THE EFFECTS OF CHESS INSTRUCTION ON THE INTELLECTUAL DEVELOPMENT OF GRADE R LEANERS

by

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Declaration

I declare that **THE EFFECTS OF CHESS INSTRUCTION ON THE INTELLECTUAL DEVELOPMENT OF GRADE R LEARNERS** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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SIGNATURE	DATE
(MRS M R BASSON)	

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Summary

The literature review indicated similarities between education and chess playing and possible transfer of knowledge between these two different domains. A link was then suggested between some aspects of intellectual abilities and chess instruction in children, but not in adults (Frydman & Lynn, 1992; Waters, Doll & Mayr, 1987). In this research study the aim was to explore the relationship between chess playing and cognitive and intellectual development in Grade R learners at Garsieland. Therefore the positive influence that chess playing brings to bear on the intelligence of 64 Grade R learners (as measured on intelligence scales) was investigated. The data was collected through short biographical questionnaires and psychometric tests and the participants in both groups were assessed on two occasions.

The study suggested that chess instruction exerted a positive (small) effect on Performance intelligence and subsequently on the Global scale of the Junior South African Intelligence Scales. The children in both groups also exhibited improved cognitive development after the 40 week period during 2009.

Key Terms

- Learners and learning
- Grade R
- Cognitive development
- Intelligence and intellectual development
- Chess instruction, chess playing or deliberate practice
- Visuo-spatial abilities
- Transfer of knowledge or training
- Metacognition
- Novices and experts
- Psychometric tests

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Chapter 1
Overview

1.1 Introduction

Chess is a highly visual, competitive and sophisticated game (or sport) of pure skill with a long tradition, but a history of uncertain origin (Charness, 1992). It is generally regarded as a game with a significant cognitive and intellectual dimension, and is therefore promoted in educational settings in many countries. For example, in Russia chess has constituted part of the school curriculum for more than 40 years (Milat, 1997).

The game of chess is of interest to researchers in psychology, not only because it has links to education and intelligence, but also because chess skills can be measured scientifically using the official “Elo” chess rating scale (Charness, 1992; Waters, Gobet, & Leyden, 2002, p. 2). The latter is a performance rating scale developed by the physicist Arpad Elo to objectively quantify the knowledge and skills of chess and to measure expertise in this domain continuously (Elo, 1965, 1978). Chess therefore offers a task environment in which careful laboratory studies of skill acquisition and expertise can be conducted. Gobet (2012) contends that the study of expertise is important for the sciences of learning, because individuals who are capable of exceptional performances offer a unique window on human cognition and help to shed light on strategies that help to overcome the limits of human cognition and rationality (Charness, 1992).

In this dissertation, the effect of chess instruction on the development of cognitive abilities in a sample of young children is investigated. However, before the study is described in greater detail, a general contextualisation of the research domain is presented in this chapter.

1.2 Chess as a Resource for Researchers in Psychology and Education

The process of teaching chess to beginners can be regarded as an instructional technique that facilitates various aspects of human cognition and learning due to the “clear-cut outcome criteria and short-term feedback cycles” in chess playing where bad moves and ideas are punished immediately, but often still present an opportunity to correct mistakes, whereas good moves are rewarded (De Groot & Gobet, 1996, p. 263; Scholz, Niesch, Steffen, Ernst, Loeffler, Witruk & Schwarz, 2008). Moreover, teaching and learning chess in a group context constitutes a form of distributed learning according to the distributed intelligence theory of Hutchins (as cited in Colman, 2006, p. 219). In such a participatory context, the sharing of information processing is key as an instructor can use a single chess set to teach aspects of the game, such as openings and combinations, to a whole group of learners (Ormrod, 2006, p. 147).

According to Nunes (1992), chess playing facilitates some kind of informal handling of mathematical concepts. Kennedy (1998) maintains that chess playing develops cognitive skills and integrates different types of thinking, and also helps to eliminate differences between learners due to, for instance, different socio-economic conditions. Waaramantry (as cited in Subotnik, 1993) argues that chess is a vehicle that highlights logical and deductive thinking skills, because when moves are evaluated and planned a player must select from different alternatives and contemplate outcomes in a logical manner. He posits that the activity of playing chess involves higher order thinking skills, such as problem solving, the use of strategy, spatial thinking, deductive reasoning, metacognition, and strategic thinking abilities. In this sense, learning to play chess may also develop important aspects of thinking and reasoning.

There are also other interesting links between these two domains (i.e., chess and education), because:

- In both settings, learners and chess players tend to learn better when presented with visual rather than auditory information (Schneck, 2005, p. 420). This visual information is then transformed into a kind of code or language because a learner reads words at school and a chess player learns the algebraic notation (Sutton & Krueger, 2002).

- Chess playing could be regarded as an activity that helps to develop the link between the abstract symbolic and visuo-spatial thinking required in mathematics (mathematics presented in class) and the understanding of mathematics (physical and visual) (Milat, 1997). McDougall (2013) even argues that mathematics and chess playing are both universal languages because they are ideal contexts for problem solving, and can be applied to various aspects of ordinary life.

- Peterson (2002) contends that many of the standards of mathematics (the standards for Mathematical Reasoning in the United States of America) reflect thinking and problem solving skills associated with chess. When learners solve problems in mathematics and chess playing, they make use of various logical principles such as identifying relationships; distinguishing relevant from irrelevant information; sequencing, prioritising and synthesising information and observing patterns; and making use of different models. Furthermore, a variety of teaching methods and materials are required to develop knowledge and understanding in these two domains, such as learning how to divide a problem into smaller parts, and to apply strategic thinking abilities (Peterson, 2002).

- Both situations involve the acquisition and development of knowledge and skills, and it requires much practise, time and effort to acquire a vast amount of domain specific knowledge and automaticity. This is discussed in greater detail in section 1.3.2.1, where *Anderson's adaptive control of thought-rational theory* is explained (see also Anderson, 1990; Detterman & Sternberg, 1993; Campitelli & Gobet, 2008).

- In both environments, learners are afforded opportunities to compete with other learners or chess players in order to promote mental alertness and elicit the highest level of achievement from the child (Stephan, 1988). The following researchers (Ormrod, 2006, p. 447; Milat, 1997) contend that when children experience successes in tasks and chess playing, they become more confident in themselves, which in turn exerts a positive effect on their cognitive development as well as their adaptation to the demands of the educational environment in terms of their personal growth.

Hence, based on the aforementioned statements, it is evident that exploring and elucidating the cognitive processes underlying chess playing is a potentially useful endeavour that may yield useful insights for contemporary educational theory (Jones, 1990). For this reason, Kennedy (1998) contends that chess playing broadens one’s understanding of intelligence, and that investigating the cognitive processes underlying chess may foster an insight into core aspects of cognition and intelligence.

1.2.1 Chess and socio-economic development in South Africa

South Africa is a country with high levels of poverty, unemployment, crime, AIDS, and strike actions involving both teachers and learners (Coetzee, 2010, p.10). Poor or insufficient infrastructure abounds, with various negative consequences for education, such as:

- A poor matric pass rate, as well as a low/poor literacy rate amongst learners who applied for a degree during 2013, and subsequently only 30 % of these learners will be able to study without additional help (Myburgh & Prince, 2014, p. 1; Kemm as cited by Kostenuik, 2012).

- In 2011, only 13 233 of approximately 500 000 matriculants obtained above 70 % for mathematics and in 2012, a poor (50 %) matric mathematics pass rate for all the matriculants who wrote mathematics during 2012, which may inhibit learners (and later adults) from logically dealing with ordinary problems they may encounter in the future (Myburgh & Prince, 2014; McDougall, 2013).

- An unsatisfactory achievement standard in mathematics and physical sciences (Rademeyer, 2010, p. 7; McDougall, 2013).
- A lack of the necessary critical thinking skills required at university level in South Africa, which would prepare students for lifelong learning. This has induced Professor Jonathan Jansen (Jansen as cited in Rademeyer, 2012) to institute a new cross-disciplinary compulsory module, the UFS 101 module, for first year students at the University of the Free State.

Garry Kasparov, a former world chess champion (2013, pp. 1-2), maintains that education is the “most effective way to address poverty and violence”, and that it could counteract the negative effects of poverty prevailing in South Africa. He recently visited South Africa to promote chess instruction at schools and argued that it could play a vital role in social upliftment as an important ancillary to education in poor or rural areas (Kasparov, 2013).

Evidently, different measures are being called for to teach young children new skills and to facilitate cognitive development (Scholz *et al.,* 2008). Chess is one such measure that may be suitable to foster problem solving abilities in difficult subjects, such as mathematics and science (McDougall, 2013; Kemm, 2012; Kemm, as cited in Kostenuik, 2012; Kemm & Cloete, 2011). Certain researchers (Peterson, 2002; Sciammas, as cited in Ezarik, 2003) recommend that chess be taught as a school subject in those American schools where it is not currently included in the curriculum. Gobet, De Voogt and Retschitzki (2004) further argue that when educators or instructors incorporate principles of mathematics during chess instruction (or board games) in class, this facilitates learning processes.

Chess practice, with all the benefits it offers, therefore has the potential to make a contribution to the cognitive development and reasoning skills of children in South Africa. It is this aspect of chess that is the focus of the research reported in this dissertation. The basic assumption is that the development of cognitive functions are at the core of human intelligence and by exposing children (Grade R learners in this study) to chess instruction they could be helped to improve their cognitive functions (Ericsson, 1988; Scholz *et al*., 2008). As Sternberg (2003, p. 521) points out, learning does not come naturally for a pre-schooler, but with guidance and the necessary educational resources, children are able “to better perceive, learn, remember, represent information, reason, decide and solve problems”. An implication is that chess coaching and tutoring may facilitate learning processes in young children, and may even foster metacognitive skills as they gradually become aware that their chess skills are malleable when these begin to improve (Dewar 2009 - 2012; also see Kennedy, 1998).

1.3 Theoretical Concepts and Themes

The research reported in this study is motivated by some of the educational and social factors described above while it also focuses specifically on the relationship between chess and intelligence. The specific issue being addressed here is whether learning to play chess could have an effect on the cognitive development and intelligence of young children. Various theoretical concepts and themes are associated with the theoretical framework underlying the research conducted in this study. A few of the core themes and concepts are described briefly below, and will be further explored in the following chapters.

1.3.1 Acquiring expertise

The educational aim in complex scientific domains such as physics is to enable learners to develop knowledge and understanding that will make them expert problem solvers. Research in cognitive psychology seems to suggest that extensive practice is necessary to achieve expertise in what Waters, Gobet, and Leyden (2002) or Gobet, Chassy, and Bilalić (2011, p. 226) refer to as "knowledge-rich domains". In complex domains such as chess and physics, skills and knowledge develop over time and learners require considerable exposure to relevant information before they achieve competence and begin to demonstrate good problem solving techniques in the particular domain. The process of acquiring such expertise is usually conceptualised as a novice-to-expert shift. For example, in the domain of chess, achieving a high Elo rating in chess is usually regarded as one of the primary manifestations of such a shift. However, as Gladwell (2013) points out, the development of such skill or mastery in chess and other complex domains is a very lengthy process. In a now famous article, Simon and Chase (1973) maintained that the acquisition of expertise in chess involves upward of 10 000 hours of constant practice (see Gladwell, 2013**):**

> There are no instant experts in chess—certainly no instant masters or grandmasters. There appears not to be on record any case (including Bobby Fischer) where a person reached grandmaster level with less than about a decade's intense preoccupation with the game. We would

> estimate, very roughly, that a master has spent perhaps 10,000 to
> 50,000 hours staring at chess positions

The field of expertise still faces some open questions and challenges such as whether there are stages in the development of expertise (Gobet, 2012), and what exactly the contribution of innate talent is in the process of developing expertise. Researchers have pointed out various similarities between the acquisition of knowledge and expertise in chess, and learning in the educational environment. In both cases, children start off with small knowledge bases and poor metacognitive skills, lack well-developed problem solving abilities and do not possess sufficient experience and background knowledge to engage in any long-term strategic planning (Waaramantry, as cited in Subotnik, 1993).

1.3.2 The skilled memory theory

In this section, the skilled memory theory of Ericson and Polson (1988) is discussed first; thereafter the approach of Ericsson and his colleagues is presented. They argue that deliberate practice is sufficient to attain high levels of expertise (Gobet, 2012). Anderson’s Adaptive Control of Thought (ACT), a computational approach to learning and expertise, is also described and discussed briefly (Eysenck & Keane, 2005, p. 456).

De Groot (1965; 1966) was the first researcher to differentiate between experts and novices. Later, Ericsson and Polson (1988) incorporated De Groot’s findings on recall studies into their skilled memory theory. They postulate that according to their theory experts and novices exhibit fundamental differences and these fundamental differences can be attributed to chess playing, that is, deliberate practice. These differences are:

- Semantic networks are more richly elaborated in experts.
- Experts have quicker and more direct access to long-term memory due to the interaction between working memory and long-term memory.
- Information is more easily encoded into long-term memory by experts.

The skilled memory theory is related to Ericsson's theory of deliberate practice, which is discussed in the next section.

1.3.2.1 Ericsson's theory of deliberate practice

The game of chess can be learned in a fairly short period; but for a player to truly master the game takes several years (Wetz, 2004). Ericsson (1988) describes three requirements for a chess player to develop the problem solving and memory skills that are essential for the game. These requirements do not only apply to chess playing, but are also very important in problem solving in educational settings (see Ormrod, 2006, pp. 196-215, and 271-273):

- When studying new material, it must be carried out in depth and information must be assembled in a meaningful manner by relating it to prior knowledge. The latter aspect appears to be important in order to facilitate transfer.

- When knowledge is being retrieved from the long-term memory, it must be retrieved from the right place and relevant cues or pointers should be stored away with the information in the working memory to enhance later retrieval. When cues are stored, time is saved for important reasoning in problem solving and it demonstrates the adaptability of experts (also see Campitelli & Gobet, 2010).
- Where there is extensive practice, the processes involved in encoding and retrieval is likely to increase, thereby producing automatic actions.

