approach to be used in interpreting the occurrences in relation to what is understood as the reality of the investigated world (Babbie & Mouton, 2011). Thus, an understanding of the real world as it occurs in the phenomenon, influences the research philosophy to be employed in a study.

The main kinds of research philosophies that are typically used include: *phenomenology, positivism, realism, and interpretivism* (Creswell, 2012). These aforementioned philosophies will be briefly discussed below:

Phenomenologists are of the belief that the world cannot be understood by merely subjecting its natural and social occurrences with numeric quantifications. This is because numeric quantifications find it difficult to easily translate texts and emotions, feelings, and reactions (i.e. epistemological reality constructs) to occurrences in the ontological reality that defining the research phenomenon (Saunders, Lewis, & Thornhill, 2016). The challenge, however, with phenomenology is that coming up with a conclusive understanding of the investigated phenomenon is difficult. This is because there are no objective results that can be used as benchmarks to what can be projected with statistical confidence (Creswell, 2012).

Positivism, on the other hand, argues that the real world can best be understood by establishing numerical significances to what is occurring in a phenomenon (Babbie & Mouton, 2011). Establishing what is commonly known as the "objective reality" is an element of positivism as it seeks to enhance the validity and accuracy of its findings to influence more precise decision-making processing (Saunders et al., 2016). Positivism is found to be the grounding philosophy for quantitative research as it focuses on establishing data accuracy with numerical quantifications necessary for understanding the phenomenon's influencing variables and constructs (Babbie & Mouton, 2011).

A realism research philosophy attempts to differentiate the human mind from reality. This philosophy is based on the assumption that what is observable may not always be the reality, leading to the 'observation-theoretic' distinction. Maree (2019, 2020) argues that the classical positivist belief that reality can be understood by establishing numerical significances to complete research in social sciences, is flawed. Rather, through realism, specifically critical realism, scholars believe that the real world is accessed by means of theoretical interpretations, and what we believe to be true should always be tested against reality (Maree, 2020; Sayer, 2010). Realism thus holds both quantitative and qualitative approaches as valid scientific methods. Furthermore, by applying a critical realism approach, the researcher is able to employ a multi-layered investigation that explores interrelationships between different stakeholders.

The Interpretivism philosophy is underpinned by two main constructs; observation and interpretation. Thus, to observe is to collect information about events, while to interpret is to make meaning of that information by drawing inferences or by judging the match between the information and some abstract pattern (Aikenhead, 1997). Walsham (1993) argues that in the interpretive tradition there are no 'correct' or 'incorrect' theories. In addition, Reeves and Hedberg (2003) note that the "interpretive paradigm is concerned with understanding the world as it is from subjective experiences of individuals" (Reeves & Hedberg, 2003, p. 32). Furthermore, interpretivist methodologies use meaning (versus measurement) oriented methodologies, such as interviewing or participant observation that rely on a subjective relationship between the researcher and subjects. Thus, interpretive research does not predefine dependent and independent variables but focuses on the full complexity of human sense-making as the situation emerges (Kaplan & Maxwell, 1994).

While each of the aforementioned paradigms has its pros and cons and are best suited for specific types of research, this study quantitatively analysed the effect of the EOT programme as a cognitive enhancement tool for primary school children. Thus, the *realist research paradigm* was deemed best suited for this study. In addition, the study followed the common research processes as identified by Lincoln (2018) and Maree (2019) and aimed to avoid the positivism-quantification association of valid science usually prevalent in multi-layered studies.

3.3. Research approach

Saunders et al. (2016) define a research approach as consisting of plans and procedures that incorporate steps from broad assumptions to detailed methods of data collection, to analysis, and interpretation. Broadly, research can be categorised as being *quantitative, qualitative or mixed*. A quantitative research approach allows for the objective reality to be established and accurate readings to be interpreted to give a more conclusive understanding of what is studied (Saunders et al., 2016). In addition, the usage of statistical inference and frequency distributions to provide assertions, enhances the validation of findings and establishes generalisability of the research's findings in other similar settings thus, making the quantitative approach more viable in this study (Babbie & Mouton, 2011). A qualitative research approach is another approach applicable to research. Using this approach, the research takes a more subjective approach through the analysis of responses from open-ended questions.

However, in a study that evaluates the impact of exposure to an educational intervention through pre-and post-testing, a quantitative research approach is more suitable. This is because results are better validated and can be generalised when numerical interpretations with statistical backing is established (Steeger et al. 2016). Furthermore, it is said that bias is minimised (although not completely eliminated) significantly in quantitative research as compared to qualitative research (Babbie & Mouton, 2011). It should be noted that while a quantitative research approach is not faultless, it was found that it was better suited for this type of research.

3.4. Research design

A research design explains the systematic and logical steps that a researcher uses to gather the primary information for future analysis (Saunders, Lewis, & Thornhill, 2016). This involves the design of the data collection instrument, the identification of the target population, the sampling technique employed, and the manner of data analysis. It therefore serves as a blueprint for the research's empirical evidence and analysis (Creswell, 2012). This study employed an experimental research design during the collection and analysis of the data. The experimental research design comprises of two sets of variables, the independent (explanatory) variable and the dependent variable (Mitchell, 2015). Experimental designs seek to establish notable cause-and-effect relationships through establishing whether changes in one variable can result from the sole manipulation of the constant variable (Creswell, 2012). In this study, a pre-test and post-test scenario was developed whereby children's cognitive performances were measured before and after their exposure to the EOT programme. The research comprised of two experimental groups (also referred to as treatment groups) and a control group. The EOT group and the educational computer games group formed part of the treatment group, while the control group included students who continued with normal schooling. The processes employed are further highlighted in section 3.6 below.

3.5. Sampling procedures

A convenience sampling technique was utilised in the selection of children who participated in this study. The sample comprised of 64 children from a school in Pretoria. Due to logistic and practical reasons, grade 2 children whose parents accepted the invitation to participate in the research study, were chosen.

The engagement process with children lasted for 3 weeks, with an average of 28 hours spent on both the EOT programme (group 1) and the educational computer games (group 2). It should be noted that while a convenience sampling method was utilised in selecting participants, the children were however randomly allocated to the 3 groups- two treatment groups (group 1 and 2) and a control group (group 3).

3.6. Treatment procedures

Before treatment, all participants took part in a series of pre-tests that aimed to collect baseline scores. Thereafter, the participants were separated into the 3 groups where the different treatment procedures were followed:

Group 1 (n = 22) was exposed to the EOT learning programme at school every morning for 2 and ½ hours and thereafter continued with their usual school syllabus for the remainder of the day. This was the primary treatment group for the study. Treatment was administered using the recommended exposure process for the EOT, including the use of periodic feedback to learners and parents.

Group 2 (n = 21) had access to educational computer games at school every morning for 2 and ½ hours and thereafter continued with their usual school syllabus for the remainder of the day. These games were developed by PopCap Games and included child-friendly and easy-to-learn games. This was the secondary treatment group and thus, they did not receive exposure to the EOT programme. Edublox opted to include this group as an active control group and for future research they wish to undertake regarding the impact of video games on cognitive functioning in children.

Group 3 (n= 21), the control group, continued with their usual day to day school work in the form of grade-appropriate Curriculum and Assessment Policy Statement (CAPS) aligned syllabus covering aspects such as literacy, numeracy, and life skills.

*It should be noted, that due to ethical reasons, group 2 and 3 also received exposure to the EOT programme after the experiment.

3.7. Data Collection procedures

According to Campbell and Stanley (2015), a pre-test is important for the measurement of development. Without conducting a pre-test, a measurement of development cannot be determined. Shadish, Cook and Campbell (2002) note that pre-and post-testing allows for the testing of equality in treatment and control groups on the dependent variable, unlike simply administering treatment to a group and measuring changes. Without a pre-and post-test, it would be difficult to measure development (if any) as a result of the EOT programme, and conclusions may not be valid (Mitchell, 2015). A pre-post-test design thus increased reliability in terms of the aim and objective of this study, which was to determine the effectiveness of the EOT programme on the cognitive functioning of children. Edublox, under the supervision of Mrs. Susan Du Plessis from Edublox, as well as the Headmaster and an appointed teaching assistant, proceeded by conducting the pre and post-testing. The inclusion of the aforementioned team was to ensure that the testing and intervention took place correctly. Moreover, it should be noted that this is a retrospective study and is based on data supplied by Edublox. Thus, the author of this research was not directly involved in the data collection process.

A pre-post-test experimental design was thus chosen by Edublox and included the following procedure: The pre-test was conducted at the beginning of the intervention – on a Monday morning, and the post-test was conducted at the end of the 3 weeks, on Friday (the last day). The following tests were utilised for the pre-post-test design:

- Classroom Behaviour Observation Checklist
- Senior South African Individual Scale-Revised (SSAIS-R), conducted by an accredited, independent educational psychologist
- Test of Auditory Processing Skills (TAPS-3), conducted by two independent registered speech therapists
- The Edublox cognitive assessments, conducted by an Edublox tutor and accompanied by a teacher from the school

The study comprised of 64 grade 2 children whose parents consented for them to partake in the research. In addition, the children were informed about the research process by the Principal of the school. Thus, Edublox attained both parental consent and child assent.

At the beginning of the Edublox intervention, all participants received a basic training programme on how to use the desktop computers. Thereafter, they completed the cognitive assessment, to achieve baseline test results (pre-testing).

One-third of the participants (n = 22) were allocated to the Edublox Online Programme group (group 1); another third of the participants (n = 21) was allocated to the educational computer games programme group (group 2) and a third (n = 21) acted as the control group (group 3). The research process that was followed by Edublox is summarised in Figure 1 in the form of a timeline.

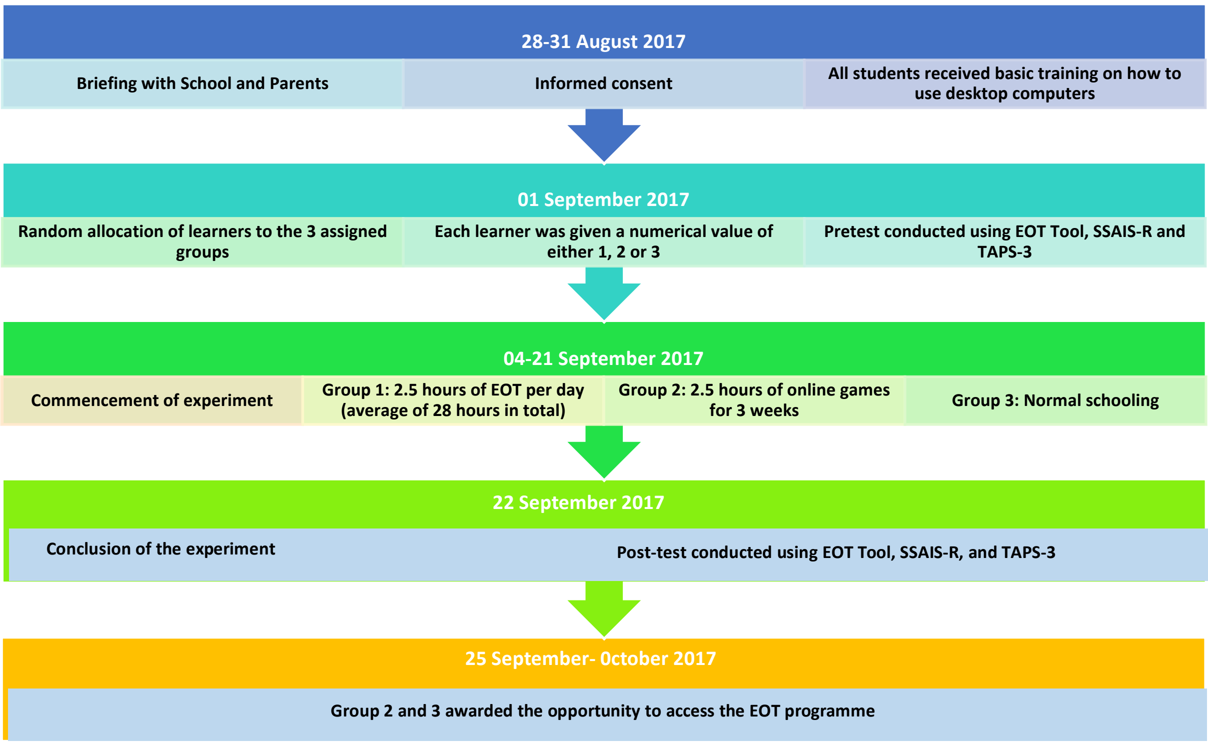

Figure 3: Research process followed by Edublox

3.8. Measurement Instruments

Four tools, namely, *Classroom Behaviour Observation Checklist*, The Senior South *African Individual Scale-Revised (SSAIS-R)*, *The Test of Auditory Processing (TAPS)* and the *Edublox cognitive assessments* were utilised in the measurement and determination on the effect of the EOT programme on the cognitive functioning of the children. These measurement instruments formed the backdrop of pre-testing and post-testing as guided the data analysis process in this study.

3.8.1. Classroom Behaviour Observation Checklist

The instrument consists of several classroom behaviours ranging from cognitive to emotional and behavioural problems. The purpose is for teachers to screen pupils for further assessment. Language as one dimension is evaluated by 8 scores of which four were used, namely, reading, speaking, spelling and writing. The purpose for this study was to determine whether improvements in conceptual skills related to language can be assessed by means of teacher observation.