Ericsson and Lehmann (1996) elaborated on the above-mentioned ideas and developed it into a general theory of expertise. According to their theory of deliberate practice, a wide range of expertise, which has four aspects, can be developed and all of which are conducive to learning:

- The task is at an appropriate or required level of difficulty.
- The learner is provided with informative feedback about his or her performance.
- The learner has sufficient opportunities for repetition.
- It is possible for the learner to correct his or her errors.

Ericsson (1988) further postulates that the development of expertise depends on deliberate practice and that the temporal aspect of this learning process is denoted in a specific curve, the Power Law of Practice. According to this law, the performance of an expert is a monotonic function of the amount of deliberate practice. However, Ericsson and Lehman (1996) argue that it is not just the accumulation of practice that is important in expertise, but rather the amount of deliberate practice in terms of time (i.e., approximately nine to ten years or from 10 000 to 50 000 hours), that leads to an improvement or maintenance of chess skill (Chase & Simon, 1973a). However, players at different levels need different amounts of deliberate practice, therefore practice alone is not sufficient for the acquisition of chess expertise (Gobet & Campitelli, 2007).

Deliberate practice comprises activities such as training activities, individual and group practice, independent reading, (serious) self-study, exposure to different problems and research. It is regarded as the primary change mechanism whereby higher order skills and numerous other skills can be taught (Jones 1990; Charness, Tuffiash, Krampe, Reingold, & Vasyukova, 2005).

Criticism against Ericsson’s (1988) theoretical approach, according to Eysenck and Keane (2005, p. 464), is that innate talent does not exert much influence on expert performance, but individual differences in innate ability are nonetheless also a factor that may affect expertise. It could be argued that individuals with high innate ability are the ones who engage in hundreds or thousands of hours of deliberate practice (Eysenck & Keane, 2005, p. 464). Numerous social, personality, and external factors may also exert an impact on practicing behaviours, such as early training and motivation provided by coaches (Ericsson & Charness, 1994).

Most of the techniques offered to explain the effects of practice and the acquisition of expertise have developed in the context of the production system models of cognition. Therefore Anderson’s Adaptive Control of Thought-Rational theory (Anderson, 1996) is discussed in the next section.

1.3.3 Anderson’s Adaptive Control of Thought-Rational theory (ACT-R)

According to Anderson’s (1990) Adaptive Control of Thought-Rational (ACT–R) theory, the cognitive system functions to optimise the adaptation of the behaviour of the organism (also see Sternberg, 2003, pp. 484-484 & 522). In this theory, declarative memory, procedural or production memory, and working memory form three interconnected systems (Eysenck & Keane, 2005, p. 456). Working memory contains information that is currently active.

Anderson’s crucial assumption of ACT-R theory is that skill acquisition involves knowledge compilation, with a progressive shift from the use of declarative knowledge to the use of procedural knowledge (Anderson, 1996). Declarative knowledge can usually be learned quickly and encoded as fairly small chunks. It constitutes a semantic network of interconnected concepts such as words, verbal symbols, relations, meaning, and rules. In this process, declarative knowledge is being transformed into production knowledge in the form of “if … then” production rules (Anderson, 1982, as cited in Eysenck and Keane, 2005, p. 456).

People obtain procedural knowledge when learning to perform skills which take more time and can be retained longer (Anderson, 1983). It is often not possible to gain conscious access to procedural knowledge, but whenever a production rule matches the current contents of working memory, automatic actions occur

(Anderson, 1990). Anderson (1990) maintains that skilled performance depends on procedural knowledge rather than declarative knowledge.

During composition, performance is improved by repeating or reducing sequences of actions to one efficient sequence (Eysenck & Keane, 2005, p. 464). According to Anderson’s ACT-R theory, there is also evidence of the process of proceduralisation which involves the creation of specific production rules in order to eliminate the necessity to search through long-term memory during skilled performance.

Criticism against the ACT theory includes the following:

- This theory cannot explain why the schemas formed by experts are extremely well-organised.
- Koedinger and Anderson (1990) discovered that the problem solving skills of experts are more systematic and occur at a higher level of abstraction than would have been predicted by the ACT theory.
- The ACT-R theory postulates that production rules acquired in one context should not be transferred to another context, but research has revealed that transfer does occur sometimes (Eysenck & Keane, 2005, p. 464).

In general, the ACT approach is most applicable to the development of routine expertise, and it is less appropriate with respect to expertise that is adaptive.

In the previous sections three important theories in expertise research, based on learning and practice, have shed light on the road to achieving chess excellence. In the next section, the best period to offer chess instruction is considered.

1.3.4 The issue of transfer

One of the aims in educational settings is to ensure that learners apply what they have learned in one domain or situation to other domains, contexts or situations, and thus to transfer from one academic subject to another or from chess to mathematics, or from academic subjects or chess to real-life situations (Eysenck & Keane, 2005, p. 446). This transfer of knowledge from one domain to another constitutes an important goal in education, because any carry-over effect of knowledge across domains facilitates the learning process (Detterman & Sternberg, 1993).

Ormrod (2006, p. 274) contends that knowledge acquired in an educational setting may be transferred in the following activities: problem solving (when one makes use of heuristics or principles learnt while studying a different subject), creativity in artistic domains, and critical thinking. Ormrod (2006, pp. 271–273) further maintains that the following factors influence the extent to which transfer occurs when new study material is presented in educational settings and in chess instruction:

- Sufficient instructional time must be provided.
- Meaningful learning must be engaged in fully.

- Learning of general principles must be shared by both domains (e.g., mathematics and chess) (Peterson, 2002).
- Examples and ample opportunities or time for practice must be provided.
- Minimal time between instruction and application must be allowed; and
- Perception of information must be context-free.

All of these factors can facilitate transfer in the early stages of learning or the development of expertise (Gobet *et al*., 2004).

Barnett and Ceci (2002) hold that transfer takes place only when there is a strong similarity in the knowledge or skills required in two domains. Likewise, Gobet and Campitelli (2006) contend that transfer from chess to other domains and vice versa is problematic and they also believe that the higher the level of expertise of a chess player is, the more restricted the transfer thereof will be. Gobet (2011) argues that the specialised knowledge of experts is partly coded as chunks and that this can lead to difficulty in transfer because the chunks involve pockets of information that have been specially coded for the specific domain of knowledge. Gobet and Campitelli (2006) also suggest that the human cognitive system operates with general mechanisms and therefore different types of skills and information are required from the environment, which limits transfer (see also Detterman & Sternberg, as cited in Sternberg, 2003, p. 381).

However, Gobet and Campitelli (2006) assert that most studies reporting transfer contain serious methodological flaws, for instance, investigations by

Redman (as cited in Gobet, 2011) indicated that only three studies (Christiaen & Verhofstadt-Denève, 1981; Frank & D'Hondt, 1979 and Fried & Ginsburg, n.d.) assigned participants randomly to the chess treatment group. Therefore the conclusions that can be drawn about the transfer of chess expertise to other domains are often limited. Gobet and Campitell (2006) suggest that when transfer studies are performed, three criteria must be adhered to in order to render them acceptable (Unterrainer, Kaller, Halsband, & Rahm, 2006). These criteria are:

- An empirical investigation must be performed;
- An objective measure must have (repeatedly) measured the potential effects in the study; and
- There must be sufficient detail in the study to evaluate the methodology employed and the results (Redman, as cited in Gobet, 2011).

Researchers should also adhere to other important requirements of methodologically sound or ideal experiments, namely random assignment of participants to the different groups, as well as the use of several treatment groups with more than one control group. Furthermore, both the participants and professionals (namely teachers) must be blind to the goal of the experiment and unaware of which participants are connected with an experiment. Unfortunately, these criteria and requirements are seldom observed in transfer studies.

The themes briefly discussed above form the broad theoretical framework in terms of which the research in this dissertation was conducted. Expertise, practice, and transfer are crucial concepts in this study because the general postulation is that children afforded extended instruction in chess will transfer some of the benefits of the knowledge and memory practice gained due to playing chess to other aspects of cognition and intelligence. However, before explaining the study in more detail, a few of the core concepts associated with the study are defined in the next section.

1.4 Clarification of Key Concepts

Some of the important constructs and concepts used in this study are explained below.

Automatic operations or a*utomatisms* refer to behaviour executed without conscious awareness, which refers to the ability to process information with little or no effort (Colman, 2006, p.70). Experts are able to make use of automatic operations during a perceptual search or in problem solving. This is made possible due to three different, but often combined aspects, namely a strong habit (conditioning), obvious procedural-sequential logic, and a hierarchical structure of the mental programme of the expert in operation (De Groot & Gobet, 1996, p. 77).

Deliberate practice and chess instruction: Ericsson, Krampe and Tesch-Römer (1993, as cited in Campitelli & Gobet, 2008, p. 446) contend that not any kind of practice will result in expert performance, but only practice “that is performed with the deliberate purpose of improving one’s own skill”. Deliberate practice consists of activities that are (deliberately) designed with the purpose of improving performance that requires considerable effort from the player and are not regarded as enjoyable or recreational (Gobet & Campitelli, 2007). In this study, the term *chess instruction* is used when referring to Grade R learners, as they are not able to read or write as yet, which is also an aspect of deliberate practice.

Expert or chess expert: Previous research (Campitelli & Gobet, 2008) indicates three different kinds of chess players, namely masters (as the best), experts, and intermediate players. *Expert or chess expert* is the term used throughout the dissertation when referring to the highest skilled player (master chess player) in the chess domain, when comparing novices with experts.

Expertise: According to Robinson-Riegler and Robinson-Riegler (2004, p. 504), *expertise* refers to “exceptional knowledge and/or performance in some specific problem domain”; in this study it refers to the chess domain.

Eye-walk: This is a learned (automatic) action or subroutine performed by expert chess players during the process of perception in problem solving, whereby the eyes are being scrolled or steered continually in a clockwise fashion during an active organised field search to detect patterns in order to act upon them (De Groot & Gobet, 1996, pp. 76–78).

Metacognitive skill: Ormrod (2006, p. 46) defines this as one’s knowledge and beliefs about one’s own cognitive processes and attempts which are used to regulate one’s cognitive processes to maximise learning and memory, in other words, our understanding and control of our cognition.

Novices: Novices and amateurs are chess players who can play a game of chess according to the rules, but are completely overshadowed by experts who have expert knowledge in the field of chess. The process of developing from a relative novice to an expert player is called the novice-expert shift (Ericsson, 1988).

Power of Law of Practice: The *Power of Law of Practice*, a law in cognitive psychology, captures a relationship between practice and performance in perceptual-motor skills, and describes the learning curve associated with specific cognitive skills (Eysenck & Keane, 2005, p. 421). This law indicates that when a chess player practises for hours and years, a general improvement in reaction time (the player becomes quicker at finding accurate moves) of the skill is captured in terms of a monotonically decreasing curve (Logan, 1988).

Skill acquisition: Skill acquisition refers to the developing of abilities through practice with the aim to increase the probability of goal achievement (Eysenck & Keane, 2005, p. 564).

Transfer: Transfer often does not happen, but when it occurs, it can refer to the facilitation or improvement of the performance of a task resulting from prior training on a different but related task (Colman, 2006, p. 774). Transfer is then described as the broader phenomenon of any carry-over of knowledge, skills or training that affects or is applied when learning or performing in another situation in problem solving (Detterman & Sternberg 1993, as cited in Sternberg, 2003, p. 381).

Positive transfer is the result of learning when a learner understands how to apply knowledge or skills learned in one situation to different contexts and thereby affects learning in another situation (Ormrod, 2006, p. 269).

Negative transfer, on the other hand, occurs when the two tasks involve similar stimuli and different responses, such as prior struggling in mathematics or in chess playing, which will hamper problem solving (Ormrod, 2006, p. 269).

Visualisation is regarded as part of an associative process which leads to skill at chess and is described as the summation of many learned skills and many previous steps (Fine, 1965, p. 364–369).

Visuo-spatial thinking: Ormrod (2006, p. 9) defines *visuo-spatial thinking* as the ability to imagine and mentally manipulate two- and three-dimensional figures. This kind of thinking appears to be related to some aspects of mathematics achievement, although the nature of the connection is not clear (Friedman, 1995).

Working memory (WM) is the conscious pool of attentional resources from which our information processing activities are drawn (Baddeley, 1992). The working memory (active memory) store is a temporary store which resides in the long-term memory store and forms part of performance intelligence (Sternberg, 2003, p. 161). Working memory stores only the most recently activated items of information from the long-term and short-term memory and manipulates and moves the information in and out of the working memory (Baddeley, 1995).

1.5 Presentation of the Research Problem

The research conducted in this dissertation is framed within the themes, constructs, and general research context described in the previous sections. These constructs and themes essentially define the theoretical framework underlying this study, and based on this the following research problem was identified.

1.5.1 Statement of the research problem

The research problem addressed in this study is whether chess playing and chess instruction has an effect on the intelligence of very young children. More specifically, the study investigated whether there was an accelerated development of specific aspects of cognition and intelligence of a group of young children exposed to chess instruction, compared to another group of children who did not receive such instruction.

The basic assumption is that chess learning and playing will influence specific aspects of cognitive development, and consequently have an effect on cognitive development as reflected by scores on an intelligence test, and as predicted by Ericsson's deliberate practice theory (Eysenck & Keane, 2005, p. 459). More specifically, it is postulated that there will be significant increases in the global and subscale mean scores of the Junior South African Intelligence Scales (JSAIS) in children who had been exposed to chess instruction (i.e., the experimental group) compared to children who had not been exposed to such instruction (i.e., the control group). Given this general supposition, the aim of the research study was to test the hypothesis on a sample of young children using an experimental research design (see section 2.8, where the formulation of hypotheses is discussed, for further detail).

The samples were taken from the predominantly Caucasian, Afrikaans speaking Grade R learners who attended school at Garsieland Pre-school in 2009 (see section 3.2.2 for further details). The participants comprised a non-probability, convenience sample of two groups.

1.5.2 Research methodology

The JSAIS was administered twice, once prior to exposure of chess instruction as a baseline (pre-level) and once thereafter (post-level). After completion of the second assessments, the data were analysed statistically by means of analysis of variance (ANOVA) using a Repeated-Measures Design. Multivariate analysis of variance (MANOVA) was used for the statistical analysis owing to the existence of various independent and dependent variables.

1.6 An Outline of the Remainder of the Dissertation

Chapter 2 furnishes the literature review of relevant constructs and discussions of theories. This study falls within the framework of the information processing paradigm in cognitive psychology and the relevance of this approach to elucidate how expertise develops is discussed. The effects of chess instruction on intelligence and specifically on performance intelligence as evident in experts in chess are also explored. A discussion of the research objectives and the formulation of hypotheses concludes this chapter. Chapter 3 discusses the methods used for data collection, which includes the research design, sampling, and the data collection methods as well as the ethical aspects thereof. The presentation of chess instruction to the experimental group is discussed briefly.

Chapter 4 reports on the results of the fieldwork in the empirical investigation, and the data profile and statistical methods used to obtain the results are also discussed.

In Chapter 5 the main implications of the findings obtained in the study are discussed. The results are related to the literature and theory in the chess domain, and thereby contribute to the existing knowledge in this field. The value and shortcomings of the study are also briefly discussed and recommendations and suggestions regarding future research, the implementation of the findings, and policy implications are furnished.

Chapter 2
Literature Review

2.1 Introduction

This chapter reviews some general research on the relationship between chess and cognition, and thus aims to present a theoretical context for the specific issue addressed in this study, namely whether learning chess has a beneficial effect on cognitive development and intelligence. The chapter begins by briefly discussing some of the research on the topic of cognitive development. Piaget's developmental theory of fairly fixed 'developmental stages' is introduced, and the information processing paradigm, with its focus on cognitive mechanisms, is then briefly presented. Thereafter, literature on the relationship between chess and cognition is considered, and research pointing to a possible causal connection between chess and intelligence cognition is discussed. The chapter concludes by setting out the research hypotheses that will be tested in the study.

2.2 Theories of Human Development

The aim of developmental researchers is to uncover the mechanisms that drive cognitive development, and thus to explain the contribution of genetic and environmental factors to this general process. It is generally acknowledged that young children's brains are still plastic or malleable until the age of about twelve years, and that it is mainly due to this plasticity that they manifest a remarkable ability to learn during this period (Gobet & Campitelli, 2007; Gobet, 2012).

2.2.1 Neural and genetic factors in development

Learning has a biological base and it is therefore evident that many physical changes have to take place in the brain for children to move from a state of relative ignorance to a state of complex cognition involving language, memory and reasoning abilities. Various neural macro-level organisational developments and structural changes are implicated in this process, for example, the development of associative networks linking different brain systems, and the brain will grow significantly in size (Ormrod, 2006, pp. 22-24).

However, even if the initial developmental period is mainly governed by genetic factors, there is considerable evidence that environmental factors also influence and facilitate learning processes in young children. Thus, Sternberg (2003, p. 519) maintains that young children benefit from additional stimulation in the form of enriching programmes (for example the Head Start programme in the United States of America) and also stimulating home environments provided by parents or caregivers. He further points out that while most researchers agree that intellectual skills can be taught, they disagree with regards to the “degree to which such improvements can be achieved and the means by which to do so”, and hence most researchers accept that there is a complex interplay between genetic and environmental influences that is not yet fully understood (Sternberg, 2003, p. 523).

Howe, Davidson, and Sloboda (1998) argue that extra stimulation may enhance normal cognitive development and foster the development of exceptional abilities. Likewise, Grieve (as cited in Foxcroft & Roodt 2005, p. 319) holds that children’s genetically determined developmental trajectories can be altered by environmental events. Grigorenko (2000) again suggests that while children's genetic inheritance due to nature may impose an upper limit of intellectual development, their individual cognitive abilities and intelligence can be still enhanced, possibly within a limited range, by exposing them to additional stimulation. Before venturing into greater detail about such stimulation, and the role that chess instruction could play in assisting the process, the theory of cognitive stages developed by Jean Piaget is considered briefly. Two caveats should be expressed regarding the approach presented here. Firstly, it should be pointed out from the outset that developmental psychology is an extremely large area of research, and that only a very brief survey of one issue relevant to this study, namely Piaget's notion of stages in cognitive development, is provided here. Secondly, because the overview is mainly intended to pave the way for an examination of the relationship between chess and cognition, it is limited in scope and focus.

2.2.2 Piaget's developmental theory

Jean Piaget's theory of cognitive development is very influential in psychology, and his theoretical framework and research findings continue to stimulate research in developmental psychology.

He is mainly known for developing an epigenetic theory of development in conjunction with his main collaborator Bärbel Inhelder (see e.g., Piaget, 1928; Inhelder & Piaget, 1958). Inhelder and Piaget (1958) consider pre-school children and children in elementary schools as neurologically immature, and contend that early developmental processes rely on maturational factors, and not only on the accumulation of knowledge. Their theory stresses the role of genetic factors, and hence the role that neurobiological structures play in the development of cognition. However, Piaget’s theory is also a constructivist theory. He maintains that children’s cognition and intelligence improve when they explore and discover aspects of the world, and that the ability to use and represent symbols must be constructed by experience and praxis before complex patterns of thinking and reasoning can unfold (Ormrod, 2006, pp. 24-31).

2.2.3 The concept of stages

Piaget theory of cognitive development is based on the notion of stages. He postulated four stages in his theory, namely the sensorimotor stage (from 2 to 6 or 7 years), the pre-operational stage (from 2 to 6 or 7 years old), the concrete operations stage (from 6 or 7 years until 11 to 12 years), and the formal operations stage (from 11 or 12 years through to adulthood). Some theorists posit a fifth stage, a post formal stage that might involve problem finding or a tendency toward dialectical thinking (Sternberg, 2003, pp. 458, 480).

According to Piagetian theory, the stages delineate a sequence of increasingly complex ways of thinking about objects and events, and reflect a fixed and universal number of incremental shifts that children pass through in their trajectory towards an adult understanding the world. During the concrete operation stage phase children's cognition becomes more logical, but it is still limited to concrete, observable objects and events. Craig and Baucum (2002, p. 332) contend that children throughout this phase seem intent on testing and challenging themselves not only physically, but mentally as well. In the formal operations stage, children become capable of formal operational thought and they can apply logical reasoning processes to abstract ideas as well as to concrete objects. As Campitelli and Gobet (2008) points out, this is probably why chess players typically begin to play competitively at this age. Other abilities that are important for sophisticated scientific and mathematical reasoning also develop at this stage which coincides with the period when plasticity in children reduces as a result of the consolidation of anatomical circuits.

There is some support for Piaget's theory, but also considerable criticism (Ormrod, 2006, p. 31; Grieve, as cited in Foxcroft & Roodt, 2005, p. 319). Therefore, his approach should rather be viewed as a theory of how children can think about the world, as the nature of cognitive development may be somewhat specific to different contexts, content areas, and cultures (Rogoff, 2003). Other researchers such as Vygotsky (1997) place a greater emphasis on social factors arguing that cognitive development is strongly linked to the input and information acquired via social interaction. Likewise, Ormrod, 2006 (pp. 465-467) and De Groot (1978) maintain that external instruction in the form of structured instruction and modelling must be provided by adults (e.g., parents, teachers, caretakers, and coaches) to children during the early stages of cooperative learning, and that this enables children to perform on a higher level. They contend that over time the support to children is diminished and children are gradually forced to take more and more responsibility for their learning as they progress. In this way children begin to drive their own learning or metacognitive processes (Vygotsky, 1997; Ormrod, 2006, pp 465-467).

2.2.4 From stages to information processing

Piaget's approach remains a historically influential contribution to our understanding of cognitive development, and its direct or indirect impact on subsequent research in this area is reflected in key research themes that have emerged from his programmatic work, and now characterise much of the contemporary research in cognitive science. These are briefly set out below.

2.2.4.1 The status of cognitive stages: discrete or continuous

Piaget's theory is based on the key idea that children's understanding and perception of the world emerge in discrete, genetically determined developmental stages, and that during each successive stage children acquire new, qualitatively different ways of mentally representing information. However, the assumption that the stages are discrete or discontinuous, is fairly contentious. Certain researchers argue that development is not characterised by qualitatively distinct and separate stages, but that it is much more of a continuous process and that there is considerable variability in task performance among children. Thus, Willingham (2008) maintains that not only will different children in the same age group perform different tasks differently, but that the same children may even execute similar tasks differently on successive days. Simulation studies using artificial neural networks have also demonstrated that stage-like transitions in development can be captured using neural networks without any specific qualitative change mechanism encoded in the network. Instead, the appearance of discrete changes is a purely emergent property based on an underlying continuous learning mechanism (see e.g., Quinlan, Van der Maas, Jansen, Booij & Rendell, 2007).

2.2.4.2 Development as a constructivist process

Piaget focuses on the acquisition and emergence of schemata, that is, schemes of how one perceives and understands the world, and he posits that in each developmental stage children acquire qualitatively different ways of mentally representing information. The theory conceptualises cognitive growth as a constructivist process, in terms of which meaning and understanding unfolds not just under the control of innate knowledge and abilities, but based on the gradual acquisition of knowledge through experience (Meyer, 2009).

Piaget asserts that children construct their knowledge and cognitive abilities by self-reflective action in the world in accordance with the processes of accommodation and assimilation. They adapt their knowledge and mental representation of the world based on their experiences in an ongoing manner. For example, children expect the world to operate in a particular way, but this expectation may be incongruent with reality, leading to failure (see Piaget & Inhelder, 1967, pp. 375-418). However, by accommodating this new experience and adapting their knowledge of the way the world works, they construct a more reliable mental conception, or model of the world. In essence, the constructivism asserts that children construct their knowledge adaptively by actions in the world.

2.2.5 Exploring cognitive mechanisms

It is within this broad theoretical landscape emerging from Piaget's work that much of the current research in cognitive development can be situated. However, Piagetian research is mainly concerned with empirical issues and attempts to describe cognitive development in terms of broad categories such as adaptation and assimilation. His approach did not entail a detailed investigation of cognitive mechanisms and he was not really concerned with the construction of testable models of cognition. Thus, Piaget postulated adaptation and assimilation as being two general processes underlying cognitive growth, but he did not really explore the cognitive mechanisms underlying these processes, nor did he formulate a model of how particular cognitive processes such as memory or perception emerge in young children.

Developmental researchers have extended Piaget’s theory in several broad directions, such as neo-constructivism (which will be discussed later in the chapter) and neo-Piagetian research. Neo-Piagetian researchers such as Robbie Case developed the notion of executive control stages as building blocks of different developmental stages and tried to explain how transitions between different stages occur (see Case, 1992, 1985).

He also addressed the issue of individual differences which Piaget did not incorporate into his theoretical framework. Of course, individual differences play a significant role in any complex domain such as physics, music, or mathematics. The notion of individual differences is also an important factor in chess where there is considerable variability in chess strength as reflected in markedly different levels of competitive play in chess tournaments, with concomitant effects on Elo-ratings.

2.2.5.1 Cognitive mechanisms in the information processing paradigm

Much of the research on developmental processes is now conducted within the information processing paradigm, which is an attendant computational metaphor to explain the machinery of the mind. The guiding idea underlying this paradigm is that information flows through a limited capacity system of mental "hardware" and "software" (Robinson-Riegler & Robinson-Riegler, 2004, p. 26). The framework is based on the notion of human computation, which is metaphorically borrowed from digital computers. The primary idea associated with this framework is that the mind can be conceptualised as the "software" running on the "hardware", the brain, and therefore, a functionalist and algorithmic description can be provided to capture different mental processes (Robinson-Riegler & Robinson-Riegler, 2004, p. 26-29).

The information processing paradigm has been extensively applied in research and theory development of various cognitive processes such as perception, memory, and learning. The approach using this paradigm is based on two main assumptions:

- Firstly, it is assumed that each of these cognitive processes constitutes an independent module according to a modular conception of cognition proposed by Fodor (1980). A divide and conquer approach is therefore used.

- Secondly, it is assumed in the early version of the approach ÷now known as cognitivism or GOFAI (good-old fashioned artificial intelligence)÷ that cognitive processes can be explained as mental rules and operations applied to internal cognitive representations. This

> framework of rules and representations underlies much of the early work in cognitive psychology and linguistics (Robinson-Riegler & Robinson-Riegler, 2004, p. 26).

The information processing account is mainly a perspective on how information and knowledge is represented and processed in human cognitive activities, but it implies a theory of learning. Essentially, the guiding notion is that learning becomes easier and therefore more efficient as the cognitive processes and procedures associated with the processing of concepts, tasks, and problems in a domain become more fluent and achieve automaticity. This notion that repeated practice facilitates the execution of cognitive processes is applied in cognitive developmental research, and is adopted to explain the acquisition of expertise in domains such as physics, chess, or music (see Ericsson, 1988). Before considering in greater detail how the information processing framework was applied to chess, it is useful to first examine the game of chess more closely.

2.3 The Cognitive Complexity of Chess

Together with the game ‘Go’, chess is one of the board games that has evoked considerable interest in cognitive psychology (see e.g., Gobet, de Voogt & Retschitzki, 2004). There are several reasons for preoccupation with chess in cognitive science and psychology. Firstly, although chess appears to be a simple game, and the rules of chess can be easily learned by novices, it is in fact cognitively a very complex game. It is very difficult to master all the intricacies of opening and end play strategies, and few players manage to achieve a standard play at international master or grandmaster levels. Secondly, there is a huge number of possible moves in a game of chess, and although some opening and end moves may be repeated in top competition-level games, the games are all different. In fact, Charness (1991) points out that there are about 50 000 opening variations in chess, and each of these could lead to millions of different middle games and end games. As Gobet, Chassy, and Bilalić (2011, p. 225) express it, in a chess game there are “arguably more possibilities than atoms in the universe”.