3.8.2. The Senior South African Individual Scale-Revised (SSAIS-R)

According to Van Eeden (1991), the SSAIS-R is an individual intelligence test that was designed to obtain a differential profile of cognitive abilities for English and Afrikaans speaking South African children who were around 7 years. The SSAIS-R measures working memory, processing speed, and auditory memory using 11 subtests which are used to construct the Verbal, Nonverbal, and full-scale scores. Verbal Tests comprise of the following subtests: *Vocabulary, Comprehension, Similarities, Number Problems, Story Memory* and *Memory for Digits.* Non-verbal subtests include *Pattern Completion, Block Designs, Missing Parts, Form Board* and *Coding*.

The skills measured by the different tests include learning ability, general knowledge, judgement, concentration, spatial perception, basic perceptual and concept-forming abilities, and visual-motor skills. In addition, an indication of global intelligence can also be obtained with a reduced form of the scale (consisting of the following subtests: Similarities, Number Problems, Block Designs, and Missing Parts). The predictive validity of the SSAIS-R showed correlations ranging from 0.04 to 0.51 (for the non-verbal scale) and from 0.20 to 0.63 (for the verbal scale) (Foxcroft & Roodt, 2005; Gregory, 1999; Van Eeden, 1991). The following subtests and scales from the SSAIS-R were utilised in the study:

- **SSAIS_S1_Story Memory:** This particular test includes a set of 20 arithmetic problems comprised of 11 verbal and 9 written problems. The purpose of this particular test is to evaluate numerical reasoning, logical thinking, and long and short-term memory and attention.

- **SSAIS_S1_Number Memory:** This particular test contains 43 facts used to assess short-term memory skills, auditory information, verbal learning, and attention.

- **SSAIS_S1_Coding:** This test comprises of digits from 1-9, supported by symbols at the top of the page. A time limit of 120 minutes is given to complete the random array of 91 digits. The fundamental purpose and characteristics of this test are that it is specifically designed to test visual associative learning, visual-motor integration, coordination, and as well as to determine attention (Cockcroft, 2013).

3.8.3. Test of Auditory Processing (TAPS)

The Test of Auditory Processing Skills-Third Edition (TAPS-3) was developed based on a fairly simple definition of auditory processing - "what we do with what we hear" (Katz, Stecker & Henderson, 1992, p. 210). The TAPS-3 has nine subtests, designed to provide the types of information necessary to assess the processing of auditory information that pertains to the cognitive and communicative aspects of language (Martin & Brownwell, 2005:9). The nine subtests are broken down into 3 broad index areas: *(i) phonological skills, (ii) auditory memory, and (iii) auditory cohesion*. The test-retest reliability of the TAPS-3 was reported to be high, with coefficients ranging from 0.72 to 0.96. In addition, the Cronbach's coefficient alpha and Spearman-Brown coefficients ranged from 0.49 to 0.96 for individual subtests (Martin & Brownwell, 2005).

3.8.4. Edublox cognitive assessments

The Edublox cognitive assessment is an informal online assessment that tests visual sequential memory, auditory memory, eye span, and logical thinking. This was conducted under the supervision of the Edublox classroom tutors and was used as a supportive assessment in the study. Outlined in Table 1, are the descriptions of each of the 4 elements of the EOT assessment. The assessment, which was formulated for children between the ages of 6-12 years old, enables both parents and teachers to assess children’s cognitive skills (Edublox, 2018). Before any subtest from this assessment is completed, a video guiding the child on how to complete the test, as well as a trial run is included. Thereafter, the child's scores were produced in the form of a report. According to Edublox, this assessment allows for their learning and tutoring programmes to be tailor-made to suit their learners and clients in the future (Edublox, 2018).

Table 1: Descriptions of EOT sub-tests

Sub-test	Number of items	Description
Visual sequential	n/a	This is a timed exercise consisting of nine rounds. A sequence of colours is displayed, with more colours added each time a student gets an answer correct in identifying the colour.
Auditory memory	9	Starting with two, 4 directions (left, right, up, and down) are called out and the student must show these directions in the same order they are called. After two consecutive mistakes, the test is discontinued.
Eye-span	9	A sequence of coloured blocks is flashed, and the student is asked to identify them. Rehearsal is not allowed, and the test is discontinued after two consecutive mistakes.
Logical thinking	9	The student is asked to complete logical sequences, for example red, blue, green, white, black, yellow, red, blue, green…? The test is discontinued after two consecutive mistakes.

3.9. Data analysis

This study was based on data that was collected by Edublox, thus secondary data analysis was conducted. Following the concept of an experimental research design, the data in this study was analysed in a manner that showed pre-and post-test results for each variable. In addition, both descriptive and inferential statistical methods were used. Regarding descriptive statistics - means, standard deviations, and standard errors were used to analyse central tendencies and dispersions of the children's scores. Moreover, mean plots conducted as part of ANOVA tests were used to show the extent of differences in mean scores pre-and post-exposure to the Edublox programmes. Regarding statistical inferencing, two types of tests were conducted per variable in the attempt to explore the

significance of differences in mean scores post introduction of the Edublox programmes. A paired samples t-test was run on each of the variables for each of the 3 test groups. This was used to evaluate changes in mean scores per test (for example-reading test, writing test, spelling test) and per group, without bundling the 3 groups together.
Results of the paired samples t-test helped to explain which variable had mean scores that significantly changed between the pre-and post-test. Secondly, the strategy utilised for data analysis consisted of a mixed-design (Gliner *et al.,* 2003), which included a repeated measurement on one within-subjects factor, and a between-subjects factor (namely, the treatment groups), thus resulting in a 2 x 3 factorial design. For this study, a repeated-measures ANOVA and post hoc t-tests were used (Gliner *et al.,* 2003). The repeated measures ANOVA yields 3 F-values, namely one for each main effect (pre/post-test and groups), and one for the interaction between test and group. Since there were only two levels for the repeated measures, the requirement of sphericity for the repeated measures was assumed to be met. This was shown in the test results as 1 (Field, 2018, p. 863-864).

The factorial Anova yielded the main effect for the pre and post-test, and between groups. In addition, to pinpoint differences where a significant main effect was found, post hoc tests with a Bonferroni adjustment was conducted to show which groups differ significantly as well as whether pre and post-tests differ. For specific groups, t-tests for the related samples were conducted (Gliner *et al.,* 2003). Furthermore, instead of presenting results per sub-variable (for example, reading, writing, and speaking as parts of cognitive tests), the repeated measures ANOVA presented only the overall mean figure for each variable. This was conducted to minimise the total number of output tables that would make up the data analysis chapter, thus minimising the length of the dissertation. The overall mean was calculated by averaging scores per sub-variable for each of the 64 children who participated in the study.

The conclusions and inferences regarding the impact of the EOT programme on the cognitive functioning of children, were based on the aforementioned statistical techniques. Furthermore, the statistical output was obtained using the Statistical Package for the Social Sciences (SPSS) and the results will be presented in the next chapter.

3.10. Ethical Considerations

The use of human participants in research necessitates an emphasis on ethical considerations. Ethical considerations were maintained by Edublox throughout the research process as noted by Willig (2013), with focus on the key principles: *informed consent, voluntary participation, and confidentiality.*

This research study consisted primarily of children, and thus informed consent was obtained from each parent. A presentation outlining the research study was given to the parents and teachers at a meeting in September 2017. The research study was entirely voluntary, and parents were free to refuse participation of their children in the study or to withdraw their permission and discontinue participation at any time. Such refusal or discontinuance did not affect the child's regular schooling in any way. A signed copy of the consent form was made available to parents, and the child's respective teachers. In addition, the research process was also communicated to the children and child assent was attained before the commencement of this experiment. Furthermore, confidentiality and sensitivity were maintained throughout the course of the study, with a file number being allocated for every child that was eligible and willing to participate in the research study.

Moreover, the secondary data that was obtained from this research will be stored by Edublox, the researcher and the University, for 15 years - as in accordance with the regulations of the University of Pretoria.

Chapter summary

This chapter focused on discussing the research processes employed in the collection of the data, the engagement with the participants, and the analysis of data. The discussion on the research philosophy showed that a realist research paradigm was best suited for this study. Moreover, since this research was conducted in the area of psychological and educational intervention, a quantitative approach, specifically a pre-post-test experimental design was chosen. In order to assess the impact of the EOT programme, the following measurement tools were used: SSAIS-R, TAPS-3, and the Edublox cognitive assessment. Lastly, the data collected from the pre- and post-tests were analysed using descriptive and inferential statistical techniques, with statistical inferencing specifically providing insights into the significance of changes in mean scores after the Edublox intervention.

The next chapter presents the analysis of the statistical output, coupled with a discussion of the attained results.

CHAPTER 4:
RESULTS

"If the result confirms the hypotheses, you've made a discovery.
If the result is contrary to the hypotheses, you've made a discovery"

- *Enrico Fermi*

4.1. Introduction

The previous chapter presented a discussion of the research methodology and approach employed in this study- which included the sampling procedure, the data collection processes, data analysis methods, and the ethical considerations. This chapter presents the findings from the data that was collected by Edublox. The findings in this chapter are grouped into 4 major variables: *(i) cognitive functioning, (ii) auditory processing, (iii) working memory,* and *(iv) processing speed*. In addition, for the purpose of this study, the aforementioned variables are grouped into a single construct called "conceptual skills". Each variable includes descriptive statistics such as mean plots and inferential analysis (paired samples t-tests) of significant changes in scores for both pre and post-tests. Furthermore, inferential analyses were conducted (ANOVA tests) to establish significant differences among the 3 groups; *group 1: EOT programme, group 2: educational computer games, and group 3: control group*.

The demographic characteristics of the participants will be discussed in the next section.

4.2. Demographic characteristics of participants

This subsection presents the demographic distribution of participants in this study. The study comprised a total of 64 (n=64) grade 2 children who were divided into 3 groups; group 1: EOT programme, group 2: educational computer games, and group 3: Control group. The children varied in gender, age, and terms of academic performance as seen in Table 2.

Table 2: Demographic Characteristics of Children

Characteristics	Group 1 EOT Programme		Group 2 Educational Games		Group 3 Control		Total	
	n=22	(%)	n=21	(%)	n=21	(%)	n=64	(%)
Age (years)								
7 years	2	9.1%	4	19.0%	4	19.0%	10	15.6%
8 years	15	68.2%	12	57.1%	12	57.1%	39	60.9%
9 years	5	22.7%	5	23.8%	5	23.8%	15	23.4%
Gender								
Male	9	40.9%	8	38.1%	8	38.1%	25	39.1%
Female	13	59.1%	13	61.9%	13	61.9%	39	60.9%
Total Academic Score								
14 – 18	10	45.5%	10	47.6%	10	47.6%	30	46.9%
19 – 23	7	31.8%	6	28.6%	7	33.3%	20	31.3%
24 – 28	5	22.7%	5	23.8%	4	19.0%	14	21.9%

Source: Edublox data

Group 1 (the EOT programme group) consisted of 22 participants while Group 2 (educational computer games group) and Group 3 (the control group) included 21 participants each. Regarding the age distribution, the majority of the participants were 8 years old (60.9%), while 23.4% of the children were 9 years old and 15.6% of the children were 7 years old. Regarding gender, it can be seen that the majority of the children were female (60.9%) while males (39.1%) made up less than half of the sample. The total academic score record shows that the highest proportion (46.9%) of all the participants had total academic scores between 14 – 18. In addition, the children were allocated more or less equally across the 3 groups based on their total academic scores, with each group having 10 children who attained 14-18 as their total academic score, and at least 4-5 children who attained lower academic scores of 24-28 points.

4.3. In-classroom conceptual and language performance

The main objective of this study was to examine the effectiveness of the EOT programme as a tool for cognitive enhancement. This subsection presents results on the analysis of the data about in-classroom observations of conceptual and language performance. Descriptive statistics as well as statistical inferencing will be outlined in this subsection.

4.3.1. Descriptive results on cognitive enhancement

To measure in-classroom conceptual and language performance, the children were observed by teachers on 4 variables which included: reading, writing, spelling, and speaking. These observations were conducted twice - before the EOT programme (pre-test) and after the EOT programme (post-test). Group 1 was given access to the EOT programme, while group 2 was exposed to the educational computer games and group 3, was the control group, and thus did not receive any intervention by Edublox. Table 3 depicts the children's scores for each test in terms of the mean, standard deviation, and the standard error of the mean.

Table 3: Descriptive analysis of cognitive enhancement of EOT programme

		N	Mean	Std. Deviation	Std. Error
Pre-Reading	G1: EOT programme	22	3.18	0.853	0.182
	G2: Educational games	21	3.29	0.902	0.197
	G3: Control group	21	3.19	0.873	0.190
	Total	64	3.22	0.863	0.108
Post-Reading	G1: EOT programme	22	3.09	1.065	0.227
	G2: Educational games	21	3.19	0.873	0.190
	G3: Control group	21	3.29	0.956	0.209
	Total	64	3.19	0.957	0.120
Pre-Writing	G1: EOT programme	22	3.18	0.958	0.204
	G2: Educational games	21	3.29	1.146	0.250
	G3: Control group	21	3.10	0.700	0.153
	Total	64	3.19	0.941	0.118
Post-Writing	G1: EOT programme	22	3.09	0.971	0.207
	G2: Educational games	21	3.00	0.894	0.195
	G3: Control group	21	3.05	0.740	0.161
	Total	64	3.05	0.862	0.108
Pre-Spelling	G1: EOT programme	22	4.09	1.065	0.227
	G2: Educational games	21	3.71	1.309	0.286
	G3: Control group	21	3.81	0.814	0.178
	Total	64	3.88	1.076	0.135
Post-Spelling	G1: EOT programme	22	3.41	0.908	0.194
	G2: Educational games	21	3.48	0.981	0.214
	G3: Control group	21	3.33	0.966	0.211
	Total	64	3.41	0.938	0.117
Pre-Speaking	G1: EOT programme	22	3.32	0.646	0.138
	G2: Educational games	21	3.48	1.078	0.235

		N	Mean	Std. Deviation	Std. Error
	G3: Control group	21	3.33	0.796	0.174
	Total	64	3.38	0.845	0.106
Post-Speaking	G1: EOT programme	22	3.36	0.790	0.168
	G2: Educational games	21	3.38	0.740	0.161
	G3: Control group	21	3.52	0.680	0.148
	Total	64	3.42	0.730	0.091
Overall scores	Pre-test scores	64	3.42	0.795	0.099
	Post-test scores	64	3.27	0.785	0.098

Source: Edublox data (2017)

Mean scores for group 1:

The mean score for reading and writing was 3.18 pre-test versus the 3.09 post-test score, while for spelling it was 4.09 pre-test versus the 3.41 post-test score. Regarding speaking, the mean was 3.32 pre-test versus the 3.36 post-test score. From the above, it can be seen that group 1 experienced an increase in the mean score on speaking, but experienced declines in reading, writing, and spelling.

Mean scores for group 2:

The mean score for reading was 3.29 pre-test versus the 3.19 post-test score, while for writing it was 3.29 pre-test versus the 3.00 post-test score. Regarding spelling, a mean score of 3.71 pre-test versus a 3.48 post-test score can be seen. With regards to speaking, a 3.48 pre-test score versus a 3.38 post-test score was obtained. From the above, it is evident that there were declines in mean performances for all tests in this group.

Mean scores for group 3:

The mean score for reading was 3.19 pre-test versus the 3.29 post-test, while for writing it was 3.10 pre-test versus the 3.05 post-test. For the spelling test, a pre-test score of 3.81 was obtained, with a post-test score of 3.33. Regarding the speaking section, the mean was 3.33 pre-test versus the 3.52 post-test score. Thus, the control group experienced an increase in the mean scores in reading and speaking, but experienced declines in writing and spelling.

Thus, the overall mean cognitive scores for the entire sample were 3.42 for the pre-test (with a standard deviation of 0.795 and standard error of 0.099) and 3.27 for the post-test (with a standard deviation of 0.785 and standard error of 0.098), thus showing a decrease. The overall mean cognitive processing score was calculated by adding all scores per child and dividing that total score by the number of sub-variables (which in this case, is 4 sub-variables). The same formula was applied in the calculation of overall mean scores for auditory processing, working memory, and processing speed.

4.3.2. Analysis of the significance of change in cognitive abilities

Two types of statistical tests were conducted to analyse the significance of changes in children's cognitive abilities post-exposure to the EOT programme.

The first test, a paired samples t-test measured the significance of changes in scores for each of the 3 groups while the second test, a repeated-measures ANOVA test, grouped the 3 groups together to evaluate whether there were significant differences in changes in cognitive scores. Table 4 displays the results of the paired samples t-tests conducted at the 95% confidence level.

Table 4: Significance in the changes in mean cognitive scores pre and post-testing

		Test value	d.f.	Significance value
Reading scores	G1: EOT programme	0.624	21	0.540
	G2: Educational games	0.810	20	0.428
	G3: Control group	-0.698	20	0.493
Writing scores	G1: EOT programme	0.699	21	0.492
	G2: Educational games	2.335	20	0.030*
	G3: Control group	0.370	20	0.715
Spelling scores	G1: EOT programme	3.215	21	0.004**
	G2: Educational games	1.420	20	0.171
	G3: Control group	2.911	20	0.009**
Speaking scores	G1: EOT programme	-0.439	21	0.665
	G2: Educational games	0.462	20	0.649
	G3: Control group	-1.706	20	0.104
Overall scores	Overall scores	2.896	63	0.005**

Source: Edublox data

* $p < 0.05$; ** $p < 0.01$

As depicted in Table 4, the tests conducted in relation to group 1 rejected the null hypothesis in 1 out of 4 tests (spelling test) but failed to reject the null hypothesis in 3 tests (reading, writing, and speaking). On the other hand, tests for group 2 rejected the null hypothesis in 1 test (writing) but failed to reject the null hypothesis in reading, spelling, and speaking. This shows that for the most part, participation in the Edublox educational games did not have a significant effect on in-classroom teacher observations of conceptual and language performance. Lastly, tests for group 3 rejected the null hypothesis in one test (spelling) but failed to reject the null hypothesis in reading, writing, and speaking.

With no educational intervention given to children in the control group, significant changes in spelling scores might suggest that there are other factors outside the scope of study that possibly led to improvements in the post-test. Lastly, overall scores show that there were significant changes in the children's scores between pre-and post-test scores.

The effect of the Edublox programmes was further investigated using a one-way repeated measures Factorial ANOVA, and the results of the test are presented in Tables 5, 6, and 7. With only two levels for the repeated measures, the requirement of sphericity for the repeated measures was assumed to be met (Field, 2018, p.863-864). In addition, Table 5 presents the results of an analysis of within-subjects effects for both pre-post samples and the 3-group classification (Group 1 = Edublox Online, Group 2 = Educational games, and Group 3 = Control Group) for cognitive scores.

Table 5: Tests for within-subjects effects for overall changes in cognitive performance

Source		Type III Sum of Squares	Df	Mean Square	F	Sig.
pre-post	Sphericity Assumed	0.696	1	0.696	8.219	0.006**
pre-post * Group	Sphericity Assumed	0.127	2	0.064	0.751	0.476
Error (pre-post)	Sphericity Assumed	5.168	61	0.085		

Source: Edublox data (2017)

* $p < 0.05$

The first part of the test evaluated the significance of changes in means for the entire sample between the pre-and post-test. With the assumption of sphericity not violated, the figures interpreted were in the 'sphericity assumed' row. Results of the test showed that there were significant changes in mean cognitive scores for the children between their pre- and post-tests, F(1, 61) = 8.219, p = 0.006. The second part of the test measured whether the changes in mean cognitive scores were significant among the 3 distinct groups. Results of the test showed that the changes in pre-and post-test scores were not significantly different between groups 1 to 3, F(1, 61) = 0.751, p = 0.476.

Table 6 presents the between-subject effect results also conducted as part of the repeated measures test.

Table 6: Between-subjects effects on changes in cognitive performance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1427.082	1	1427.082	1187.130	0.000**	0.951
Group	0.012	2	0.006	0.005	0.995	0.000
Error	73.330	61	1.202			

Source: Edublox data (2017)

* *p < 0.05*

As depicted in Table 6, results of the between-subjects effect assessments confirmed results of the within-subjects effects which showed that there were no significant differences in mean changes between groups 1, 2, and 3, F (2, 61) = 0.005, p = 0.995. Furthermore, Table 7 presents the results of post-hoc assessments (Bonferroni adjustment for multiple comparisons) conducted to establish where the changes in mean scores occurred.

Table 7: Post-hoc pairwise comparisons for cognitive performance scores

(I) Name of group	(J) Name of group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower	Upper
Between subjects						
Edublox online	Educational games	-0.010	0.237	1.000	-0.593	0.572
	Control group	0.014	0.237	1.000	-0.569	0.596
Educational games	Edublox online	0.010	0.237	1.000	-0.572	0.593
	Control group	0.024	0.239	1.000	-0.565	0.613
	Edublox online	-0.014	0.237	1.000	-0.596	0.569

Control group	Educational games	-0.024	0.239	1.000	-0.613	0.565
Within subjects						
pre-test	post-test	0.148^{*}	0.051	0.006	0.045	0.250
post-test	pre-test	-0.148^{*}	0.051	0.006	-0.250	-0.045

Source: Edublox data (2017)

* *$p < 0.05$*

Since the test results presented in Table 5 showed that within-subjects differences were not significant, there was no need to explore the Bonferroni adjusted scores. However, the Bonferroni adjustment for the between-subjects effects revealed that there were significant differences (p = 0.006) between pre-test and post-test cognitive scores for the entire sample (± 0.148).

Overall, Figure 4 provides a graphical representation of mean plots showing in-classroom teacher observations of conceptual and language performance of children on both pre-and post-tests, once all results from reading, writing, spelling, and speaking were consolidated.

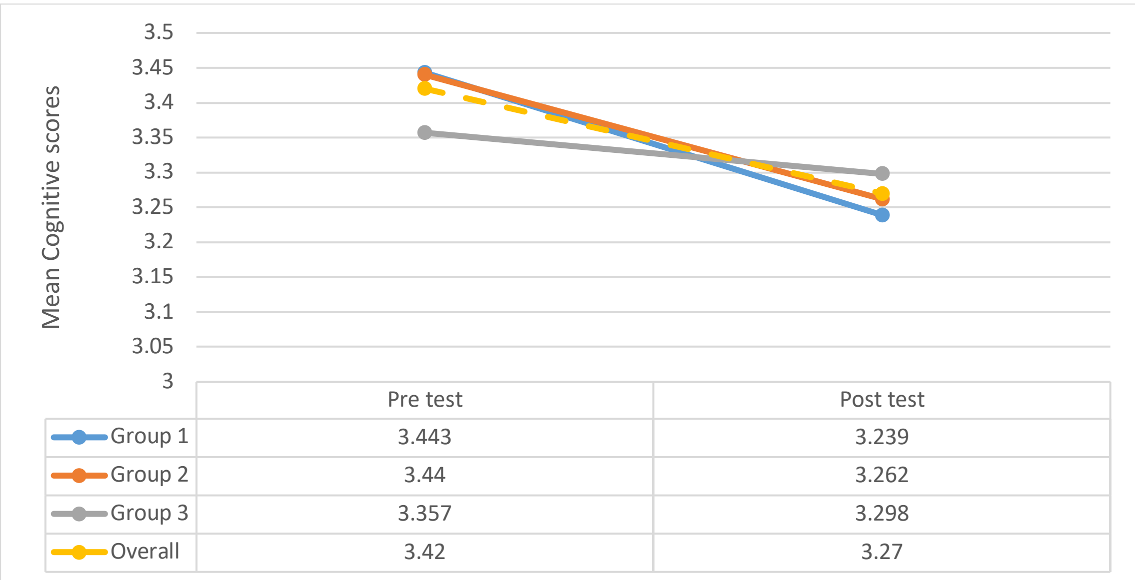

Figure 4: Means plot for children's cognitive performances

As depicted in Figure 4, the mean performance for group 1 was 3.44 pre-test and 3.24 post-test, while for group 2 it was 3.44 pre-test versus 3.26 post-test. Group 3 had a mean of 3.36 pre-test and 3.30 post-test. Results show that there was a decline in the mean performances for all groups, with group 1 registering the greatest decline and group 3 registering the smallest decline. While the evidence of mean plotting appears to suggest that the EOT programme led to a decline in cognitive performance of children who participated in this study, results of the repeated measures ANOVA tests showed that these changes were not significant. The test results, therefore, failed to reject the null hypothesis. It can hence be concluded at the 95% confidence level that while mean in-classroom teacher observations of conceptual and language performance changed significantly between the pre-and post-tests, exposure to the EOT and educational computer games did not significantly improve children's in-classroom behaviour.

4.4. Auditory processing tests

Similar to the analysis of the results from the above cognitive assessments, results for the auditory tests were grouped into descriptive and inferential statistics. This subsection presents the results of the children's performance in auditory tests which included numbers, words, and sentences.

4.4.1. Descriptive statistics on auditory processing

Table 8 displays the mean scores, standard deviations, and standard errors for the 3 auditory tests undertaken by the children.

Table 8: Descriptive analysis of auditory enhancement of EOT programme

Test	Group	N	Mean	Std. Deviation	Std. Error
Test1 Numbers Pre-test	G1: EOT programme	22	15.14	3.091	0.655
	G2: Educational games	21	15.14	3.119	0.684
	G3: Control group	21	16.33	3.425	0.747
	Total	64	15.53	3.212	0.401
Test1 Numbers Post-test	G1: EOT programme	22	16.91	3.531	0.773
	G2: Educational games	21	15.29	3.408	0.735
	G3: Control group	21	15.43	3.310	0.722
	Total	64	15.89	3.446	0.431
Test2 Words Pre-test	G1: EOT programme	22	15.50	3.488	0.744
	G2: Educational games	21	15.24	3.208	0.701
	G3: Control group	21	15.14	2.851	0.622
	Total	64	15.30	3.151	0.394
Test2 Words Post-test	G1: EOT programme	22	17.14	2.965	0.619
	G2: Educational games	21	15.67	2.887	0.663
	G3: Control group	21	16.24	3.145	0.686
	Total	64	16.36	3.015	0.377
	G1: EOT programme	22	16.77	2.487	0.469

Test	Group	N	Mean	Std. Deviation	Std. Error
Test3 Sentences Pre-test	G2: Educational games	21	16.76	3.145	0.729
	G3: Control group	21	17.19	2.015	0.440
	Total	64	16.91	2.556	0.319
Test3 Sentences Post-test	G1: EOT programme	22	18.23	2.759	0.588
	G2: Educational games	21	16.71	2.171	0.474
	G3: Control group	21	17.52	2.502	0.546
	Total	64	17.50	2.532	0.317
Overall auditory scores	Pre-test scores	64	15.91	2.392	0.299
	Post-test scores	64	16.58	2.539	0.318

Source: Edublox data (2017)

Mean scores for group 1:

The mean score for the number assessment was 15.14 pre-test versus the 16.91 post-test, while for the word assessment, the mean score was 15.50 pre-test versus the 17.14 post-test. The mean score for the sentence part of the assessment was 16.77 pre-test and 18.23 post-test. Thus, an increase was seen in the mean auditory scores in all 3 of the aforementioned assessments conducted.