The complexity of chess has been demonstrated in mathematical and computational analyses. For example, one way to quantify the complexity of games is with the aid of the theory of computational complexity which was developed in discrete mathematics and theoretical computer science (Garey & Johnson, 1979). Computational complexity theory analyses problems in terms of their inherent difficulty. It is based on the assumption that an indication of the level of difficulty associated with problems is given by the resources (i.e., memory) and the time, which is measured as the number of computations (i.e., computational steps or state transitions), required to solve them on an abstract machine. More specifically, in computational complexity theory a distinction is drawn between the set of decision problems solvable by a deterministic Turing machine in $O(^{2p(n)})$ time, and those that cannot be solved by such a machine in polynomial time, because they require exponential (rather than polynomial) time and exorbitant memory resources. This very difficult set of problems is called the NP-complete problems, where NP is non-polynomial (Garey & Johnson, 1979). Currently, there is no known computer algorithm or mathematical method of finding correct solutions to the NP-complete problems in even any remotely practical amount of time, and many mathematicians doubt that such algorithms exist, although this has not yet been proven (see Papadimitriou, 1994). However, it may be possible to find an approximation to the correct solution by using heuristics, for example, using a guessing machine such as the oracle or super-Turing machines described in the theory of hypercomputation (Copeland & Proudfoot, 1999).

2.3.1 Analysing the computational complexity of chess

In the case of chess, the notion of solving chess entails calculating a method of winning the game. This, in turn, means finding a sequence of moves that will checkmate the opponent, starting from any given opening move that the opponent makes. Shannon (1950) estimated that the complexity of solving chess falls in the computational complexity class of EXPTIME, which is even more difficult to solve than the NP-complete problems. In a more recent, and rigorous mathematical analysis, Storer (1983) has demonstrated that for various opening board positions in chess, determining whether there is a winning strategy for one of the players constitutes a PSPACE-hard computational complexity task. In other words, he reaches a conclusion similar to that of Shannon (1950) by providing a mathematical analysis suggesting that solving chess is even more complex than the very difficult, intractable NP-complete problems (Storer, 1983). There is therefore some consensus in the mathematical analyses of the complexity of chess that it is not practically possible to compute a sequence of moves that is guaranteed to win the game in chess. The computational complexity of chess derives from the fact that even though it is a deterministic, perfect information game (i.e., nothing is hidden from either player), there is a veritable combinatorial explosion of possible moves in any reasonable chess game (i.e., one that is not concluded by a mate within the first 10 moves) (Shannon, 1950; Fraenkel & Lichtenstein, 1981). A recent analysis suggests that the number of reachable positions that are legal in a chess game (i.e., the number of positions that can be logically achieved in actual chess games that obey the rules of the game) may be an astounding 2^{155} (Open Chess, 2014).

Chess is not solvable by simple brute form strategies on even the most powerful supercomputers currently available. It is possible that in the future chess might be solvable on a quantum computer, but for that to happen, new algorithms for quantum computation have to be developed first because the current algorithms used in quantum computation such as Shor’s factorisation algorithm and Gover’s database lookup algorithm, cannot be applied to chess in any straightforward manner (Chess beta, 2014).

In the light of the excessive move complexity of chess, players have to develop knowledge of both opening theory and end play techniques. Chess is associated with a large number of different openings, each including best lines of play as well as possible gambit lines in which players have to know the risks associated with taking a piece sacrificed by the opponent. Competitive players thus learn openings of chess strategies and devote considerable time to studying the games of both classical players such as Capablanca as well as those of modern players such as Fischer, Kasparov, and Carlsen (Wikipedia, 2015). To learn to play chess at an expert level requires considerable time and effort, and even natural talent is not sufficient to guarantee success in the game; this requires hard work. Thus, Simon and Chase (1973) maintain that up to 3000 hours are needed to become an expert in chess, and more than 30 000 hours to become a chess master.

Ericsson *et al*. (1993) also estimate that ten years may be required to achieve the top levels of performance in complex domains such as chess, mathematics, and music (e.g., playing the piano and violin).

2.3.2 Strategic thinking in chess

Green and Gilhooly (2012, p. 320) note that chess is an adversarial game, because it is played against an opponent. In chess, knowledge of the opponent is an important factor, because players adapt their approach and opening to the strength and playing style of their opponent. Bluff techniques and other psychological strategies besides chess strategies also form part of the chess game. For example, if a chess player made a bad move, or one that he or she thinks could possibly be a losing move, it is preferable to keep a straight face (and suppress any impulses to show a reaction) and not alert the opponent, as the opponent may not have noticed the mistake, or the opponent may make an even more critical mistake (Waaramantry, as cited in Subotnik, 1993). Mikhael Tal (1997, p. 78), a former world champion in chess, observes that it is important to take the playing style of the opponent into account, and that he sometimes reserved dangerous variations “for a fight night surprise”. Likewise, Waitzkin (2007) describes his own approach to learning as well as various strategies tailored to specific opponents, which facilitated his own development in chess and helped him to become an international chess master (Waitzkin, 2007).

Consider the following anecdotal example as well. Recently, Gary Kasparov was furious on the social network media after being duped to play a much stronger player than he had expected. He presented a simultaneous exhibition in South

Africa to a group of 30 players, and was informed by the organisers that he would be playing a group of relatively weak chess players, all with Elo ratings below 1600. However, after playing several moves on the different boards, Kasparov discovered that one of the players was actually a strong international master with an Elo rating of over 2200; he vehemently objected to being cheated. Kasparov's reaction was captured on a *Youtube* video, which elicited considerable discussion on chess forums (see e.g. TalkChess.com, 2015).

Certain studies have also explored the extent to which learning and playing chess can improve business acumen or strategic thinking in a managerial context (see e.g., Cannice, 2013). As this discussion served to illustrate, chess is cognitively complex not only because of its inherent computational complexity, but also because strategic thinking and knowledge of the opponent are crucial factors in the game. Because it is such a complex and cognitively demanding game, the cognitive processes associated with chess, and particularly the connection between chess and intelligence, have been extensively researched in the cognitive sciences. In the next section, some of this research is reviewed.

2.4 Chess and the Cognitive Dimensions of Expertise

A research strategy that is extensively used in cognitive psychology to gain insight into the cognitive demands associated with complex domains is to explore the difference between experts and novices in such a domain. This research field is known as expertise, and the research aim is to discover what knowledge and problem solving abilities are required to become an expert in the relevant domain. As Gobet *et al*. (2011, pp. 225-227) point out, top players in sports such as tennis or cricket or games such as chess are capable of extraordinary physical and mental feats; so what sets them apart from ordinary players? Are they born with better physiological and mental characteristics, or do they only acquire these after very long and systematic practice? The role of extended practice in chess as well as in activities that require expertise more generally was discussed in Chapter 1. As noted, the theory of extended practice was elaborated by Ericsson (1988); this currently forms the main theoretical framework for explaining expertise. Ericsson and his co-workers attribute the superior performance of experts to the acquisition of an elaborate, domain-specific knowledge base, which they believe derives from exposure to the domain and extensive practice in problem solving tasks associated with the domain.

Prior to 1956, it was believed that the outstanding performance of an expert reflected some innate capacity or talent (for instance, some older theories emphasise a structural view of intelligence, namely the “*g*” factor of Spearman), but since the emergence of the cognitive psychology, this view has given way to what might be termed an information-processing model of intelligence and of expertise (Ericsson & Charness, 1994). Thus, Sternberg (2003, p. 494) postulates that human information processing theorists are interested in studying how people (or symbol manipulators) mentally manipulate, monitor or process what they learn and know about the world with the help of strategies such as those acquired in chess playing. In the case of expertise, the guiding notion is that experts have accumulated a rich knowledge base and strategies for dealing with problems in the target domain due to extensive exposure and long hours of practice (e.g., more than 10 000 hours) in the target domain (see e.g., Gladwell, 2008). In this vein, Ericsson and Ward (2007, p.

348) bluntly assert that “individual differences in more ‘basic’ cognitive processes (e.g. intelligence, memory capacity, and perceptual functioning) have not, to date, been predictive of attained levels of skilled performance”.

High official ratings of chess experts reflect their chess skill, and is indicative of the number of chess games that they had played and won in competition-level play during a certain year (Charness, Krampe, & Mayr, 1996). Chess experts further differentiate themselves from novices with regard to problem solving abilities in various ways (see e.g., Bédard & Chi, 1992).

- They have a very large repertoire of problem solving knowledge and an array of different problem solving strategies and heuristics. Some of the strategies are automatised which saves time, thus allowing more time for important reasoning. Their knowledge enables them to know when and where to use particular strategies when making decisions or solving problems in the relevant domain (Eysenck & Keane, 2001, pp. 413, 416 & 463–464; Green & Gilhooly, 1992).
- In the process of achieving excellence in a domain, experts not only learn to find creative solutions to problems, they also demonstrate some of the characteristics of creative people. Experts display much self-confidence; they have a high degree of intrinsic motivation, and an ability to persevere in spite of failure or adversities (Reed, 2000; Robinson-Riegler & Robinson-Riegler, 2004, pp. 476–477, 517; Goleman, 1995).

- Chess experts are very successful in decision-making and exhibit selectivity and accuracy in generating solutions. Their decision-making skills seem to derive from abundant practice, and are reflected in chess in the ability to make strategic and high quality move selections (De Groot, 1946). Experts are able to make better evaluations of board positions and problems than novices. Due to their knowledge and understanding of the game, they are also able to make accurate evaluations of chess positions and to calculate the results of tactical combinations (Holding, 1989a; Klein & Peio, 1989; De Groot & Gobet, 1996, pp. 5, 7 & 210).

When learners monitor their own learning processes, their metacognitive processes enable them to learn to understand why they have failed and they learn how to correct their mistakes and/or to avoid failure, which is a very important factor in chess (De Groot 1978, p. 125). Metacognitive skills contribute to experts' success in problem solving and decision-making because when experts regulate their cognitive processes, they do the following (Ormrod 2006, pp. 46 & 352–353):

- They identify and focus on the overriding goal, namely to arrive at a solution of a problem or to win a match and continually monitor their progress towards that goals.

- They employ a working forwards strategy in contrast to novices who mainly rely on means-ends analysis (i.e., dividing a problem into smaller parts and attending first to subgoals). Thus, experts would focus on the information given and devise a problem solving based strategy, whereas novices will try to work backward from what they perceive to be the solution and try to solve the problem one part at a time (Green & Gilhooly, 2012, p. 322). They plan problem solving by deciding ahead of time how best to use their time and resources, since both of these are cognitively scarce commodities (Gobet & Simon, 1996c).

- Experts evaluate their problem solving strategies and progress very carefully to modify their selection and use of various strategies in the future (Winne & Hadwin, 1998). This evaluation of strategies is particularly important in chess (Schunk & Zimmerman, 1997) where top players have to learn from their mistakes and adapt their play accordingly.

De Groot (1978, p. 125) maintains that problem solving in chess playing starts off with the external mode of instruction such as coaching, deliberate practice, and other factors, and over a period of years, is maintained by the internal mode of self-instruction of the chess player. However, researchers differ about the input of educators or coaches at different stages of learning or the acquisition of skills (Gobet, 2012; Waters *et al.,* 2002). There are still unresolved issues regarding the structure of the environment necessary to become a chess expert (Gobet, 2012). According to Judith Polgar (2013), one of the top 100 chess grandmasters, young chess players do not only need help from coaches, they also need a great deal of support (physical, and/or psychological) from parents, in various forms. However, not only young players, but even chess experts also make use of outside help, have assistants; they make extensive use of computational resources such as chess engines and databases to analyse positions and openings (Computer-chess Wiki, 2013).

The nature of expertise and also the specific relationship between chess and cognition have been extensively researched with reference to a variety of different cognitive processes. Some of this research is now briefly reviewed.

2.4.1 Perceptual processing abilities

The ability to perceive correctly in reading and learning in educational settings is very important, because if learners perceive incorrectly, they could experience problems in reading, with detrimental consequences/outcomes, for instance, low confidence in their abilities (Clutton, 2007; Schneck, 2005, p. 420).

In the context of chess, ‘perception’ denotes a form of visuo-spatial reasoning in which players contemplate the results of different moves based on the configuration of chess pieces on a board. They have to visually search through the consequences of various plausible move sequences (De Groot & Gobet, 1996, p. 75). In this manner, chess players try to make sense of the proverbial chaos in a complex tactical position in order to find the correct positional strategy. Chess experts routinely apply many of the visual techniques for figuring in technical analyses of sport psychology, for example, goal-directed organised field searches, the construction and manipulation of imagery, mental modelling methods such as eye walks through a position or game, and chess-specific visual iterative analyses (Schunk & Zimmerman, 1997; De Groot & Gobet, 1996, p. 75).

Out of choice or necessity, humans are able to modulate their connection with the environment and hence how much information they want to receive from it (Gobet, 1997; Gobet & Simon, 1996a). The two processing procedures required for the process of perception are bottom-up (or data driven) and top-down processing (concept-driven). Bottom-up processing refers to processing based on environmental data, but when context, previous knowledge and/or expectations derived, from existing knowledge are invoked to identify a stimulus, it is called top-down or conceptually driven processing with focused attention (Eysenck & Keane, 2005, p. 556). Chess players make use of both processing procedures; for example, when they are scanning a chess board under strategic control, they employ top-down processing because they draw from their large knowledge bases (Jongman, 1968). Owing to extensive practice, these processes eventually become ingrained and scanning and interpretation can occur almost instantaneously.

De Groot & Gobet (1996, pp. 80–83; 224) describe two stages in perception in the context of chess expertise, namely:

- An elaborate search of the chess pieces in the perceptual space, guided by attack and defence heuristics and by long-term memory, which results in a complex pattern of chess pieces stored; and
- The detection of highly informative perceptual features, which includes the selection of a perceptually critical characteristic or a threatened chess piece.

The first rule of (the internal mode of) self-instruction applies to the first stage in perception, when an expert begins to search the chess board during an active search routine during a perceptual search (De Groot, 1978, p. 125). Experts perform a more selective search in routine problems and typically search no deeper than non-experts, but when the task demands it, they can contemplate (i.e., search through) different solution paths to great depths and with intense concentration (Gobet, De Voogt, & Retschitzki, 2004).