Mean scores for group 2:

The mean score for the number assessment was 15.14 pre-test versus the 15.29 post-test, while for the word assessment, the mean score was 15.24 pre-test versus the 15.67 post-test. The mean score for the sentence part of the assessment was 16.76 pre-test and 16.71 post-test. Thus, there were increases in mean auditory scores for the number and word assessments, but a decrease in mean scores for the sentence part of the assessment.

Mean scores for group 3:

The mean scores for the number assessment were 16.33 pre-test versus the 15.43 post-test, while for the word assessment, the mean score was 15.14 pre-test versus the 16.24 post-test. The mean score for the sentence part of the assessment was 17.19 pre-test and 17.52 post-test. Thus, this group experienced an increase in the mean scores for the word and sentence assessments but experienced a decline in mean scores for the number assessment.

The overall mean auditory scores for the entire sample were 15.91 for the pre-test (with a standard deviation of 2.392 and standard error of 0.299) and 16.58 for the post-test (with a standard deviation of 2.539 and standard error of 0.318), thus showing an increase. The next subsection makes reference to the extent of significance in the overall increase for auditory processing.

4.4.2. Analysis of the significance of change in auditory processing

To test for significant changes in mean auditory scores, a paired samples t-test and a repeated measures Factorial ANOVA were conducted. The results of the paired samples t-test are presented in Table 9.

Table 9: Significant changes in mean auditory scores pre and post-testing

		Test value	d.f.	Significance value
Numbers scores	G1: EOT programme	-3.318	21	0.003**
	G2: Educational games	-0.359	20	0.723
	G3: Control group	1.979	20	0.062
Words scores	G1: EOT programme	-2.537	21	0.019**
	G2: Educational games	-1.523	20	0.143
	G3: Control group	-1.449	20	0.163
Sentences scores	G1:EOT programme	-2.663	21	0.015*
	G2: Educational games	0.526	20	0.605
	G3: Control group	-0.770	20	0.450
Overall scores	Overall scores	-3.871	63	0.000**

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

As shown in Table 9, the results for group 1 reject the null hypothesis in all of the tests (numbers, words, sentences). Thus, this leads to the conclusion that children's exposure to the EOT programme significantly leads to improvements in their auditory scores. However, the results of group 2 failed to reject the null hypothesis in all of the above tests, thus suggesting that the exposure to the educational games does not lead to a significant improvement in auditory scores. Similarly, tests conducted on the control group all failed to reject the null hypothesis at the 95% confidence level, thus suggesting that there were no significant improvements in children's pre and post auditory scores in the control group. Overall scores however suggested that changes in auditory scores were significant at the 99% confidence level. This suggests that, by pairing the pre-and post-test samples, evidence showed significant increases in children's levels of auditory processing.

In addition to the paired samples t-test, a repeated measures Factorial ANOVA test was conducted to analyse group differences in pre-and post-test scores which are presented in Tables 10, 11, and 12. Similar to results on cognitive performance scores, the significance value for Mauchly's Test of Sphericity could not be calculated with only two samples (pre-test and post-test). Table 10, thus presents the results of within-subjects effects for changes in auditory scores. With the sphericity assumption not violated, the 'sphericity assumed' row was used in interpreting the findings for this study.

Table 10: Tests for within-subjects effects for changes in auditory scores

Source		Type III Sum of Squares	Df	Mean Square	F	Sig.
pre-post	Sphericity Assumed	13.798	1	13.798	18.452	0.000**
pre-post * Group	Sphericity Assumed	15.107	2	7.553	10.101	0.000**
Error (pre-post)	Sphericity Assumed	45.615	61	0.748		

Source: Edublox data (2017)

* *p* < 0.05; ** *p* < 0.01

Results in Table 10 show that mean auditory scores significantly changed between the pre-test and post-test for the entire sample, F(1, 61) = 18.452, p = 0.000. However, results on the interaction of pre-and post-tests and the 3 groups show that changes in mean scores between pre-and post-tests were significantly different between Group 1, 2, and 3, F(2, 61) = 10.101, p = 0.000. In addition, Table 11 presents further ANOVA analysis for the between-subjects effects.

Table 11: Between-subjects effects on changes in auditory scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	33748.759	1	33748.759	2975.779	0.000**
Group	14.411	2	7.206	0.635	0.533
Error	699.519	61	11.468		

Source: Edublox data (2017)

* *p* < 0.05; ** *p* < 0.01

Results in Table 11 suggest that changes in mean scores were not significantly different between groups F(2, 61) = 0.635, p = 0.533. This may suggest that while differences exist between groups, the effect size was relatively small. To establish the exact changes in scores between groups, a Bonferroni post-hoc adjustment was conducted, and the results of pairwise comparisons are presented in Table 12.

Table 12: Post-hoc pairwise comparisons for auditory scores

(I) Name of group	(J) Name of group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower	Upper
Between subjects						
Edublox online	Educational games	0.812	0.726	0.804	-0.976	2.601
	Control group	0.304	0.726	1.000	-1.484	2.093
Educational games	Edublox online	-0.812	0.726	0.804	-2.601	0.976
	Control group	-0.508	0.735	1.000	-2.317	1.301
Control group	Edublox online	-0.304	0.726	1.000	-2.093	1.484
	Educational games	0.508	0.735	1.000	-1.301	2.317
Within subjects						
pre-test	post-test	-0.656*	0.150	0.000**	-0.855	-0.351
post-test	pre-test	0.656*	0.150	0.000**	0.355	0.957

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

As depicted in Table 12, the post-hoc tests revealed that the effect sizes of between-groups auditory scores were not large enough to reject the null hypothesis ($p > 0.05$). Furthermore, assessments of within-subjects effects showed that there were significant changes in mean scores (± 0.656) between the pre-and post-test ($p < 0.001$), thus confirming what was found with the t-tests above. Figure 5 graphically outlines the results of the mean plot on auditory scores of children pre and post-test, once all results from the numbers, words, and sentence assessments were consolidated.

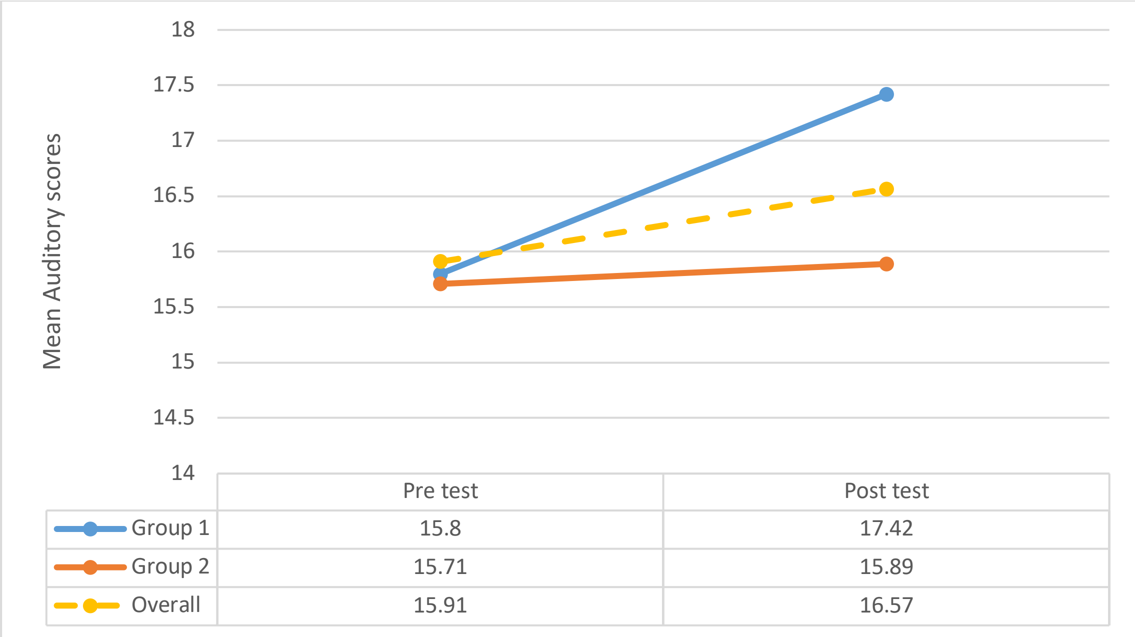

Figure 5: Means plots for the children's auditory scores

As outlined in Figure 5, the mean auditory score for group 1 was 15.80 pre-test versus a mean score of 17.42 post-test, while for group 2, the mean was 15.71 pre-test and 15.89 post-test. Group 3 had a mean of 16.22 pre-test and 16.39 post-test. Thus, it is evident that there were increases in mean auditory scores for all groups with the largest increase in group 1, followed by group 3 and group 2 respectively. A repeated-measures ANOVA test, however, showed that while the changes were significant between the pre-and post-test, they were not significant within the 3 groups. With the Bonferroni adjustment, test results hence failed to reject the null hypothesis. It can therefore be concluded that exposure to the EOT and educational computer games programme did not lead to significant improvements in auditory scores among children.

4.5. Working memory assessments

The study also included an assessment of children's changes in working memory pre and post-exposure to the EOT programme. Working memory tests were divided into 4 distinct subtests: story memory, number memory forward, number memory reverse, and coding.

4.5.1. Descriptive statistics on working memory

Table 13 outlines the descriptive statistics for the 3 groups of children over the 4 separate tests meant to measure working memory changes pre and post-exposure to the Edublox intervention.

Table 13: Descriptive analysis of working memory changes

		N	Mean	Std. Deviation	Std. Error
Pre-Story memory	G1: EOT programme	22	10.91	6.309	1.258
	G2: Educational games	21	9.19	4.986	1.116
	G3: Control group	21	10.90	4.426	0.966
	Total	64	10.34	5.295	0.662
Post-Story memory	G1: EOT programme	22	13.36	7.512	1.495
	G2: Educational games	21	14.62	5.670	1.388
	G3: Control group	21	13.29	6.428	1.403
	Total	64	13.75	6.520	0.815
Pre-Number memory forward	G1: EOT programme	22	9.05	2.299	0.490
	G2: Educational games	21	8.90	2.022	0.442
	G3: Control group	21	9.38	2.291	0.500
	Total	64	9.11	2.183	0.273
Post-Number memory forward	G1: EOT programme	22	9.32	1.937	0.394
	G2: Educational games	21	9.05	2.012	0.459
	G3: Control group	21	9.33	2.869	0.626
	Total	64	9.23	2.273	0.284
Pre-Number memory reverse	G1: EOT programme	22	3.41	1.182	0.242
	G2: Educational games	21	2.86	1.526	0.344
	G3: Control group	21	3.38	1.830	0.399
	Total	64	3.22	1.527	0.191
Post-Number memory reverse	G1: EOT programme	22	3.50	1.102	0.233
	G2: Educational games	21	3.05	1.203	0.273
	G3: Control group	21	2.86	1.352	0.295
	Total	64	3.14	1.233	0.154
Pre-Coding	G1: EOT programme	22	32.82	9.163	1.893
	G2: Educational games	21	32.19	6.161	1.427
	G3: Control group	21	30.95	7.039	1.536
	Total	64	32.00	7.509	0.939
Post-Coding	G1: EOT programme	22	38.86	9.508	2.014
	G2: Educational games	21	40.52	8.629	1.901
	G3: Control group	21	35.90	7.077	1.544
	Total	64	38.44	8.563	1.070
Overall working memory scores	Pre-test scores	64	13.67	2.679	0.335
	Post-test scores	64	16.14	3.180	0.397

Source: Edublox data (2017)

Mean scores for group 1:

The mean score for story memory was 11.64 pre-test versus the 14.24 post-test score, while for the number memory forward subtest, the pre-test mean was 8.95 and the post-test mean was 9.23. For the number memory reverse subtest, a pre-test mean score of 3.36 and a post-test mean score of 3.56 was obtained. For the final subtest, coding, a mean score of 33.09 pre-test versus a mean score of 38.91 post-test can be seen. Thus, it can be deduced that this group experienced an increase in the mean scores on all tests conducted.

Mean scores for group 2:

The mean score for story memory was 8.43 pre-test versus the 13.67 post-test score, while for the number memory forward subtest, the pre-test mean was 9.00 and the post-test mean was 9.14. For the number memory reverse subtest, a pre-test mean score of 2.90 and a post-test mean score of 3.19 was obtained. For the final subtest, coding, a mean score of 31.90 pre-test versus a mean score of 40.48 post-test can be seen. Thus, it can be deduced that this group also experienced an increase in the mean scores on all tests conducted.

Mean scores for group 3:

The mean score for story memory was 10.90 pre-test versus the 13.29 post-test score, while for the number memory forward subtest, the pre-test mean was 9.38 and the post-test mean was 9.33. For the number memory reverse subtest, a pre-test mean score of 3.38 and a post-test mean score of 2.86 was obtained. For the final subtest, coding, a mean score of 30.95 pre-test versus a mean score of 35.90 post-test can be seen. Thus, this group experienced an increase in the mean working memory scores in story memory and coding, but experienced declines in number memory forward and number memory reverse scores.

The overall mean working memory scores for the entire sample were 13.67 for the pre-test (with a standard deviation of 2.679 and standard error of 0.335) and 16.14 for the post-test (with a standard deviation of 3.18 and standard error of 0.397), showing an increase. The next subsection makes reference to the extent of significance in the overall increase for working memory.

4.5.2. Analysis of the significance of changes in working memory

This subsection presents results of a paired samples t-test and a repeated measures Factorial ANOVA on the significance of changes in children's working memory post-exposure to the Edublox intervention. Table 14 shows the results of paired samples t-tests which are separated per group as well as for each of the 4 tests conducted with the overall score.

Table 14: Significance in the changes in mean working memory scores pre and post-testing

		Test value	d.f.	Significance value
Story memory scores	G1: EOT programme	-2.633	21	0.016*
	G2: Educational games	-6.242	20	0.000**
	G3: Control group	-2.707	20	0.014*
Number memory forward scores	G1: EOT programme	-0.563	21	0.579
	G2: Educational games	-0.389	20	0.701
	G3: Control group	0.137	20	0.893
Number memory reverse scores	G1:EOT programme	-2.665	21	0.011*
	G2: Educational games	-0.754	20	0.460
	G3: Control group	1.290	20	0.212
Coding scores	G1: EOT programme	-5.552	21	0.000**
	G2: Educational games	-8.216	20	0.000**
	G3: Control group	-4.748	20	0.000**
Overall scores	Overall scores	-11.764	63	0.000**

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

In Table 14, the results of tests conducted on group 1 rejected the null hypothesis in 3 out of 4 test scores, which were story memory, number memory reverse, and coding. Similarly, results for group 2 rejected the null hypothesis on story memory and coding while the null hypothesis could not be rejected on number memory forward and number memory reverse. These results could suggest that exposure to educational games tends to improve working memory scores. Lastly, similar to group 2, tests in group 3 rejected the null hypothesis on story memory and coding while the null hypothesis could not be rejected on number memory forward and number memory reverse test scores. This suggests that there were also significant improvements in some of the children's cognitive scores even though they were exposed to neither the EOT programme nor the educational games.

Thus, the overall score showed significant improvement in working memory at the 99% confidence level.

Tables 15, 16, and 17 present results of further analysis on the changes in children's working memory, with regards to the significance of differences using a repeated measures Factorial ANOVA. Similar to cognitive and auditory performance results, the significance value for Mauchly's Test of Sphericity could not be calculated, and sphericity was assumed.

Table 15: Tests for within-subjects effects for changes in working memory

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
pre-post	Sphericity Assumed	196.200	1	196.200	170.199	0.000**
pre-post * Group	Sphericity Assumed	18.751	2	9.375	8.133	0.001**
Error (pre-post)	Sphericity Assumed	70.319	61	1.153		

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

In Table 15, results of changes in mean scores between the pre-and post-tests were significant, $F(1, 61) = 170.199$, $p = 0.000$. In addition, before post-hoc assessments, results in Table 15 show that changes in mean scores were significantly different within groups 1, 2, and 3. Moreover, Table 16 displays the further between-groups analysis of working memory changes.

Table 16: Between-subjects effects for changes in working memory

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Intercept	28404.924	1	28404.924	1750.268	0.000**
Group	10.458	2	5.229	0.322	0.726
Error	989.963	61	16.229		

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

As depicted in Table 16, the estimation of effect sizes suggests that there were no significant differences in mean working memory changes within the 3 groups, $F(2, 61) = 0.322$, $p = 0.726$. Furthermore, Table 17 explores these changes by presenting results of a Bonferroni adjustment on working memory changes.

Table 17: Post-hoc pairwise comparisons of results on working memory scores

(I) Name of group	(J) Name of group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower	Upper
Between subjects						
Edublox online	Educational games	0.106	0.869	1.000	-2.034	2.245
	Control group	0.653	0.869	1.000	-1.486	2.793
Educational games	Edublox online	-0.106	0.869	1.000	-2.245	1.034
	Control group	0.548	0.879	1.000	-1.617	2.712
Control group	Edublox online	-0.653	0.869	1.000	-2.793	1.486
	Educational games	-0.548	0.879	1.000	-2.712	1.617
Within subjects						
pre-test	pre-test	-2.477	0.188	0.000**	-2.854	-2.100
post-test	post-test	2.477	0.188	0.000**	2.100	2.854

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

The post-hoc tests in Table 17 revealed that the effect sizes of between-groups working memory differences were not large enough to reject the null hypothesis ($p > 0.01$). However, assessments of within-subjects effects showed that there were significant changes in mean scores (± 2.477) between the pre-and post-test ($p < 0.001$). Figure 6 presents results of a mean plot showing working memory scores of the pre and post-test scores, once all results from the 4 tests were consolidated.

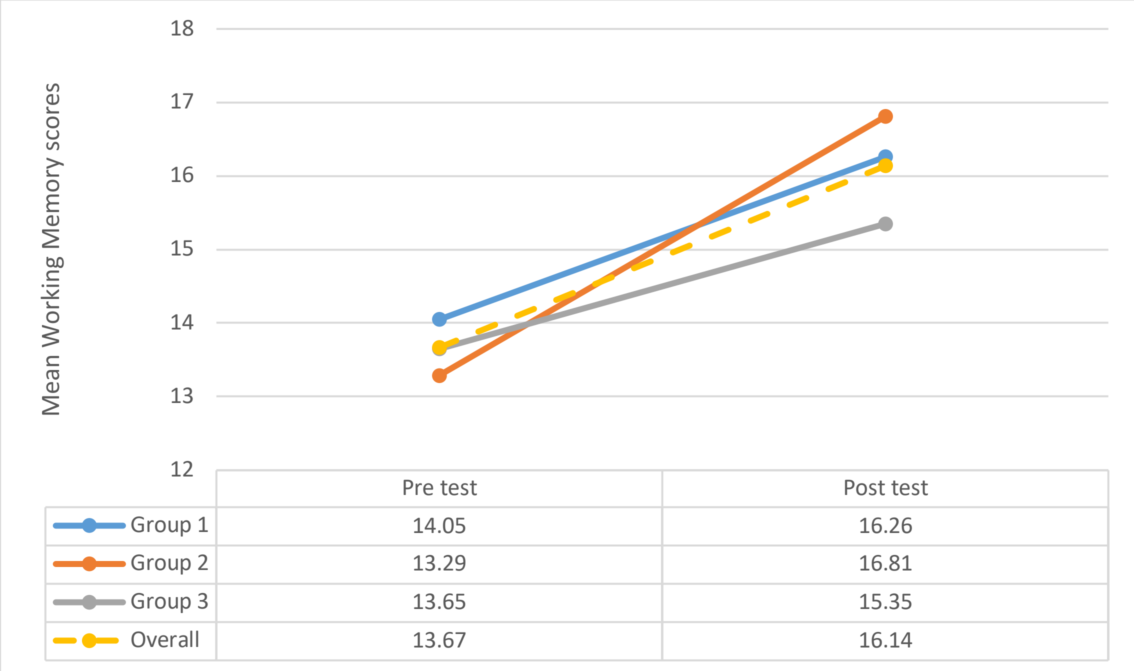

Figure 6: Mean plots for children's working memory tests

In Figure 6, the mean performance for group 1 was 14.05 pre-test versus a mean score of 16.26 post-test, while for group 2, the mean score was 13.29 pre-test and 16.81 post-test. Group 3 had a mean score of 13.65 pre-test and 15.35 post-test. There were recorded mean increases in working memory scores for all groups with the biggest increase in group 2, followed by group 1 and lastly, group 3. However, while there were significant increases in mean working memory scores between pre-and post-tests, post-hoc analysis of within-groups ANOVA failed to reject the null hypothesis. It can be concluded that exposure to the EOT and educational computer games programme did not lead to significant improvements in children's working memory.

4.6. Processing speed assessments

The last variable explored in this study was changes in children's processing speed post-exposure to the Edublox programmes. Processing speed was broken down into 4 distinct tests namely sequencing scores, auditory memory, eye span, and logical thinking score. This subsection presents the results of the descriptive and inferential analysis of changes in children's processing speed.

4.6.1. Descriptive statistics on children's processing speed

Table 18 presents descriptive results of children's processing speed scores based on the mean, standard deviation, and standard error of the mean.

Table 18: Descriptive analysis of processing speed

		N	Mean	Std. Deviation	Std. Error
Pre-Sequencing Score	G1: EOT programme	22	2.32	1.171	0.250
	G2: Educational games	21	2.38	1.161	0.253
	G3: Control group	21	2.43	0.978	0.213
	Total	64	2.38	1.091	0.136
Post-Sequencing Score	G1: EOT programme	22	6.05	2.126	0.453
	G2: Educational games	21	3.52	1.327	0.290
	G3: Control group	21	3.24	1.136	0.248
	Total	64	4.30	2.029	0.254
Pre-Auditory Memory Score	G1: EOT programme	22	1.55	0.963	0.205
	G2: Educational games	21	2.10	1.091	0.238
	G3: Control group	21	2.00	1.414	0.309
	Total	64	1.88	1.175	0.147
Post-Auditory Memory Score	G1: EOT programme	22	3.45	1.683	0.359
	G2: Educational games	21	2.76	1.261	0.275
	G3: Control group	21	2.95	.921	0.201
	Total	64	3.06	1.344	0.168
Pre-Eye Span Score	G1: EOT programme	22	1.77	0.922	0.197
	G2: Educational games	21	1.62	0.805	0.176
	G3: Control group	21	1.95	1.024	0.223
	Total	64	1.78	0.917	0.115
Post-Eye Span Score	G1: EOT programme	22	3.14	1.167	0.249
	G2: Educational games	21	2.29	1.189	0.260
	G3: Control group	21	2.38	1.024	0.223
	Total	64	2.61	1.177	0.147
Pre-Logical Thinking Score	G1: EOT programme	22	3.09	0.971	0.207
	G2: Educational games	21	2.81	0.602	0.131
	G3: Control group	21	3.33	0.856	0.187
	Total	64	3.08	0.841	0.105
Post-Logical Thinking Score	G1: EOT programme	22	4.86	1.490	0.318
	G2: Educational games	21	2.24	0.995	0.217
	G3: Control group	21	2.43	1.076	0.235
	Total	64	3.20	1.701	0.213
Overall processing speed scores	Pre-test scores	64	2.27	0.619	0.773
	Post-test scores	64	3.29	1.176	0.146

Mean scores for group 1:

The mean score for sequencing was 2.32 pre-test versus the 6.05 post-test score, while for the auditory memory subtest, the pre-test mean was 1.55 and the post-test mean was 3.45. For the eye-span subtest, a pre-test mean score of 1.77 and a post-test mean score of 3.14 was obtained. For the final subtest, logical thinking, a mean score of 3.09 pre-test versus a mean score of 4.86 post-test can be seen. Thus, this group experienced increases in the mean scores on all tests conducted.

Mean scores for group 2:

The mean score for sequencing was 2.38 pre-test versus the 3.52 post-test score, while for the auditory memory subtest, the pre-test mean was 2.10 and the post-test mean was 2.76. For the eye-span subtest, a pre-test mean score of 1.62 and a post-test mean score of 2.29 was obtained. For the final subtest, logical thinking, a mean score of 2.81 pre-test versus a mean score of 2.24 post-test can be seen. Thus, this group experienced increases in the mean scores on sequencing, auditory memory, and eye span, but experienced a decline in logical thinking scores.

Mean scores for group 3:

The mean score for sequencing was 2.43 pre-test versus the 3.24 post-test score, while for the auditory memory subtest, the pre-test mean was 2.00 and the post-test mean was 2.95. For the eye-span subtest, a pre-test mean score of 1.95 and a post-test mean score of 2.38 was obtained. For the final subtest, logical thinking, a mean score of 3.33 pre-test versus a mean score of 2.43 post-test can be seen. Similar to group 2, this group experienced increases in the mean scores on sequencing, auditory memory, and eye span, but experienced a decline in logical thinking scores.

The overall mean processing speed scores for the entire sample were 2.27 for the pre-test (with a standard deviation of 0.619 and standard error of 0.773) and 3.29 for the post-test (with a standard deviation of 1.176 and standard error of 0.146), showing an increase. The next subsection makes reference to the extent of significance in the overall increase in processing speed.

4.6.2. Analysis of significant changes in processing speed

This subsection presents results from a paired samples t-test and a repeated measures Factorial ANOVA which were conducted to assess the significant improvements in processing speed post-exposure to Edublox programmes.

Table 19: Significant changes in mean processing speed pre and post-testing

		Test value	d.f.	Significance value
Sequencing test scores	G1: EOT programme	-10.866	21	0.000**
	G2: Educational games	-4.382	20	0.000**
	G3: Control group	-2.968	20	0.008**
Auditory memory scores	G1: EOT programme	-6.062	21	0.000**
	G2: Educational games	-2.467	20	0.023**
	G3: Control group	-2.790	20	0.011**
Eye span test scores	G1:EOT programme	-5.095	21	0.000**
	G2: Educational games	-3.162	20	0.005**
	G3: Control group	-1.337	20	0.196**
Logical thinking test scores	G1: EOT programme	-5.626	21	0.000**
	G2: Educational games	2.335	20	0.030**
	G3: Control group	4.990	20	0.000**
Overall scores	Overall scores	-7.048	63	0.000**

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

Table 19 infers that the results of the paired samples tests in group 1 rejected the null hypothesis on all tests (sequencing, auditory memory, eye span, and logical thinking). This finding suggests that children's exposure to the EOT programme has significantly resulted in improvements in post-test scores in the processing speed domain. Similarly, tests in group 2 also rejected the null hypothesis in all 4 tests. This also suggests that exposure to educational computer games resulted in significant improvement in children's post-test processing speed scores. In group 3, the null hypothesis was also rejected in all tests: sequencing, auditory memory, logical thinking tests, and eye span score. Overall, these test results were also similar to the other tests, where a significant improvement in processing speed for the entire sample at the 99% confidence level was found.