De Groot and Gobet (1996) propose that chess experts have an early advantage to novice chess players in perception, for the following reasons:

- Experts do not only view a problem differently than novices, they are also able to intuitively find a solution and solve it, probably made possible by the presence of perceptual chunks (Holding, 1985, 1992; Gobet, 2011). Experts also make use of different perceptual strategies in recall during the first seconds of seeing a position.
- Threats can be perceived automatically owing to quite a large number of highly tuned automatisms (De Groot & Gobet 1996, pp. 75 & 78, 86–91).
- There is also evidence in a study carried out by Ferrari, Didierjean, and Marméche (2006) that experts make use of anticipation processes during the encoding of the information into a different form.

All these factors and skills enable chess experts to be very successful in decision-making.

When experts perceive, they also make use of an internal representation of the external board as an aid to update the game they are following. As a result of practice, experts possess very powerful, abstract, and visuo-spatial internal mental representations, which they use in problem solving, generating moves or in blindfold chess. They are also very quick to generate moves in the mind's eye (De Groot & Gobet 1996, pp. 104, 112 & 232). Structures in the mind's eye can be subjected to visuo-spatial mental operations and new incoming visual information can be abstracted from them by separating the relevant and irrelevant information from each other (Chase & Simon, 1973). Thereby experts can ignore irrelevant perceptual information and contribute to more successful problem solving (Campiteli & Gobet, 2005, pp. 23–45).

Pattern recognition plays a major role in chess excellence. It consists of two mechanisms, namely forward search and mental imagery, which enable experts to make good decisions (Gobet *et a*l., 2004; About.com Chess Guide, 2002-2008). Pattern recognition refers to each time that an expert encounters a new position, their previous experience helps them to find the right pattern in the new position. After recognition of similarity and pattern, a global strategy can be developed to solve problems and experts can generate alternatives (About.com Chess guide, 2002-2008). Pattern recognition happens automatically, instantly, and very quickly by experts in recognising chunks in a board position (Chase & Simon, 1973a, 1973b). Experts are also more accurate than less skilled players in recognising chess configurations, which has been theoretically ascribed to their very elaborate networks of knowledge and the nets and the vast amount of nodes and connections in these networks (Reynolds, 1982). The networks of novices are still reasonably small, and have been estimated as typically comprising only about 200 nodes (Gobet as cited in De Groot & Gobet, 1996, p. 259). The very fast, almost intuitive type of processing exhibited by experts may thus derive from their superior content knowledge and pattern recognition abilities in the particular domain (De Groot & Gobet, 1996, pp. 250 & 259).

2.4.1.1 Visual imagery, visualisation, and visuo-spatial abilities

Various researchers (Frydman & Lynn, 1992, p. 235; Howard, 1999 & 2005; Campitelli & Gobet, 2005; Saariluoma, 1992) maintain that visual imagery, visuo-spatial abilities and visualisation are important in chess expertise. Gobet (1997) postulates that results in a study emphasised the role of long-term memory in expertise and suggests that players use processes that enable them to smoothly combine information from the environment with mental images. Visual imagery plays an important role in learning and is regarded as a link between pattern recognition and move selection, therefore it plays an important role in problem solving (Gobet, 2003). However, little is known about the role it plays in problem solving such as the link between expertise and the use of mental images and how expertise mediates mental images (Campitelli & Gobet, 2005, pp. 23-24). Further research is therefore needed in this regard.

Waters *et al.* (2002) propose that the three studies (Frydman & Lynn, 1992; Frank & D'Hondt, 1979; Horgan & Morgan, 1990) performed on young chess players indicate a correlation between chess skill and visuo-spatial abilities in children, as measured by performance intelligence psychometric scales. However, Gobet and Campitelli (2006) argue that such scales do not only relate to visuo-spatial skills, as assumed by researchers, but measures a slew of non-verbal abilities (Frydman & Lynn, 1992).

Studies on adult players carried out by researchers (Djakow *et al*., 1927; Schneider, Gruber, Gold, & Opwis, 1993; Doll & Mayr, 1987) do not consistently support a link between chess skill and visual memory ability. In a study conducted by Doll and Mayr (1987), the findings indicate that there was an improvement in intelligence, information processing, and processing speed, but no improvement in visuo-spatial tasks. Djakow *et al*. (1927), found that there were no differences in general intelligence or visuo-spatial memory, except where meaningful chess positions had to be recalled. Waters *et al.* (2002) also compared the performance of very skilled and less skilled adult chess players on a psychometric measure, but visual memory ability did not correlate with chess skill. According to Waters *et al.* (2002), it is possible that visual memory abilities, and perhaps visuo-spatial abilities, are important (Frydman & Lynn, 1992) in the early stages of the development of chess skill (when domain knowledge is low), but not important in the long-term acquisition of chess skill. Chess players can become chess experts without having outstanding visual memory abilities.

In the previous section, processing in perception and the early perceptual advantage that experts have over novices were discussed. In the next section, attention will be discussed, illustrating how experts can overcome the normal limits of attention.

2.4.2 Attention

Attention can be defined as a set of processes which one uses to monitor and focus on incoming information (Robinson-Riegler & Robinson-Riegler, 2004, pp. 2 & 106). This cognitive process can be regarded to be essential for learning, because for explicit learning processes at least, information must be first attended to before it can form the focus of learning processes (Ormrod 2006, pp. 191–192).

Young children tend to be quite distractible, but they gradually become less so as they grow older (Ormrod 2006, p. 43). In certain studies (Betz & Niesch, 1995; Gobet & Campitelli, 2006; Scneider, Gruber, Gold, & Opwis, 1993), research findings indicate that there is evidence of transfer of chess playing to higher attention abilities, for example, children who learn to sit still and concentrate in educational settings, as well as take an interest in school matter in underprivileged environments (Gobet, 2011). The improvement in concentration is very important to educationalists because it applies directly to everyday life (Salomon & Perkins, 1989). According to De Corte (2003), this type of (positive) transfer can be facilitated by the development of metacognitive skills, a very important aspect of intelligence, in educational settings as well as in chess excellence (Sternberg 2003, pp. 309, 464). After years of deliberate practice, the eye fixations of experts are faster than those of novices when they direct their attention during a five-second presentation of a position or in the move space. Furthermore, experts concentrate on key features of the situation, (De Groot & Gobet, 1996, p. 161). Even though chess experts experience lapses in concentration and also make mistakes, they are able to concentrate their attention for much longer periods than novices when they compete in tournaments and in simultaneous chess. While playing chess, experts probably switch their attention between different aspects of the position and they demonstrate heightened attention control by focusing on problematic positions for extended times (Gobet as cited in De Groot & Gobet, 1996, p. 259). Thus, the chess grandmaster Trois from Brazil once pondered for 2 hours and 20 minutes to make his seventh move in a chess game (Chess poster.com, 2000).

Although humans are in general only able to concentrate on one task at hand, extended practice enables them to execute two or three well-learned, non-demanding, automatic tasks at the same time (Eysenck & Keane, 2005, p. 178). Hunt and Landsman (1982) maintain that more intelligent people may have learned how to use their brains more efficiently by focusing their thought processes on a given task as well as by allocating time more efficiently between two tasks (divided attention) and to perform tasks effectively (see section 2.4.3.1 for further detail, where processing and capacity limitations in WM, is discussed).

In selective attention, most evidence supports the existence of a bottleneck in processing in early-selection theories, where the filtering step occurs before incoming information is analysed to determine its meaning (Treisman, 1964). The stage at which selection occurs is flexible to an extent and depends on the perceptual load (Eysenck & Keane, 2005, p. 184). However, experts are often capable of overcoming such bottleneck constraints in attention and working memory by developing efficient access to long-term memory (Ericsson & Kintsch, 1995). In the next section *working memory* is discussed for greater detail.

2.4.3 Problem solving and working memory

Working memory capacity predicts performance on a wide range of complex cognitive tasks, including measures of general intelligence and practical cognitive skills. Problem solving and reasoning typically occur in working memory, entail cognitive processing of relevant information drawn from memory, and are carried out over a sequence of different knowledge states (Mayer, 1990, p. 284; Drummond, 2000).

2.4.3.1 Processing and capacity limitations in working memory

Working memory is a limited capacity system because information is only held in this system for relatively short periods. For this reason, Campitelli and Gobet (2010, p. 361) argue that because time is important in expertise, in intelligence, and as a (limited) resource, it “should be allocated wisely”. Sternberg (2003, p. 500) postulates that more intelligent people allocate their time differently from the way less intelligent people do. More intelligent people spend more time planning for and encoding the problems they have to deal with, but less time engaging in the other components of task performance. This is also true in regard to the difference between chess experts and novices (Campitelli & Gobet, 2010).

Ormrod (2006, pp. 32, 347 & 529) contends that no problem solving can occur when the working memory capacity has been exceeded or if the normal limitations of working memory have not been overcome. However, some researchers report that learners can display improved functioning of their respective working memory stores after exposure to chess classes (Scholz *et al*., 2008; Schneider *et al.,* 1993).

2.4.3.2 Expertise and overcoming the normal limits of working memory

To attain expertise in a domain requires extensive practice and the acquisition of relevant knowledge and skills, but in addition to this, becoming an expert in a domain entails overcoming some of the capacity limitations of working memory. Research suggests that there are two ways in which experts can achieve this.

Firstly, the use of organisational strategies such as chunking helps to increase the capacity of working memory (De Groot & Gobet, 1996, p. 102). Expert chess players appear to employ this strategy when they memorise board positions, and some research suggests that they chunk a chess board into several familiar units enabling them to quickly access information about chess positions. In this way, experts are capable of holding and processing more information about board positions (2.5 pieces up to five boards) than novices (about 1.9 pieces) in working memory (Chase & Simon, 1973a).

Secondly, extensive exposure and practice of problems in a domain eventually culminates in a form of automatic processing, which in turn enables experts to process information very fast and effortlessly. For example, when certain visuo-spatial patterns (chess openings), pertinent equations (physics) or calculations and theorems (mathematics) are easily accessible to working memory owing to practice, this will free up processing resources which can then be devoted to other aspects of the problem solving task.

There are also some additional factors to consider.

- The rich knowledge bases of experts facilitate the transfer of information from long-term memory to working memory (Ericsson & Kintsch, 1995). Experts have large interconnected knowledge structures in their domain of expertise, and can probably access these via a variety of retrieval cues from working memory. For example, strong chess players will have memorised most of the 30 best opening moves of the Queen's Gambit, and can therefore quickly process and play positions associated with this opening, freeing resources in working memory. Certain researchers argue that this type of increased working memory capacity probably applies only in domains such as mathematics, physics, music and chess (Ericsson & Delaney, 1998, pp. 104–105).

- An assumption made in some of the research on working memory described above is that becoming an expert in a domain coincides with an improvement in working memory capacity. However, it is also possible that expertise depends on possessing a good working memory, and that people with a high-functioning working memory are more likely to become experts in a domain than those with a weaker working memory. Thus, Sternberg (2003, pp. 494–499 & 522) also argues that intelligence has a strong relationship with working memory, because intelligent individuals are able to divide attention successfully and possess the ability to manipulate more information within a given period than less intelligent people. To some extent the relationship between working memory and expertise is still a chicken-egg problem. The direction of the causal connection has not yet been established.

2.4.4 Expertise and long-term memory

The relationship between expertise and long-term memory is now well established in literature. Experts are generally thought to have acquired extensive domain-specific knowledge of rules, concepts, and patterns in their domain as well as problem solving abilities that have been honed over many years of practice. This is also true of top chess players.

However, people experience difficulty remembering things which they were taught for various reasons, for example, interference, memory loss, or missing cues needed to process information. The latter though can be problematic when recalling the information that is needed (Schacter, 1999). Chess experts display lower rates of forgetting than novices in the chess domain and an almost immediate understanding of many positions so that Gobet *et a*l., (2004) postulate that experts have detailed information about chess positions stored in their long-term memory (Eysenck & Keane, 2005, p. 452; Gobet & Simon, 1998a). In fact, numerous studies indicate that chess experts have excellent memories of board positions and classic chess games (Djakow *et al.,* 1927; De Groot, 1946 and 1978; Chase & Simon, 1973a; 1973b).

Gobet and Simon (1996a and 1996b) indicate that strong chess players have excellent recall not only for the positions of the game that they are playing, but also for random legal chess positions in chess (i.e., positions that could arise from a game of chess), and that they can accurately recall these positions after being exposed to them for only a few seconds. They seem to have acquired chess-specific knowledge structures, such as chunks and schemata, which are stored in their long-term memories as a result of prolonged chess practice (Gobet & Simon, 1998a). Research suggests that chess masters could have approximately 100 000 chunks of knowledge associated with chess positions which play a role in evaluating combinations and deciding on the best line of play (Gobet, 1997; Eysenck & Keane, 2005, pp. 453, 464 & 565).

When chess players keep on practising chess, they make use of these chunks, which become large, abstract templates or complex data structures, similar to a schema(s). Templates consist of both fixed and variable information and experts possess far more templates and chunks than novices. These retrieval structures are also interconnected (with one another) to allow rapid integrative and non-deliberate encoding of board locations into long-term memory as well as rapid access to other templates (Eysenck & Keane, 2005, p. 453).

In this section, some of the cognitive structures and processes associated with learning and the development of expertise in chess were discussed. The focus of this research falls on how expertise in a complex domain such as chess develops, which does not entail any specific assertion about the relationship between chess and intelligence. In the next section, some research about the latter relationship is reviewed, beginning with a brief discussion of approaches to intelligence, and then a presentation of some research in which the connection between chess and intelligence has been explored.

2.5 Theories of Intelligence

Intelligence was and remains a controversial and multifaceted construct. Researchers have identified various characteristics associated with this construct. As a result, the status of the research field associated with intelligence remains rather murky due to a lack of theoretical consensus on what exactly constitutes intelligence as a cognitive ability and how it is best measured (Ormrod, 2006, p. 586).