Table 20 presents the results of a repeated-measures ANOVA to establish the significance of differences in processing speed post-exposure to Edublox programmes.

Table 20: Tests for within-subjects effects for changes in processing speed

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
pre-post	Sphericity Assumed	31.789	1	31.789	104.824	0.000**
pre-post * Group	Sphericity Assumed	23.368	2	11.684	38.529	0.000**
Error (pre-post)	Sphericity Assumed	18.499	61	0.303		

Source: Edublox data (2017)

* *$p < 0.05$; ** $p < 0.01$*

As outlined in Table 20, there were significant changes in mean scores between the pre- and post-test scores for the entire sample, F(1, 61) = 104.824, p = 0.000. In addition, results also show that before post-hoc adjustments, changes in processing speed scores were significantly different within the 3 groups, F(2, 61) = 38.529, p = 0.000. Thus, Table 21 presents the results of further assessments of changes in processing speed.

Table 21: Between-subjects effects for changes in processing speed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	986.859	1	986.859	1142.261	0.000**	0.949
Group	16.641	2	8.320	9.631	0.000**	0.240
Error	52.701	61	.864			

Source: Edublox data (2017)

* *$p < 0.05$; ** $p < 0.01$*

Results in Table 21 corroborate with the results presented in Table 20, thus inferring that changes in mean processing speed scores were significantly different between groups 1, 2, and 3 F(2, 61) = 9.631, p = 0.000. To further test for the effect sizes and significance of changes in processing speed, Table 22 shows results with a Bonferroni adjustment.

Table 22: Post-hoc pairwise comparisons of results on processing speed scores

(I) Name of group	(J) Name of group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower	Upper
Between subjects						
Edublox online	Educational games	0.814	0.201	0.000**	0.321	1.308
	Control group	0.689	0.201	0.003**	0.196	1.183
Educational games	Edublox online	-0.814	0.201	0.000**	-1.308	-0.321
	Control group	-0.125	0.203	1.000	-0.624	0.374
Control group	Edublox online	-0.689	0.201	0.003**	-1.183	-0.196
	Educational games	0.125	0.203	1.000	-0.374	0.624
Within subjects						
pre-test	pre-test	-0.997	0.097	0.000**	-1.192	-0.802
post-test	post-test	0.997	0.097	0.000**	0.802	1.192

Source: Edublox data (2017)

* $p < 0.05$; ** $p < 0.01$

As shown in Table 22, there were significant differences in the changes in mean scores between the EOT group and the educational computer games group (±0.814, $p < 0.01$), as well as the EOT group and the control group (±0.689, $p < 0.01$). The null hypothesis was therefore rejected on the differences between scores in the EOT group and the other two groups. Changes in mean scores were however found to be insignificant between the educational games and control groups. Moreover, Figure 7 provides a representation of changes in mean scores between groups 1, 2, and 3 based on consolidated processing speed scores.

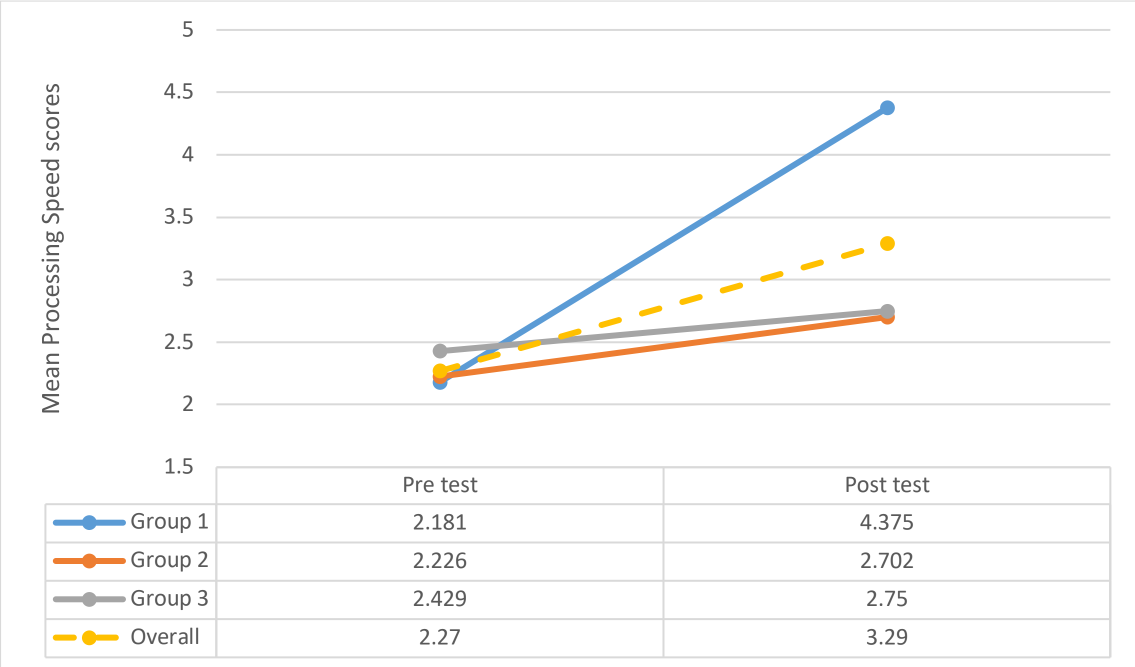

Figure 7: Mean plots of children's processing speed tests

Figure 7 displays the mean processing speed performance scores. For group 1, the mean processing speed score was 2.18 pre-test versus 4.38 post-test, while for group 2, it was 2.23 pre-test and 2.70 post-test. Group 3 had a mean score of 2.43 pre-test and 2.75

4.7. Discussion of findings

The primary objective of this study was to examine whether exposure to the EOT programme has an impact on children's cognitive functioning (specifically working memory, processing speed and auditory memory). Findings of the study were generally mixed on the effect of the Edublox interventions, with some showing significant improvements after exposure, some showing insignificant improvements, and one showing declines, albeit insignificant.

Descriptive results on in-classroom teacher observations of conceptual and language performance showed that for all 3 groups, there was a decline in mean scores when comparing pre and post scores. With the analysis of overall changes showing that the decline was not significant and results of the control group also showing declines, it is difficult to conclude that exposure to the EOT programme led to a reduction in in-classroom observations of conceptual and language performance.

In addition, inferential results of the paired samples t-test and between-group ANOVA showed that for the complete sample, mean in-classroom teacher observations of conceptual and language performance changed significantly. However, within-groups assessments found that changes in mean scores between groups 1, 2, and 3 were not significant after children were exposed to the Edublox programmes for 3 weeks. This suggests that changes in mean scores were most likely coincidental and not affected by children's exposure to the Edublox programmes. The fluctuation in scores most likely can be attributed to teacher perceptions but more weight can be assigned to performance tests discussed in the remainder of this section.

In the auditory performance domain, descriptive results showed improvements in mean scores for children exposed to the EOT programme. By pairing this group with the control group as well as the educational games group one after the other, it was found that exposure to the EOT programme led to significant improvements in children's auditory performance based on the paired samples t-test and between groups repeated measures ANOVA. However, the results of between-groups ANOVA showed that increases in scores of children exposed to the EOT programme and educational computer games were not significantly higher than the control group scores.

Moreover, mean scores for working memory using descriptive statistics were found to have increased for all participant groups. This can be attributed to issues with pre-test administration. Using a paired samples t-test and between-subjects ANOVA, results on overall mean scores showed improvements from the pre-test to the post-test. In addition, results before the Bonferroni adjustment suggested that changes in mean working memory scores were significantly different between groups 1, 2, and 3. However, after the Bonferroni adjustment, it was found that scores of children exposed to the EOT programme were not significantly different from scores of children exposed to the educational computer games or the control group.

Lastly, findings on processing speed were contrary to findings on auditory performance, and processing speed. Descriptive statistics showed that while scores improved for all of the 3 groups, scores of children exposed to the EOT programme improved by a much greater percentage than the other groups. Results of a repeated-measures ANOVA test confirmed the descriptive results, showing that there were significant differences in the improvements in mean processing speed of children in groups 1, 2, and 3.

Furthermore, after the Bonferroni adjustment, it was found that children exposed to the EOT programme registered significantly higher improvements in processing speed as compared to the other groups. However, changes in mean processing speed for children exposed to the educational computer games were not significantly different from changes experienced by children in the control group. Table 23 displays the overall mean pre-test and post-test score changes for the test group (group 1: EOT programme). The scores show, using descriptive data, how exposure to the EOT programme contributed to the measured increases or decreases in conceptual skills.

Table 23: Overall mean pre-test and post-test scores for all variables

Variable	Pre-test score	Post-test score	Direction
In-classroom teacher observations of conceptual and language performance	3.44	3.24	Decreased
Auditory processing	15.80	17.42	Increased
Working memory	14.05	16.26	Increased
Processing speed	2.18	4.38	Increased

Table 23 shows that post-test scores decreased for teacher observations, but increased for the objective tests for auditory processing, working memory, and processing speed. Overall, analyses revealed that in one out of the 4 conceptual skills, exposure to the EOT programme significantly improved children's cognitive conceptual skills (specifically processing speed). The results of this study may however be difficult to replicate due to the low sample size of 64 participants. With a lower sample size and the tests conducted, the chances of making either type I error or type II error or both increases, and findings may be difficult to replicate. With studies such as Gelderblom (2017) and Blablová (2015) noting that the EOT programme significantly leads to improvement of processing speed, working memory, auditory memory, and other cognitive skills and behaviour of children, parts of this study's findings were contrary to previous literature. However, the findings of this study might be better explained by Steeger *et al.* (2016) who argue that the EOT programme cannot offer positive results over a short period, but rather offer gradual improvements in cognitive conceptual skills. With a period of about 3 weeks from the administration of the pre-test and post-test, it is possible that the EOT programme may not have had enough time to take effect on the children's cognition and yield maximum benefit.

4.8. Chapter summary

This chapter focused on the analysis of data collected from 64 children who were exposed to the EOT programme and educational computer games as part of an Edublox intervention. The analysis was divided into 4 major factors; in-classroom teacher observations of conceptual and language performance, auditory performance, working memory, and processing speed. Overall findings of the study showed that changes in processing speed were significantly explained by the children's exposure to the EOT programme, while changes in cognitive processing, auditory processing, and working memory were not. A portion of the findings were contrary to some previous studies, but may be explained by the short period within which children were exposed to the programme, given that there might be a need for more time for positive results to show.

The next chapter provides a summary of the results, conclusions, as well as recommendations for the improvement of children's cognitive conceptual skills.

CHAPTER 5:
DISCUSSION OF RESULTS AND CONCLUSION

"The important thing is not to stop questioning…"

- *Albert Einstein*

5.1. Introduction

This study sought to evaluate the effectiveness of the EOT programme on the cognitive functioning of primary school children. The research comprised of a sample of 64 grade 2 children who were supervised by Edublox. Data was collected using an experimental research design that included pre-and post-assessments of cognitive performances (before and after exposure) to the EOT programme. A quantitative research design was adopted throughout the study, with varying data analysis techniques, such as mean plots, paired-samples t-tests, and one-way repeated measures ANOVA tests. In this chapter, a discussion of the results in relation to the findings from literature and the data analysis will be discussed. Furthermore, the chapter concludes with the research limitations of this study as well as recommendations for further research.

5.2. Summary of findings from the literature

The literature review sought to provide insight on the purpose and functioning of the EOT programme, the empirical effects of educational programme interventions (such as Edublox) on learner cognitive performance, and the effect of other interventions on cognitive performance.

A review of the Edublox programme found that there were two main interventions employed by Edublox for cognitive enhancement; The *Edublox Online Tutor (EOT)* and the *educational computer games*. The EOT programme contains several interventions delivered online which target children's perceptions, visual discrimination of colours, auditory processing, decoding, and imagination among others, while the educational computer games included a series of games which were developed by PopCap and included child-friendly and easy-to-learn problem-solving activities. The aforementioned interventions were included in addition to the children's existing daily schooling.

In the development of the research conceptual structure, two main theories were reviewed: *Vygotsky's Sociocultural Theory* and the *Cognitive Information Processing Theory*. Developed by Vygotsky (1986), the Sociocultural Theory argues that cognitive development among children is determined directly by the socio-cultural situations in which those children reside. As a result, children's living contexts need to be addressed by introducing interventions that enhance children's cognitive performance. Vygotsky's (1986) work is supported by empirical findings from studies such as by Gredler (2012), Mercer (2013), Helou and Newsome (2018), and Stahl (2005). The Cognitive Information Processing Theory views an individual as a computer who is capable of receiving inputs, processing the input information, and producing outputs (Atkinson & Shiffrin, 1968). The theory argues that to ensure maximum output, input information should be optimised so that there is no information overload (McLeod, 2008). Scholars such as Lutz and Huitt (2003) and Hummel and Huitt (1994) support the applicability of the Cognitive Information Processing Theory especially in explaining how cognitive performances can be improved among children in early childhood development. Thus, the aforementioned theories helped in the formulation of a conceptual structure for this study, which focused on analysing cognitive performances based on a variety of tests.