Sternberg (2003, pp. 484–485 & 522) groups the definitions proposed by fourteen psychologists into two common themes, namely the capacity to learn from experience and the ability to adapt to the environment one lives in coupled with metacognition and the role that one’s culture plays (also see Anderson, 1990 & 1996). Ormrod (2006, pp. 140-141) also emphasises other components of what some theorists consider that which intelligence should encompass, for instance, that intelligence is not a permanent unchanging characteristic, because it can be modified through experience and learning (for instance by chess playing) (Sternberg, 1979; also see Sternberg 2003, pp. 508–510). The latter characteristic of intelligence can therefore be considered to be important for educational applications (Ormrod, 2006, pp. 147–148).

The traditional psychometric scales used to measure intelligence are typically based on Western culture. Thus, reaction speed is an important psychometric measure of numerical intelligence, but in certain non-western cultures, speed of processing is not considered to be an important factor (Ormrod 2006, p. 143). Furthermore, many characteristics regarded as important in science and art are not measured by traditional intelligence tests, such as creativity, intuition, motivation, goal-setting, and planning (Sternberg, 2003, p. 510). According to Wagner (2000), traditional intelligence tests also mostly measure analytical abilities and there is little assessment of relative and practical aspects. For this reason, certain researchers (Sternberg & Kaufman, 1996) argue that these intelligence tests are one-sided and they maintain that there is a need for changes in the assessment of intelligence and that a more well-rounded assessment system is needed.

Sternberg (2003, pp. 485-522) identifies two different historical traditions as a base for contemporary measurements of intelligence or cognitive abilities. Researchers emphasise either the structures or processes underlying intelligence, or they attempt to integrate various approaches into comprehensive models of intelligence (Sternberg, 2003, pp. 485-523).

2.5.1 Theories emphasising structures of intelligence

Theories of the structures of intelligence focus on individual differences, various factors, and the psychometric assessment of intelligence. This approach includes:

- The “g” theory of Spearman (1863–1945) poses that intelligence is based on factor analysis, where intelligence is viewed as a function of one general factor, “g” where this single general factor can explain all the differences between individuals (Sternberg 2003, p. 491). It can be regarded as the result of mental energy.
- Cattell (1905–1998) in his two-factor theory elaborated on the one general factor and states that Spearman’s “g” could be split into two

separate gs, which he called “gf” or fluid intelligence (also called performance intelligence) and “gc” or crystallised intelligence, regarded as responsible for intelligent behaviour.

- Thurstone (1887–1955) argues that the essential part of intelligence resides in numerous (seven) factors in his primary-mental abilities model, namely verbal comprehension, verbal fluency, inductive reasoning, spatial visualisation, number, memory, and perceptual speed (Sternberg 2003, p. 493).

Some researchers subscribing to such a structural conception of intelligence (e.g. Jensen, 1998; Carroll, 1997) hold that there is still support for Spearman and Thurstone’s theories of intelligence and both still influence current research. The focus in Cattell’s theory falls on the measurement of differences in reaction time, and since 1980, once again a focus fell on reaction time (Foxcroft & Roodt 2005, 176). For example, the JSAIS which was used to measure levels of intelligence functioning in this current study is based on the two-factor theory of Cattell (1905-1998). This instrument is discussed in the next chapter.

2.5.2 Theories emphasising processes of intelligence

Alternative approaches to intelligence emphasise the *processes* of intelligence, and are concerned with the cognitive and information processing aspects of intelligence and not only with psychometric assessment (Sternberg 2003, pp. 494-499). Researchers such as Gardner (1993b) and Sternberg (2003, p. 508) have attempted to integrate the various approaches to intelligence into comprehensive systems models of intelligence, which seek to extend beyond the pure psychometric framework (Sternberg 2003, p. 522).

2.5.2.1 Gardner's theory (1993b) of multiple intelligences

Gardner (1993b) developed a theory of multiple intelligences consisting of a bodily, kinaesthetic, logical-mathematical, linguistic, spatial, musical, interpersonal and intrapersonal skills or intelligences, and natural intelligence, which broadened the view of intelligence (Sternberg 2003, pp. 506–508). A person can represent more characteristics in one type of intelligence than in another. The logical-mathematical intelligence in this theory probably best describes the type of intelligence associated with games such as chess.

2.5.2.2 Sternberg's triachic theory

Sternberg (1984; 1985a) postulates multidimensional characteristics comprising three abilities such as compensational intelligence, experience intelligence and contextual intelligence in his theory of human intelligence. Different factors are important in these abilities, namely cognitive processes such as knowledge acquisition and metacognition play a role in compensational intelligence; prior experience of novel to highly familiar tasks and situations associated with the experiential sub-theory of intelligence, and adaptation, selection and shaping of the environment are regarded as important in contextual intelligence. The theory further attempts to account for diverse aspects of learning in educational settings such as how an 'intelligent' person tries to make the most of his or her strengths, and also attempts to find ways to improve his or her weaknesses. For example, the experience sub-theory is meant to explain how a top chess expert would practise for several years to improve his or her chess skill, and thus highlights the importance of instruction in shaping intelligence (Ormrod 2006, pp. 144–147). While Sternberg’s triarchic theory still essentially conceptualises intelligence in terms of the analytical aspects stressed in information-processing theories, it also incorporates the practical and creative components of intelligence (Sternberg 2003, pp. 508–510).

2.5.3 Distributed intelligence

Numerous other theories of intelligence have been developed by researchers who draw attention to various other aspects associated with intelligence or the manifestations of intelligent behaviour. Thus, Goleman (1995) presented a theory of emotional intelligence, which stresses the interpersonal aspects of intelligence, and the ability to sense the emotional reactions of others and use this to guide thinking and behaviour. Hutchins (1995) elaborated the theory of distributed intelligence which is ecologically oriented and considers aspects such as how crews of naval intelligence cooperate during a navigation task, thus manifesting a form of collective intelligence in which components of the overall task are spread out or distributed among a group of agents. The theory of distributed intelligence postulates that intelligence is not only in the mind, but constitutes a nexus of body and mind, and that the environment also contributes importantly to intelligence and forms an extension that facilitates intelligent behaviour. It thus emphasises the embodied aspects of cognition and intelligence, and breaks away from the purely internal representational framework prevailing in the cognitivist tradition. In the embodied approach, the assumption is made that agents “off-load” parts of their cognitive processing by exploiting aspects of the environment external to the body, so that cognition is distributed across the agent and the “physical, social, and cultural environment” (Stanford encyclopedia, 2011, pp. 1-2, 2011).

As this short discussion indicates, intelligence (and indeed also cognition) is a theoretically loaded concept and there is no simple agreement among researchers about what it really designates. Nonetheless, in chess research, a fairly straightforward psychometric conception of intelligence is typically adopted, because the main focus falls on measuring intelligence and comparing for example, IQ to Elo-rating. Two issues of particular interest in chess research are (a) whether good chess players are generally smarter than average, and (b) whether there is a transfer from complex domains such as chess to either intelligence, or to performance in other domains. Alternatively stated, (b) relates to the question whether learning chess will exert a positive effect on intelligence and performance in subjects such as mathematics. We now turn to consider this issue of transfer in the next section.

2.6 Transfer between Domains: Chess and Intelligence

Chess has been called the drosophila of both cognitive psychology and artificial intelligence because certain researchers believe that achieving an understanding of the cognitive and computational processes associated with a complex domain such as chess, and an analysis of expertise in the domain, will open a window into the mechanisms of mind. They also believe that such research may reveal some ideas for developing intelligent machines (Ensmenger, 2011, p. 1).

On a relatively basic level, research on chess within cognitive psychology at least, has focused on the issue of whether problem solving abilities associated with expertise transfer to other aspects of cognition. Transfer is a widely researched topic in studies of expertise, and there are several issues attendant on this notion. One issue is whether attaining expertise in a particular domain is associated with a generally more efficient method of processing information, which would then be reflected in enhanced abilities to process information in visual perception, memory, and problem solving abilities by experts in relation to novices. This issue was dealt with in the previous section. A more fundamental issue is whether attaining expertise in a particular domain such as chess would also facilitate learning and foster achieving high levels of performance in other domains such as physics and mathematics. Here, the issue is whether there is some transfer of expertise from one domain to another.

The transfer of knowledge across domains is evidently very important in learning, and in chess a core research question is whether there are any positive carry over effects to other disciplines with regards to learning chess. In the exploration of such effects, most research has been concerned with relatively short-term effects, and quasi-experimental rather than rigorous research designs. There have been some attempts to explore long term benefits such as the study conducted by Bilalić, McLeod and Gobet, (2007) on children who had just started learning chess with the aim of charting their development over a period so as to investigate the long term effects of exposure to chess. However, for the most part, relatively short correlational research has addressed this topic with mostly equivocal findings as discussed below.

One aspect associated with the notion of transfer that has evoked considerable attention, relates to the question whether expertise is causally linked to general intelligence. This aspect is of particular interest in the case of chess, because there is a fairly pervasive perception among the general public that good chess players are smart people, and that a high level of intelligence (i.e., high IQ) is required to play very good chess. There is some support for the belief that chess players constitute an elite class. Thus FIDE news (2013) reports that 78 % of the World Chess Federation's (FIDE) chess players in the United States of America are university graduates; they are academically better qualified and more informed than people who have never played chess and they enjoy higher incomes (over $120.000) than non-chess players. Levitt (1997) argues that different levels of expertise in chess can be mapped against IQ levels in countries; his argument is based on statistical distributions. Thus, he maintains that the probability of achieving a grandmaster norm in a given country is equivalent to having an IQ of above 160, and derives an equation (the Levitt equation) in support of this postulate.

The implication of Levitt's position is that expert-level performance may simply derive from the statistical distribution of performance ability relations in the general population, and thus from individual differences. In contrast, Ericsson in various publications argues that expertise is gradually acquired through extensive practice and the acquisition of domain-specific knowledge structures (Ericsson, 2013). There is certainly no reason to believe that Levitt's simple distributional argument resolves the intricate and fundamentally unclear relationship between chess Elo-rating and the intelligence necessary to achieve it. There is insufficient data of measurements, and there are a large number of nuisance variables to consider. In this regard, Bilalić *et al*. (2007) argue that there is little evidence supporting the widespread conviction that chess players are smart and that many studies that have explored this topic suffer from methodological problems. For example, the amount of practice and years of experience are not taken into account; instead, researchers tend to focus on one variable (intelligence) and ignore other variables that may impact on the acquisition of skill in chess.

Other researchers maintain that some threshold level of intelligence is required for the attainment of expertise. Thus, Grabner (2014) conducted a meta-analysis of several studies that have employed psychometric tests of intelligence in research on chess. He argues that the results of this analysis confirm that expert chess players do indeed possess above-average intelligence, that their playing strength in chess corresponds with their individual levels of intelligence, and that they display significantly higher intelligence than the controls. He thus notes that these results clearly demonstrate that “expert chess play does not stand in isolation from intelligence” (Grabner, 2014, p. 310).

Similarly an analysis performed by Howard (2009) on a longitudinal data set of a large group of chess players (n=3471) showed that there were considerable individual differences that cannot be attributed solely to differences in the amount of practice devoted to the game. Some players attained expert-levels of performance more quickly and with fewer games than others did. A factor analysis of various variables in the data set found evidence for an underlying natural talent factor that seemed to affect the performance level that was ultimately attained.

In the current state of research on the relationship between intelligence and chess, it therefore seems that there is still no consensus about whether extended practice is sufficient for expertise in chess or whether some innate ability thresholds may constrain the process of becoming an expert in complex domains such as chess.

2.6.1 Transfer to mathematics

Several studies have reported positive effects of chess instruction on mathematical problem solving or numerical thinking, but only a few of these studies are generally deemed to have applied sound methodological methods (e.g., Frank & D'Hondt, 1979; Fried & Ginsburg, n.d.; and Scholz, *et al.*, 2008); thus no really valid conclusions can be drawn regarding the relationship between chess and mathematics. However, Isabella (as cited in McDonald, 2010) reviews a number of different studies which have demonstrated a positive effect of chess on mathematical problem solving in classrooms. She speculates that the benefit of chess on mathematics may derive from the fact that chess may help children to deal with symbols, because in chess, symbols (e.g., chess notation) are linked in a concrete manner to visuo-spatial patterns on a board, whereas mathematics involves only "pure symbolic manipulation" (Isabella, n.d., p. 97). Wells (2012) discusses a number of different ways in which games such as chess influences mathematical thinking. He points out that like a chess player, a mathematician must observe a problem and contemplate various different approaches (moves) to solving it, spot possibilities while the mathematician also "studies objects like the pieces in an abstract game of chess" (Wells, 2012, p. 3). Trinchero (2013) conducted an experimental study investigating whether training in chess could improve the PISA mathematics scores of pupils in Italian primary schools. He found a positive gain in the mathematics achievement by the experimental group. This was also positively correlated with the duration of the chess course ($p<001$, $r=.139$) (Trinchero, 2013).

Thus, although the final verdict about the effect of chess and mathematics is still uncertain, some studies suggest that a positive relationship exists between these domains, and there are also some intuitive connections that suggest that this issue may warrant further research. For example, children must acquire an understanding and visualisation of spatial relations in chess. Spatial visualisation is a process that refers firstly to one's ability to orient oneself in surroundings, but it also relates to the ability to manipulate images of objects mentally. In chess playing, spatial visualisation is important because players are not allowed to move chess pieces physically when selecting a move, but must do this mentally and in this manner construct an image of the effect of the move on the configuration of pieces on the board (Fine, 1965, pp. 364–369). This understanding and visualisation of spatial relations could well be significant for the subsequent development of mathematical abilities in areas such as geometry or topology where spatial visualisation is also important (Sternberg, 2003, pp. 468–469).

2.6.2 Transfer to reading and verbal aptitudes

In certain studies carried out by researchers (Frank & D'Hondt, 1979; Margulies, 1993; Liptrap, 1997; Wetz, 2004) there is also evidence of children and adults who report improvements in reading and verbal aptitudes after exposure to chess.