In reviewing the impact of the EOT programme on the cognitive performance of children, it was noted that most studies related to the EOT programme were either conducted by or sponsored by Edublox itself. As a result, it is difficult to rule out the possible influence of conflict of interest on the study findings. Studies such as by Edublox (2014) showed that the Edublox programme was able to induce a significant improvement in children's cognitive performance after an exposure period of only 5 days. Other studies by De Wet (1989) and Van Staden, Badenhorst, and Esterhuyse (2008) reported significantly positive improvements in the cognitive abilities of children exposed to the Edublox programmes. A review of further empirical studies found that there are several other reported cases where educational interventions such as the Edublox programmes resulted in improved cognitive performance among children. Adubasim (2018), as well as Du Plessis and Maree (2019), corroborate the findings from Edublox funded research with studies that found positive links between specific educational interventions and cognitive performance. However, other studies dispute the magnitude of reported effects on educational interventions such as the Edublox programmes.

For instance, Steeger et al. (2016) dispute Edublox (2014)'s assertion that educational interventions have the potential to register positive improvements after only 5 days of exposure. Rather, the impact of educational interventions was found to be a result of gradual exposure to cognitive enhancement programmes (Steeger et al., 2016). On the other hand, a study by Rosa et al. (2017) found that after an educational intervention, improvements in cognitive performance were recorded in both the experimental group and the control group, with no significant differences between the two. From the above, it is evident that current studies pertaining to this area of research can thus be said to be open ended, with no real inclination as to whether such learning interventions like the Edublox initiative has an impact on cognitive performance. Thus, this warrants the need for further exploration in a growing field of educational technology where hybrid and blended learning are becoming more prominent.

The literature review concluded with a discussion of other interventions that were targeted towards improving the cognitive performances in children. It was found that pharmacological interventions as well as non-pharmacological interventions, such as exercise were still popular across the world (Aikins, 2011; Van den-Berg et al., 2019). While pharmacological interventions were seen as a quick way to improve cognitive performance, the desired improvements were found to be mostly short term (with children requiring sustained medication). Furthermore, the continued use of medication and supplements led to unwanted, negative side-effects (Aikins, 2011; Hinshaw & Arnold, 2015).

Literature reviews of various studies led to the conclusion that currently, there is no ‘one’ intervention capable of producing sustained positive effects on cognitive performance. While a combination of pharmacological and non-pharmacological methods could be employed to yield a multimodal intervention, currently there is no evidence to support this. Thus, this dearth in literature necessitates the need to explore the aforementioned suggestions or other interventions for cognitive enhancement in children.

5.3. Summary of findings in relation to the research questions

This section summarises the research findings from the data analysis, per research question. The research questions will be presented under subheadings. Furthermore, the findings in relation to the available literature will be discussed.

5.3.1. How effective is the EOT programme in enhancing in-classroom conceptual and language performance in areas of reading, writing, and spelling?

Helou and Newsome (2018) note that performance among children can be improved through the intervention and involvement of parents, teachers, or other tools. Van Staden et al. (2008) found that the Edublox programmes significantly contributed to improvements in the cognitive performance of children. To evaluate the effectiveness of the EOT programme in improving in-classroom conceptual and language performance in this study, a one-way repeated measures ANOVA test was conducted with post-hoc testing.

Descriptive results (Table 3) on performance showed that for all 3 groups, there was a decline in mean scores when comparing pre and post-test scores. With the analysis of overall changes showing that the decline was not significant and the results of the control group also showing declines (Table 5), it is difficult to conclude that exposure to the EOT programme led to a reduction in in-classroom conceptual and language performance. Moreover, inferential results of the paired samples t-test and repeated measures ANOVA tests showed that for the complete sample, mean scores changed significantly. However, within-groups assessments found that changes in mean scores between groups 1, 2, and 3 were not significant after children were exposed to the EOT programme for 3 weeks. The Bonferroni adjusted post-hoc scores also confirmed the aforementioned results. This suggests that changes in mean scores were most likely coincidental and not affected by children's exposure to the EOT programme.

Moreover, the findings on changes in scores dispute previous studies funded by Edublox such as Edublox (2014) and Van Staden (2008) which found that access to the EOT programme led to significant improvements in children's cognitive scores. By examining the results of the repeated measures ANOVA, it can be seen that while the overall mean scores combining the 3 groups significantly declined, the differences in mean scores were not significant between groups 1, 2, and 3.

This could suggest that the observational scores of teachers were not adequately reliable Furthermore, such results could suggest that the content composition, delivery, or other factors were perhaps not enough to register performance improvements among children.

5.3.2. How effective is the EOT programme on the enhancement of auditory performance with reference to numbers, words, and sentences?

Regarding auditory performance, descriptive results (Table 8) showed improvements in mean scores for children exposed to the EOT programme. By pairing this group with the control group, as well as the educational games group one after the other, it was found that exposure to the EOT programme led to significant improvements in children's auditory performance. This conclusion was based on the paired samples t-test (Table 9) and the within-groups repeated measures ANOVA. The paired samples t-test results further revealed that there were no significant changes in mean auditory scores between pre-and post-tests in the educational games and control groups. In addition, results of within-groups repeated measures ANOVA (Table 10) showed that increases in scores of children exposed to the EOT programme were significantly greater than the educational games and control group scores. Hence, it can be concluded that increases in auditory memory scores can be attributed to significant influences of children's exposure to the EOT programme. In addition, mean plots (Figure 5) graphically displayed the changes in scores, showing a comparatively sharp increase in auditory scores of the children exposed to the EOT programme; with smaller increases for children exposed to the educational games and the control group. Furthermore, the post-hoc analysis showed that the auditory score increases were significant overall, but not significantly different between the 3 groups since all groups registered an average increase in mean scores.

The significant improvement in auditory scores for children exposed to the EOT programme supports Vygotsky's (1986) views on how external interventions can be used to improve children's auditory performance. Gredler (2012), as well as Helou and Newsome (2018), offer a further expansion of the Sociocultural Theory through their indication of how children are able to grow as individuals and evolve, as long as they have access to enabling tools. In addition, the findings on auditory improvements also corroborate with Rosa et al. (2017) who found decreases in the levels of ADHD among children in the experimental group, who were exposed to auditory enhancement training. However, in their findings, Rosa et al. (2017) in agreement with Rutledge et al. (2012), emphasise that results on auditory improvements may be inconclusive where small sample sizes are used. As mentioned above, this can be attributed to the fact that small sample sizes in such studies increase the likelihood of finding relatively similar changes in test scores between the experimental and placebo groups.

5.3.3. How effective is the EOT programme in enhancing working memory?

Mean scores for working memory were found to have increased for all groups (Table 13). Using a paired samples t-test which was conducted on each group across the 4 working memory indicators (i.e. story memory, number memory forward, number memory reverse, and coding), results revealed that there were significant improvement in scores for all groups on story memory and coding (Table 14). While the improvements in scores were not significant for the number memory forward indicator, they were significant for the number memory reverse indicator in the EOT group.

Moreover, the results of the repeated measures ANOVA showed improvements from the pre-test to the post-test for the overall sample, and within the 3 groups (Table 15). In addition, results before the Bonferroni adjustment confirmed that changes in mean working memory scores were significantly different between groups 1, 2, and 3. The mean plot (Figure 6) showed that participants in group 2 scored the lowest on the pre-test, but scored the highest on the post-test. In addition, the mean scores for group 1 were highest on the pre-test, but second-highest on the post-test. However, in comparison to the aforementioned groups, the scores of participants in the control group did not change much between the pre-and post-tests.

Results on working memory improvements were found to be in accordance with Mays (2012), an Edublox funded study which found that exposure to Edublox training resulted in improvements in children's visual and sequential memory. However, Mays (2012) found that in isolation, the Edublox programme may not be enough to register significant working memory improvements between the experimental and control groups.

Rather, recent empirical findings appear to point towards the superiority of combining medical interventions (Hinshaw & Arnold, 2015), educational programmes (such as the EOT), and other general activities, such as outdoor exercise to achieve optimal results in the enhancement of working memory (Singh et al. 2018; Yildirim & Akamca, 2017; Van den-Berg et al. 2019).

5.3.4. How effective is the EOT programme in enhancing processing speed?

Descriptive statistics on processing speed showed that while scores improved for all 3 groups, scores of children exposed to the EOT programme improved by a relatively greater percentage (Table 18). Furthermore, the paired samples t-test results for all elements of processing speed (i.e. sequencing, auditory memory, eye span, and logical thinking) found that there were significant increases in processing speed for all groups. In addition, the results of the repeated measures ANOVA test (Table 21) confirmed the descriptive and paired samples t-test results, showing that there were significant differences in the improvements in mean processing speed of children in groups 1, 2, and 3.

Moreover, after the Bonferroni adjustment, it was found that children exposed to the EOT programme registered significantly higher improvements in processing speed as compared to children exposed to the educational games and the control group. In addition, changes in mean processing speed for children exposed to the educational games group were not significantly different from changes experienced by children in the control group. These results were further confirmed through mean plotting (Figure 7) which showed that pre-test scores for all groups were virtually equal, but post-test results of the EOT group ascended much sharper than the other groups.

Results on the improvements in processing speed were found to be in accordance with Atkinson and Shiffrin's (1968) information processing theory. The theory offers suggestions on how and at what stage teacher or parent intervention is necessary to improve children's processing speed (Lutz and Huitt, 2003). In addition, results were found to corroborate with Adubasim (2018) who found improvements in both working memory and processing speed in children that were exposed to the Brainfeed intervention programme. The length of intervention utilised in this study was fairly similar to the Adubasim's (2018) study which included a month’s worth of training. However, it should be noted that this study differed in sample size, given that Adubasim (2018) collected data from 24 727 pupils.

In summary, Table 24 highlights the overall decisions based on the findings per research question and its relevant hypothesis. It should be noted that with reference to the improvements in cognitive functioning, several studies propose that in addition to the educational programme itself, the delivery approach and the environmental setting is equally important. This view by scholars such as Du Plessis and Maree (2019), Sellah, Jacinta and Helen (2017) as well as Dunlosky et al. (2013) expands on the understanding of the effectiveness of the EOT programme by advocating for it to be implemented in an enabling environment, using valuable approaches and contexts. By doing so, the EOT programme can be fully evaluated and analysed in a more thorough and effective manner.

Table 24: Overall decisions per research hypothesis

Research question	Hypotheses	Decision
1.	H1: Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of reading, writing, and spelling	Failed to reject the null hypothesis
2.	H2: Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of numbers, words, and sentences	Failed to reject the null hypothesis
3.	H3: Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of working memory	Failed to reject the null hypothesis
4.	H4: Mean test scores for the entire sample between pre-and post-tests are not significantly different in all areas of processing speed	The null hypothesis was rejected

5.4. Conclusion

Overall, analyses revealed that exposure to the EOT programme significantly improved children's conceptual skills in one out of the 4 variables tested in cognitive performance i.e. processing speed. However, other findings such as that of auditory performance showed that while there were overall improvements in mean post-test scores, there were no significant differences in mean post-test scores between the experimental groups and the control group.

While studies by Adubasim (2018), Gelderblom (2017), and Blablová (2015) noting that the Edublox programme significantly leads to the improvement of cognitive performance, processing speed, working memory, auditory memory, and other cognitive skills – a part of this study's findings were contrary to previous literature. One of the reasons for this contradiction can be attributed to the low sample size of 64 participants that was used in this study. With the tests conducted and a lower sample size, the chance of making either a type I error, a type II error (or both) increases, and thus findings may be difficult to replicate. However, the findings of this study might be better explained by Steeger et al. (2016) who argue that the Edublox programme cannot offer positive results over a short period, but rather offer gradual improvements in cognitive conceptual skills. With a period of about 3 weeks from the administration of the pre-test and post-test, it is possible that the EOT programme may not have had enough time to take effect on the children's cognition and yield maximum benefit. Furthermore, the results of this study should be interpreted in relation to the findings by Hinshaw and Arnold (2015), Singh et al. (2018), Yildirim and Akamca (2017), and Van den-Berg et al. (2019) who argue that there is a need to combine several approaches into a composite programme in order to effectively improve children's cognitive conceptual skills.

5.5. Limitations of the study

While the study succeeded in evaluating the impact of the EOT programme on the cognitive functioning in children, several limitations were identified. Thus, it is imperative that the results obtained in this study should be interpreted within the context of its limitations:

Firstly, both the learning programmes and the pre-post testing were administered by Edublox. In addition, the auditory and working memory tests were conducted by independent audiologists; other tests were done by an independent psychologist whilst the Edublox assessments were conducted by personnel of Edublox but with oversight from a teaching assistant appointed by the Headmaster of the school. Thus, measures were largely in place for limiting experimenter effects, but could not be totally ruled out in Edublox's case.

Secondly, the children were only exposed to 3 weeks of the EOT programme. This could propose a challenge when questioning the validity of the findings of this study- when compared to other studies which argue that children need a longer exposure to educational interventions before they can experience significant improvements in cognitive ability.