However, Gobet (2011) conclude that the results of these studies (Christiaen & Verhofstadt-Denève, 1981; Frank & D'Hondt, 1979; Fried & Ginsburg, n.d.) only weakly supported the hypothesis of transfer from chess instruction to other domains with little evidence of an increase in intelligence, school performance, and creativity. Gobet*'s* (2011) interpretation agrees with previous research studies known in psychology as transfer, for instance, that transfer is limited and that chess playing may be beneficial in the early stages of acquiring chess skill, but it appears to decrease in the later stages of improving skill when an amount of deliberate practice is necessary as well as specificity of the information that is acquired. Chess practice also fosters interest in school matter in underprivileged areas. Furthermore concentration skills improve, and children also learn the concept of loosing as a result of the transfer of skills (Gobet, 2011).

A longitudinal, repeated-measures design of Bilalić *et al*. (2007) included the following variables, namely chess skill, motivation, intelligence, amount of practice and personality, although certain researchers (Campitelli & Gobet, 2008) argue that other variables are also related to expertise such as handedness, season of birth, and general cognitive abilities. These variables as well as starting to play seriously at an early age are regarded as important in the first stages of a chess career (to reach high levels of expertise).

2.7 Chess as an Educational Instrument

Numerous researchers (Gobet & Campitelli, 2007; Elo, 1965 & 1978) investigated the optimal age for exposing children to chess playing. There is some research that supports the link between chess skill and intelligence, as represented on an intelligence measure, in children, but not adults (Frydman & Lynn, 1992; Waters *et al.,* 2002). A report compiled by the Kasparov Chess Foundation cites numerous studies that have revealed that chess instruction can be used to facilitate cognitive development of learners and reasoning skills in a scholastic environment (KCFE, 2011). In a similar vein, McDonald (2010) presents several studies that elaborate on the positive effects that chess instruction can make on children's general cognitive and intellectual development, verbal reasoning, memory, and learning mathematics. The authors of these studies mention various educational benefits that chess could potentially offer to school children, for example, fostering problem solving abilities by giving immediate feedback on problem solving strategies, rewards, aiding development of mental alertness, creating a positive attitude towards learning, and participating in competitions (McDonald, 2010, p.3). In South Africa, chess has been advocated by a KwaZulu-Natal Education MEC as a mechanism for addressing weak levels of performance in science and mathematics at many schools (Jansen, 2015). When she has also suggested that phrenology should be used, she was accused of basing her claims on pseudoscience.

Gobet and Campitelli (2006) present a somewhat less enthusiastic endorsement of chess. They argue that whereas some researchers make strong claims about its purported educational benefits, there is not much solid research to support this claim, mainly because it is difficult to separate the effects of transfer and individuals in a sound methodological manner.

Gobet and Campitelli (2006) argue that because it is still such a controversial topic, research into the scholastic and cognitive benefits of chess need to follow the constraints of the ideal experiment. Such an ideal investigation would require a proper design in which randomisation is applied, placebo effects of children divided into the experimental rather than control groups should be taken into account, and nuisance variables should be properly controlled. In particular, problems associated with the direction of causation as well as the correlation-causation issue should be considered in the data analysis. Bart (2014, pp. 1-3) points out that the current state of the literature is still inconclusive regarding the educational benefits of chess, and presents a critical review of studies that have explored this topic. He concludes that whereas some studies show that chess could have a “salutatory cognitive and educational effect”, further research is clearly needed to establish such a conclusion in a scientifically valid manner. He also suggests that further research is needed on this topic because converging evidence may eventually help to settle the matter via systematic reviews and meta-analyses of the existing data.

Thus it appears that most of the controversies mentioned in the previous section about transfer between chess and intelligence, also hold true for the use of chess in educational environments as a means to improve intelligence and scholastic performance. Clearly further research is required, and the study that will be described in the next chapter aims to contribute, in a small way, to that endeavour.

2.7.1 When to offer chess instruction?

Findings in a study carried out by Doll and Mayr (1987) indicate that the starting age for national chess players is 10.3 years and 7.25 years for international players. Certain researchers (Halford, Wilson & Philips, 1998) postulate that when children are exposed to chess instruction, they must be older than five years, because children are capable of reasoning relationally, integrating multiple relations, and making transitive inferences only after the age of five. The latter are all processes implicated in chess. Ormrod (2006, p. 21) contends that in human development there are sensitive or critical periods for the development of different characteristics or abilities, namely for reading and writing. For instance, there is no critical period for reading, as a person can learn to read until he or she is very old, but children learn a language more easily when they are younger than in adolescence or adulthood (Ormrod, 2006, p. 21).

Gobet and Campitelli (2007) argue that a critical starting age for chess playing exists due to a correlation between chess skill and the starting age, because at a neuronal level, reduction in plasticity and the consolidation of anatomical circuits at the age of twelve occur. Charness, Tuffiash, Krampe, Reingold, and Vasyuoka (2005) do not support a critical starting age. However, Elo (1978) is of the opinion that if a chess player wants to attain a level of excellence in the game, he or she must engage in chess playing at a young age in order to accumulate the desired amount of deliberate practice, which is typically estimated to be at about ten years as explained earlier in this chapter.

Exposure to a chess environment at an early age is important for various reasons; that is, when different skills are being developed, it may facilitate the acquisition of knowledge used in important pattern recognition tasks (Gobet & Campitelli, 2007). Young children tend to size up problems easily and they learn to recognise patterns more globally and intuitively, which is a more effective way of learning than when they are older and only then exposed to chess playing (Horgan, 1987, p. 9). A chess environment that includes deliberate practice will also direct young children’s attention to the important aspects of chess and prevent the development of bad habits (Gobet & Campitelli, 2007). For instance, the process of pattern recognition (which forms part of perception) is a learned phenomenon and when young chess players learn to perceive during chess playing (during a perceptual search), they are being taught to perform an eye-walk to detect attack and defense positions, which after prolonged practice can become an automatic operation.

Kemm (as cited in Kostenuik, 2012) suggests that South African children must engage in chess playing at pre-school level due to the present unsatisfactory educational situation in governmental schools. Likewise, the researcher in this current study is of the opinion that young children are best exposed to chess instruction from the age of 5 to 6 years old, during a sensitive period, for the following reasons:

- Children of these ages have a higher incidence of synaptogenesis, which equips them to cope with different conditions and circumstances (Bruer, 1999).

- Researchers (Bjorklund & Green, 1992; Piaget, 1980) contend that children of these ages are also very curious, eager to learn and to explore, and they display positive self-concepts, high self-esteem and a little overconfidence in handling new and difficult tasks such as chess.

- Young children tend to overestimate their capabilities and memory skills and consequently they will probably not assume that a versatile game such as chess will be too difficult for them (Lockhart, Chang &

> Storey, 2002). They also believe that they can easily overcome initial failures, therefore it is possible that they will persevere in spite of making mistakes (Lockhart *et al.,* 2002).

Ormrod (2006, p. 69) argues that the elementary school years are critical for the development of self-confidence. Therefore Erikson (1972) postulates that when children engage in new activities (such as chess playing) and receive positive reinforcers for their efforts, they acquire confidence and belief in their own abilities, which positively affects their development and later learning and achievement across multiple domains (De Corte, 2003).

For a child to benefit optimally from chess playing, it is probably best to learn the game from the age of 5 to 6, but for someone who only wants to learn the game, age is irrelevant, as the game of chess is accessible to any child or adult capable of comprehending the rules of the game (Polgar, 2012). Although researchers believe that children in 5-6 year old age group should benefit most when engaging in chess playing, the researcher of this study is of the opinion that children in this age group do not learn to play the game as easily as older children do, and they are in need of cognitive monitoring. For instance, they do not know strategies that enhance memory and the functions of chess pieces must be repeatedly explained to them, and ample opportunity must be allowed for practice (Sternberg, 2003 p. 521). Children of this age group also tend to be very impulsive, do not plan their activities at first and do not understand their own limitations (Waaramantry, as cited in Subotnik, 1993; also see Ormrod, 2006, p. 43).

2.8 Formulation of Hypotheses

In the light of the literature reviewed in the previous section, it is clear that there is still no real clarity on the relationship between chess and intelligence, and much of the research findings remain equivocal. Furthermore, the effect of chess on the initial development of cognition and intelligence in young children is still largely unexplored. This research aims to address this topic, and focuses on the effect of chess playing on the cognition and intelligence of young preschool children.

As explained more fully in Chapter 3, a small group of children were included in an experiment to establish whether teaching the children to play chess would exert a positive effect on their cognitive abilities as predicted by Ericsson’s deliberate practice theory (Eysenck & Keane, 2005, p. 459). In the current study, the participants were mostly in Piaget’s pre-operational stage at the beginning of 2009, but by the end of the year, many of the participants had turned 6 or 7 years old and could then be in the concrete operation phase. During the pre-operational stage children’s language skills develop significantly, which provides the basis for a new form of social interaction, verbal communication. Children at this stage display an inability to reason or understand change processes such as transformation, but when they engage in chess playing, they learn that pawns can promote to queens or to other important chess pieces and subsequently they learn to understand the process of metamorphosis (also see Ormrod 2006, pp. 28–31). Numerous skills also develop during this and the other stages.

The data was collected on two occasions by administering an intelligence test (the JSAIS, see Chapter 3) and a short questionnaire soliciting certain biographical data of each participant, with due consideration of ethical principles regarding anonymity. With these measures in place, numerical data were gathered with the aim of testing the model that scores for an intelligence test will exhibit an increase after exposure to chess instruction. The research reported in this study thus constitutes an attempt to model the relationship between chess instruction and intelligence (global, performance, verbal, and numerical intelligence). After exploring the literature in this chapter, the following specific research hypotheses have been formulated to provide further structure for the research process.

Hypothesis 1 (H1):

It is hypothesised that both groups (the control group which was not exposed to chess instruction and the experimental group which was exposed to chess instruction) will exhibit improved cognitive development during the period in which the research was conducted; therefore it is hypothesised that there will be a significant improvement in cognitive development in both groups (the control group which was not exposed to chess instruction and the experimental group which was exposed to chess instruction) as evidenced in the groups' mean scores of the GIQ scale of the JSAIS for the second assessment period.

Rationale:

Piaget maintains that children's cognition and intelligence improve when they explore and discover aspects of the world (see section 2.2.2 for further detail, where *Piaget's Developmental Theory,* is discussed) (Inhelder & Piaget, 1958). The participants in this study varied in age (they varied from four and a half years to seven years during 2009) and were mostly in Piaget’s pre-operational stage at the beginning of the year. Children of these ages and in this stage differ from one another regarding biological characteristics and nurture effects (such as stimulation at home), but due to the characteristics of biological maturation, neural plasticity, malleability and an enriching educational environment (such as Garsieland), it is believed that all the participants will display improved cognitive development during 2009 (see section 2.2.1 for further detail, where the neural and genetic factors in development is discussed). The latter is not only applicable to general cognition (as exhibited in GIQ), but also cognitive development as displayed in the subscales (PIQ, VIQ and Num scale) of the JSAIS.

Hypothesis 1.1 (H1.1)

There will be a significant improvement in cognitive development in both groups as evidenced in the groups’ mean scores of the PIQ scale of the JSAIS for the second assessment period.

Rationale:

Piaget maintains that children begin to think more logically and become capable of inductive reasoning owing to various skills that emerge during the concrete operations stage (Ormrod, 2006, p. 28). During the children’s Grade R year, the teachers follow a prescribed curriculum which exposes the learners to different tasks (for instance, to build puzzles or build with blocks) and thereby the teachers are able to address developmental delays in learners. In so doing, school readiness can be facilitated and the children can be prepared for formal schooling. There are many educational toys or aids (such as climbing frames and computer classes) that can be utilised in the enriching Grade R environment.

Hypothesis 1.2 (H1.2)

There will be a significant improvement in cognitive development in both groups as evidenced in the groups' mean scores of the VIQ scale of the JSAIS for the second assessment period.

Rationale:

Ormrod (2006, p.27) contends that children's language skills develop significantly ("virtually explode") and their vocabularies grow tremendously during the early part of the pre-operational stage. This enables the children to represent and think about a wide variety of objects and events. It also provides a basis for a new form of social interaction, verbal communication. One must also bear in mind that the Grade R learner is mostly unable to read words and instructions are mostly given verbally by the teachers. Most of the communication in classes is verbal, which in turn will also foster verbal skills of the learners. Every class is also furnished with colourful pictures and books, which can probably further contribute to their vocabulary.

Hypothesis 1.3 (H1.3)

There will be a significant improvement in cognitive development in both groups as evidenced in the groups' mean scores of the Num scale of the JSAIS for the second assessment period.

Rationale:

Again, due to the theories of cognitive development, neural plasticity, biological maturation and malleability, children (here, participants in both groups) will develop numerous skills during Piaget's pre-operational stage and the other stages. This can probably be facilitated by an enriching environment (plus additional stimulation at home or elsewhere) where all the teachers follow a prescribed curriculum and where learners have to be exposed to a prescribed number of hours of mathematical reasoning (and counting) per week.

Hypothesis 2 (H2):

In this dissertation, it is hypothesised that there will be a significant difference between the control (Grade R learners who were not exposed to chess instruction) and the experimental (who were exposed to chess instruction) groups' mean scores on the global scale, the GIQ scale of the JSAIS at the Post-test condition. Chess instruction will confer a cognitive gain and hence a between groups effect will be observed on the experimental group's GIQ scores.

Rationale:

It is a core research question whether there are any positive carry-over effects of learning chess to other disciplines and this is also central in this dissertation (see section 2.6, where transfer between domains, in this case, chess and intelligence, is discussed in greater detail). Nonetheless, findings in a study on adults (Grabner, Stern, & Neubauer, 2007) indicated that there was a significant improvement in chess players' scores in the global-general-intelligence score. Hence, one could probably assume that an improvement in one of the subscales of the JSAIS, would also affect the GIQ. Therefore, it is hypothesised that the experimental group will obtain higher scores on the GIQ at the second assessment.

Hypothesis 3 (H3)

There will be a significant difference between the control and the experimental groups' mean scores on the Performance Intelligence Quotient scale (PIQ), inasmuch that the experimental group will achieve higher significant scores than the control group on the PIQ at the end of the 40 week period.