Lastly, the small sample size of 64 participants may have been inadequate to reveal distinct patterns in cognitive abilities. Statistically, the law of large numbers states that the larger the sample size, the more accurately it represents the population (Gravetter & Forzano, 2012). As a result, the power of a statistical test is influenced by smaller sample size (Shadish et al., 2002). Another possible consequence of a small sample size is that the researcher is more prone to a Type II error i.e. when the results of the sample do not show a significant effect when a real effect occurs in the population (Field, 2013). Thus, this could have resulted in low statistical power which may have impacted the statistical conclusion validity of this study.

5.6. Recommendations

Based on the analysis of findings from the literature, the findings from this study, and the limitations of the study, the following recommendations have been formulated:

The need for a longer treatment period

Findings from the literature showed that in some contexts, results in children's conceptual skills shifted more significantly with repeated exposure and post-testing. In this regard, it is recommended that Edublox extend its EOT programme to a minimum of two months. The approach would entail the following process: the conduction of a pre-test before exposure to the programme, one post-test at the end of the first month, and another post-test at the end of the second month. The focus will be on establishing at which point the cognitive scores were most significant; either between the pre-test and the first post-test or between the first post-test and the second post-test. By utilising the aforementioned approach, the effectiveness of the programme and its impact on cognitive performance can be better evaluated and understood.

Inclusion of other tools and interventions

Through literature, it was found that programmes such as the EOT may not be sufficient on their own to register improvements in cognitive performance, auditory performance, working memory, and processing speed.

New and upcoming interventions such as the integration of physical exercise into the training routine as well as the tried and tested medical interventions might be provide a holistic and multimodal approach. However, the introduction of medical interventions might not be feasible for institutions such as Edublox whose main value proposition relies on the use of non-pharmacological programmes.

Rather, a combination of hybrid and other non-pharmacological programmes may be a useful consideration for new players that are entering the market in the field of cognitive enhancement. This can be attributed to the fact that a multimodal approach offers a greater chance in evaluating and attaining a greater probability in cognitive enhancement

Implementation of varied delivery approaches and environment

An analysis of this study suggests that it is possible to attain varying results on cognitive improvements depending on the type of delivery approaches used as well as the environmental setting. While there was a dearth in literature and data to support this notion, it seems to provide an interesting angle on how children can be better assisted. An example of a varying environment can include online delivery vs classroom delivery or a day to day delivery vs delivery with constant breaks. Therefore, the analysis and impact of such studies following the aforementioned approaches will focus on how each variation to the same training programme affects changes in conceptual skills.

5.7. Suggestions for future research

The following suggestions are based on the study's limitations, with focus on enhancing the reliability and validity of future research in this field:

- Data collection for future studies should be collected by independent researchers to reduce the potential for bias and enhance the comparability of findings.
- Administrators of the EOT programme and educational games sessions should consider lengthening the exposure period possibly by an additional 3 weeks. Instead of running a single post-test, the first post-testing can be conducted at the end of 3 weeks, and the second post-test at the end of the experimental period.
- The data arising from such a study can help bridge the gap in research and contribute to the discussion on the length of time needed to expose children to the Edublox programmes to obtain maximum effect.
- Lastly, future studies should consider obtaining a larger sample size to improve the reliability and enhance the comparability of the study's findings.

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APPENDIX A: ETHICAL CLEARANCE

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Humanities 100.
Since 1919

05 November 2020

Dear Miss NE Dawood

Project Title:	The impact of the Edublox Online Tutor (EOT) programme on the cognitive functioning of primary school children
Researcher:	Miss NE Dawood
Supervisor(s):	Prof DJF Maree
Department:	Psychology
Reference number:	11024489 (HUM032/0820)
Degree:	Masters

Thank you for the application that was submitted for ethical consideration.

The Research Ethics Committee notes that this is a literature-based study and no human subjects are involved.
The application has been **approved** on 5 November 2020 with the assumption that the document(s) are in the public domain. Data collection may therefore commence, along these guidelines.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. However, should the actual research depart significantly from the proposed research, a new research proposal and application for ethical clearance will have to be submitted for approval.

We wish you success with the project.

Sincerely,

Prof Innocent Pikirayi
Deputy Dean: Postgraduate Studies and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail:PGHumanities@up.ac.za

Fakulteit Geesteswetenskappe
Lefapha la Bomotho

APPENDIX B: INFORMED CONSENT

PO BOX 14484
HATFIELD
0028
anelize@confido.co.za
TEL: (012) 323 5766
FAX: (012) 323 1196

PRETORIA INTERNATIONAL COLLEGE: SECT 21 CO REG NO 2001/020440/08

T/A **CONFIDENCE COLLEGE** (GDE No: 231704)

Information Page and Consent Form: Edublox Research Project 2017

Edublox reading, maths and learning clinic has been helping us since 2011 by doing brain training with our learners. The brain training sessions help the learners to concentrate and remember better, process faster, and improve reading and learning skills.
See www.edublox.co.za for more information.

We have seen great results with the brain training sessions. A research study in 2013, for example, was done at our school. Our Grade 4-7 learners took part for only 22.5 hours and showed an average increase in visual and visual sequential memory of nearly 1.5 years.

In a new experiment, Edublox wishes to see how well the brain training works for other learning skills such as processing speed and auditory memory. They wish to present a training course for our Grade 2 learners at the school during school hours. They have arranged for the donation of 10 computers, as well as 100 licenses of this programme to our school.

Edublox will be assessing the following:

- Auditory memory, which will be done by a registered speech and language therapist.
- Working memory and processing speed, which will be done by a registered psychologist.
- An Edublox in-house informal online cognitive assessment will be done, under supervision of the classroom tutors.
- Classroom observation by means of a teacher questionnaire.

Although it might be during different phases of the research process, all children who are participating in this study will be exposed to Edublox Online Tutor, an online multisensory brain training programme. The programme is designed to enhance overall cognitive development, including concentration, processing speed, memory and reasoning ability.

Please complete the consent form below and return to the school. Thank you for your support in this effort!

Sincerely,
Anelize van Eeden
Principal

Consent Form: Edublox Research Project 2017

The results of the research project will serve as information for a post-hoc research thesis for Ms Dawood, a student completing her master's degree in research psychology. Her supervisor is Professor David Maree, Head of the Department of Psychology at the University of Pretoria (UP). Edublox can be contacted at 012 345 1480 for more information.

Before the start of the study, tutors approved by Confidence College will explain to the learners what is required and they will supervise the learners during the training. All learners will complete the assessments before and after starting the programme.

To ensure that the study is ethical, we must get consent from each parent before their child can participate in the study. If you are not comfortable to give consent, your child's regular schooling will continue as normal. You are also welcome to withdraw you child at any point, and the data will be destroyed.

Terms and conditions:

1. Research information will be treated as confidential and will remain anonymous.
2. I undertake to provide all the information as required in the research.

I confirm that my child may participate in the research project and that I understand and agree with said terms and conditions.

Parent/guardian's name and surname:…………………………………………………..……..…………

Learner name and surname:……………………………………………………………………...………..

Signature:……………………………………………….

Date:……………………………………………….   ID

number:……………………………………………

APPENDIX B: EDUBLOX IN-HOUSE INFORMAL ONLINE ASSESSMENT

Strictly confidential

Sequencing

Sequencing refers to our ability to perceive items in a specific order, and also to remember that sequence. In saying the days of the week, months of the year, a telephone number, the alphabet, and in counting, the order of the elements is of paramount importance.

Students with reading difficulties often have trouble with sequencing. Naturally this will affect their ability to read and spell correctly. After all, every word consists of letters in a specific sequence. In order to read one has to perceive the letters in sequence, and also remember what word is represented by the sequence of letters in question. By simply changing the sequence of the letters in *name*, it can become *mean* or *amen*.

SCALE	NUMBER OF ITEMS CORRECT
1	3
2	5
3	7
4	9
5	11
6	13
7	15
8	17
9	19

Auditory Memory

A weakness in auditory memory can have serious consequences in the realm of learning for students.

Auditory memory involves being able to take in information that is presented orally, to process that information, store it in one's mind and then recall what one has heard. Basically, it involves the skills of attending, listening, processing, storing, and recalling. Because students with auditory memory weaknesses pick up only bits and pieces of what is being said during a classroom lecture, they make sense of only little of what is said by the teacher. Afterwards they are able to recall only a small amount or none of what was said.

Students with auditory memory deficiencies will often experience difficulty developing a good understanding of words, remembering terms and information that has been presented orally, for example, in history and science classes. These students will also experience difficulty processing and recalling information that they have read to themselves. When we read we must listen and process information we say to ourselves, even when we read silently. If we do not attend and listen to our silent input of words, we cannot process the information or recall what we have read. Therefore, even silent reading involves a form of listening.

A poor auditory short-term memory is often the cause for a person's inability to learn to read using the phonics method. Phonics is an auditory learning system, and it is imperative to have a sufficient auditory short-term memory in order to learn, utilize and understand reading using the phonics method.

SCALE	NUMBER OF ITEMS CORRECT
1	(2)
2	(3)
3	(4)
4	(5)
5	(6)
6	(6)
7	(7)
8	(8)
9	(9)

Eye Span

When your eyes move across a line of print, they move in a series of quick movements broken by very brief pauses. The movements are called "saccades." They are so fast that you are not aware of them. Your brain manages to blank out whatever signals come from your eyes during these saccadic movements. You are only aware of what you see during the pauses.

You aren't even really aware of the pauses, so it is easy to believe that your eyes move smoothly across the page. But if you watch another person read you can clearly see the quick jerky movements.

What you probably can't do, because they are so quick, is to count the movements. The pauses, which are called "fixations," last only one-quarter to one-fifth of a second.

The normal beginner reader makes an average of two fixations per word or, in other words, sees or recognizes less than one whole word at each fixation. This statistic was determined by photographing the reading of over a thousand first graders with *The Reading Eye*, a camera made especially for this purpose. Each child read a selection of approximately 100 words. During the reading the average child made 224 fixations, about two fixations per word or an eye span of .45 of a word. This average span of recognition increases very slowly to 1.11, or slightly more than one word per fixation, for normal college students at an average speed of 280 words per minute. The average number of words seen at each fixation does not reach one whole word until the eleventh grade.

A poor reader will be inclined to pause more often for fixations, and the duration of each fixation will also be longer than that of the typical reader.

Another important difference between good and poor readers lies in *regressive movements*. All of us move our eyes backwards from time to time in reading. Poor readers do it more often than good readers, but there is a further difference: Good readers know *where* to regress to. They go back to the beginnings of phrases and sentences, and they can pick out important and difficult passages to reread (because that is what regressive movements amount to). Poor readers just move their eyes back because they don't understand what they have just read.

By increasing the learner's eye span, the number of fixations, the duration of the fixations, and regressive movements can be reduced, leading to faster and smoother reading.

SCALE	NUMBER OF ITEMS CORRECT
1	(2)
2	(3)
3	(4)
4	(5)
5	(6)
6	(7)
7	(8)
8	(9)
9	(10)

Logical Thinking

Logical thinking is the process in which one uses reasoning consistently to come to a conclusion. Problems or situations that involve logical thinking call for structure, for relationships between facts, and for chains of reasoning that "make sense".

The basis of all logical thinking is sequential thought. This process involves taking the important ideas, facts, and conclusions involved in a problem and arranging them in a chain-like progression that takes on a meaning in and of itself. To think logically is to think in steps.

It has been proven that specific training in logical thinking processes can make people "smarter." Logical thinking allows a child to reject quick answers, such as "I don't know," or "this is too difficult," by empowering them to delve deeper into their thinking processes and understand better the methods used to arrive at a solution and even the solution itself.

Scoring: 9 Logical thinking tests are provided. Use the highest correct to determine the level.

Exercise	**Description**
Auditory Memory	Starts with two arrows, 4 directions, be answered in the same number.
Auditory Card	Starts with two circles and are placed in grid memory.
Flash	Flash of a sequence coloured block. Rehearsal is also prevented.
Shapes Pattern	Starts with two circles and the shaped displayed on grid needs to be memorised and are replaced eventually.
Blocks Pattern	A time exercised and starts with two blocks. Half of blocks are randomly replaced. More blocks can also be added of existing blocks are replaced correctly.
Grid Pattern	Six blocked time exercise and the blocks are randomly removed by answering questions correctly.
Sequence	Also, a time exercised where colour is displayed and added on answering correctly.
Logical Thinking	Logical sequence is required to be completed such as red, blue, green, black and others.

COGNITIVE SKILLS THAT SUPPORT READING AND LEARNING

The following scale defines the cognitive skill levels.

1 = Very Poor; 2 to 3 = Poor; 4 to 6 = Average; 7 to 8 = Good; 9 = Very good

The skill level calculation takes age into consideration.

Visual Sequential Memory

Sequencing refers to our ability to perceive items in a specific order, and to remember that sequence e.g. months of the year, a telephone number, the alphabet.

Date	Skill Level
16 October 2017	5 - Average

Auditory Memory

Auditory memory involves being able to take information that is presented verbally, to process that information, store it in one's mind and then recall what one has heard. Basically it involves the skills of attending, listening, processing, storing and recalling.

Date	Skill Level
16 October 2017	2 - Very poor

Eye Span

By increasing the learner's eye span, the number of fixations, the duration of the fixations and regressive movements can be reduced, leading to faster and smoother reading.

Date	Skill Level
16 October 2017	2 - Very poor

Logical Thinking

Logical thinking is the process in which one uses reasoning consistently to come to a conclusion and is a foundational skill of reading comprehension.

Date	Skill Level
16 October 2017	3 - Poor