Rationale:

The specific aim of this hypothesis is to establish whether learning to play chess fosters the performance aspects of the PIQ scale significantly more so than the other aspects (verbal, numerical, or global) of the scales of the JSAIS, as postulated by certain researchers (Frydman & Lynn, 1992). Since chess is a strongly visuo-spatial skill, it is noteworthy that the aforesaid researchers regarded visuo-spatial abilities, presumably measured by the performance scale, as being very important in chess skill (see section 2.4.1.2 for further detail, where visual imagery, visualisation and visuo-spatial abilities are discussed). However, this scale also includes speed tests. The PIQ can also give researchers an indication of a child's functioning of respective working memories (see sections 2.4.2 and 2.4.3 for further detail, where attention, problem solving and working memory*,* are discussed) (Gobet & Campitelli, 2006, as cited in Scholz, *et al*., 2008). In this study, it is therefore hypothesised that the experimental group will yield higher mean scores on the PIQ than the control group after the 40 week period.

Hypothesis 4 (H4)

There will be a significant difference between the control and the experimental groups' mean scores on the Verbal Intelligence Quotient scale (VIQ), inasmuch that the experimental group will achieve higher significant scores than the control group on the VIQ at the end of the 40 week period.

Rationale:

Chess has a language (and vocabulary) of its own, because during chess playing (especially during tournaments) players record their own matches by making use of algebraic notations (De Groot & Gobet, 1996, pp. 4 & 260). According to the ACT-R theory of Anderson (1990), an important assumption is that declarative knowledge can be learned quickly and encoded as relatively small chunks (see section 1.3.3 for further detail, where *Anderson's Adaptive Control of Thought-*

Rational theory is discussed). Chess experts thus possess extensive knowledge bases in which to store their information about chess rules and openings, as well as tactical and positional strategies.

In the current study, the participants were mostly in Piaget's pre-operational stage at the beginning of 2009; during this stage children's language skills develop tremendously. In studies carried out on young children, certain researchers (Frank & D'Hondt, 1979; Liptrap, 1997) also reported improvements in the VIQ (of the experimental group; therefore it is hypothesised that chess exposure will yield higher scores on the VIQ scales of the experimental group (see section 2.6.2 for further detail, where transfer to reading and verbal aptitudes is discussed).

Hypothesis 5 (H5):

There will be a significant difference between the control and the experimental groups' mean scores on the Numerical scale (Num scale), inasmuch that the experimental group will achieve higher significant scores than the control group on the VIQ at the end of the 40 week period.

Rationale:

According to Peterson (2002), chess playing and mathematics share similar principles; therefore it is hypothesised that exposure to chess instruction will yield higher scores in the Num scale in the experimental group (see section 1.2 for further detail, where chess as a resource for researchers in psychology and education, is discussed).

Several studies (e.g., Frank & D'Hondt, 1979) have reported positive effects of chess playing on mathematical problem solving or numerical thinking (see section 2.6.1 for further detail, where transfer to mathematics, is discussed).

These hypotheses will guide the empirical investigation in the next chapters.

2.9 Conclusion

This chapter presented a brief review of Piaget's theory of stages and explained the transition from the largely descriptive Piagetian framework to an information processing paradigm in which an attempt is made to elucidate cognitive mechanisms. The discussion then moved to chess and cognition, first briefly summarising certain research referring to the cognitive and computational complexity of chess. Thereafter, the acquisition of expertise was discussed and research findings pertaining to the effect of expertise in chess on cognitive processes such as perception, memory and problem solving in the cognitive domain were reviewed.

After a brief introduction to psychological theories of intelligence, the longstanding but still largely unresolved issue of transfer of abilities from a domain in which expertise has been acquired to other domains was dealt with. Research studies that explored the connection of transfer in the context of chess were subsequently discussed and some of the conflicting research on this issue was reviewed. In the case of chess, a theoretically and practically important issue concerns the application of chess as a training technique in educational settings to enhance intellectual functioning, which possibly also influences performance positively in other academic subjects. A short overview of intelligence theories was furnished, and the carry-over effects of chess instruction and practice to intelligence were subsequently discussed. The literature review suggests that a link between some aspects of intellectual abilities and chess instruction in children does exist, but not in adults. Transfer though is limited and applies more so to the early stages of acquiring chess skill (Bilalić *et al.*, 2007, Gobet, 2011).

Chapter 3
Research Methodology

3.1 Introduction

This chapter discusses and introduces the research process used in the current study from a methodological perspective. The primary purpose of the empirical investigation in this study is to explore the effects of *chess instruction* on *intelligence or intellectual development* and to establish if there is a relation between the variables indicated below. The influence chess instruction has on intellectual abilities (as represented by scores of the Junior South African Intelligence Scales, JSAIS) is explored within two different groups in order to ensure fair and valid testing of all the children. The variables that are being studied are the following:

a. The treatment or intervention variable in the study is 'exposure to chess instruction'.
b. The dependent variable is 'intelligence' (such as performance, verbal, numerical and global intelligence) as represented by performance on the JSAIS.

The specific aims of the empirical inquiry reported in this dissertation have been discussed in Chapter 2. A representative sample was selected to achieve the stated research aims and therefore, the sampling process, procedure and instruments used in the research will be described in this chapter. Ethical issues will also be considered. The development of the measuring instrument, the JSAIS in this study, will be highlighted and the reliability and validity of this existing instrument will be verified. The process of gathering of primary data and data capturing will be discussed briefly as well as measures to minimise errors. The statistically testing of hypotheses relating to abilities on the JSAIS (see section 2.8, where the formulation of hypotheses is discussed for further details and a justification of these questions) will be discussed in Chapter 4 together with the statistical methods used for the data analysis.

3.2 Research Design

The research design will be discussed in the next section and thereafter the sample and sampling process of this design.

3.2.1 Research design

In this study a quasi-experimental design was chosen for collecting and analysing data, because there is not full control over the nuisance variables that could influence the results and no randomisation, but there is manipulation of treatment in this current study (chess instruction) (Colman, 2006, p. 628). The amount of control in the study is in the form of a control group.

3.2.2 A description of the sample used in the study

The purpose of the research study is to explore the positive influence chess playing has on Grade R learners' intelligences, over time. The sample was taken from predominantly Caucasian, Afrikaans-speaking Grade R learners attending school at the Garsieland Pre-school. The children participating in the study were aged between 4-and-a-half and 6 years at the beginning of 2009.

At the beginning of 2009, the sample of Grade R learners in the study involved 64 children. The experimental group consisted of 34 grade 0 children (19 boys and 15 girls) who were not yet able to play a game of chess, but during chess classes at school during 2009 they were taught the basics of chess. The control group consisted of 30 Grade R children (14 girls and 16 boys) who were not exposed to chess instruction at school during 2009. No preference was given to gender and these mixed groups can be regarded as an unbalanced design due to the uneven cells in the two groups. However, this could not have been prevented due to practical realities. None of the children received any additional therapeutic or instructional interventions, but 2 children in each of the control and experimental group started to take medication (Ritalin or Concerta) to improve their concentration.

The participants selected for the research are assumed to represent all Grade R learners (age 4-and-a-half to 6 years in the beginning of 2009 and up to 7 years by the end of 2009) in Afrikaans schools in South Africa. The participants in the sample were furthermore homogeneous in terms of aspects such as language (Afrikaans was home language) and educational status, as they were all in Grade R during 2009.

The participants in the experimental group received chess instruction from the researcher who taught them the rules of the game, and allowed them to play against one on a weekly base during the chess classes at school. The experimental group received approximately 20 hours of chess instruction during 2009 (40 weeks over 4 terms, 40/2 = 20 hours). It is though unknown if the participants in the control group received any chess instruction prior to the onset of this investigation and/or during the period of the investigation. It is possible that young children of these ages could also have taught one another to play the game of chess, without anyone even knowing and this could not have been controlled by the researcher.

3.2.3 The sampling process

A decision was made to select participants who were enrolled at Garsieland, a pre-school that forms part of a government school, Garsfontein Primary School, due to the researcher's affiliation as chess instructor with this school. Another reason for selecting learners in Grade R, is that the literature highlights the benefits pertaining to this age group as well as the plasticity of learners' brains for environmental influences (see sections 2.2.1, and 2.6.1, neural and genetic factors in development, and when to offer chess instruction, is discussed for further detail) (Foxcroft & Roodt, 2005, p. 319).

Letters were handed out to all children, thus all were given the opportunity to receive chess instruction, but not all decided to partake in this activity at Garsieland. Sampling was not done on a random basis where the participants would be chosen for representativeness, but was rather based on accessibility or convenience (Colman 2006, p. 170). A non-probability, convenience sample was used to form two subgroups consisting of learners receiving chess instruction (the experimental group) at the school, and a control group of learners of the same age at the same school, but who did not receive any chess instruction classes.

3.2.4 The procedure

In a quasi-experimental design, all the decisions with regard to the investigation are made prior to the onset of the study. Decisions concerning the measuring instrument, the JSAIS, had to be made with regard to the applicability and suitability of this instrument for the assessments carried out in this study. In determining the appropriateness of the instrument all the relevant aspects were considered. Thereafter, the JSAIS and the accompanying response booklets were obtained from an authorised distributor as some scales are copyrighted.

In this quantative research study the mode of inquiry and data collection were two-fold, firstly parents were asked to fill in a biographical form and give written consent when submitting their children to the research study and secondly, objective, primary data were obtained when the JSAIS, was administered to participants within groups. This was done in order to obtain numerical data that can be used to test research questions (see section 4.4, where the results of the investigation is discussed for more detail) as well as to confirm or refute hypotheses. All the necessary relevant biographical data about the participants were recorded on the response booklets and on the computer for processing and safe-keeping. The (pre)test was then administered (as a baseline) individually to all the participants during the course of the first term of 2009 (see section 3.4.1.3 for further detail, where administration of the JSAIS*,* is discussed).

The participants in the experimental group commenced with chess instruction at the end of January 2009, after voluntary enrolment. Both groups' intelligences were measured at the post condition at the end of the year, during November and early December 2009 by using the JSAIS. This second assessment period was shorter than the first one, probably due to exposure to assessments and the participants became more test-wise. It appeared as if they were more able to understand what was required of them (Foxcroft & Roodt, 2005, pp. 335-337).

Due to the standardisation of instructions and scoring, objectivity of the assessment procedure was ensured by the assessment practitioner. The response booklet was scanned for unanswered questions and raw points were converted to scale points in order to compare it to norms and to each other. The numeric data were captured on a spreadsheet (Microsoft Excel) for further statistical (empirical) analysis, as described in the next chapter.

3.2.4.1 How chess instruction was presented

Young children usually lack a good working knowledge of chess, and therefore the participants had to be taught the basics of chess, to lay a foundation for further learning (Waters *et al.,* 2002; Ormrod, 2006, pp. 45-46)**.** This took place during group classes or lessons on Thursday or Friday mornings to accommodate the 34 participants in two groups and the duration of each lesson was a half an hour. Chess pieces and rules were introduced to the participants over approximately 9 to 10 weeks.

The background of chess and the functions of the pieces were provided to the participants by adhering to Ericsson's (1988) requirements to develop high memory skills (see section 1.3.2.1, where *Ericsson's theory of deliberate practice* is discussed, for further details). Therefore when a new chess piece was introduced to participants, new information was related to prior knowledge and was then studied in depth. The latter was achieved by making use of different methods of instruction, such as a variety of colourful pictures, different stories emphasising crucial concepts and themes, puppets, physical or board games, role play and by demonstrating tasks. After a new chess piece was introduced, sufficient practice was provided to the participants.

Prior to each week's new lesson and before individual chess playing, the participants revised what they had learned previously to facilitate retention of this knowledge. After each chess lesson, the equipment was packed away and the participants each received a small reward (sweet, privilege, game or a star) if they performed in an acceptable way. After the foundation had been laid during the introductory period, participants continued to practise their skills (such as the positioning of chess pieces and openings or some principles) and could then put more thinking into planning and reasoning, such as how to capture an opponent's king (Peterson, 2002). During chess playing the instructor supported the participants by giving them feedback, making suggestions and hints to improve their competence in chess and also to enhance their self-confidence in their own playing ability (Vygotsky, 1997; Ormrod, 2006, pp. 41-42).

3.3 Ethical Aspects

Permission to conduct the investigation was obtained from all relevant parties, such as the Department of Education, the governing body of Garsfontein Primary School, the University of South Africa, and then lastly informed consent was obtained from the parents. The psychometrist administering the psychological tests had to comply with all the requirements of the Health Profession Council of South

Africa and underwent all the necessary training in administration of the JSAIS. All of the above had to be done in order to ensure that assessment practices were done professionally and ethically according to the 1999 ethical code of professional conduct (Foxcroft & Roodt, 2005, p. 116).

During an open day in August 2008 prospective parents were informed about the purpose of the pre-planned, future research and forms were handed out to parents and caretakers (as legal representatives of the children) in January 2009, to obtain informed consent for participation in the study. The participants' rights were stipulated in writing and they were informed about the following (see section 4, Appendix A, to view the consent form, for further details):

- The purpose of the study was for research purposes and the results will only be used as such, therefore no feedback of the assessments will be communicated to parents.
- Participation is voluntary and participants have the right to withdraw at any time with no consequences.
- Participants' results of assessments would be treated confidentially and only the researcher will have access to the results.
- Although names of the participants were known to the researcher and entered into statistical programmes, anonymity of participants' names would be adhered to for protection, while writing and reporting about them.

- Parents were informed about the location and the period when the assessments would take place.
- Lastly, both children and parents were thanked for their contributions.

The research process that includes the collection of numeric data and the analyses thereof was conducted under the supervision of a supervisor.

In the next section one of the data collection methods, the JSAIS, used in the study, will be discussed.

3.4 Description of the Measuring Instrument

The reasons for choosing the measuring instrument, the JSAIS, to gather data in this study, will now be discussed in the next section and it will be explained how the JSAIS was developed.

3.4.1 Junior South African Individual Scales (JSAIS)

The 12 tests in the GIQ scale (Global Intelligence Scale) is a suite of ability tests that are used to asses children's ability to comprehend, reason, judge and memorise when trying to solve verbal-numerical problems and manipulate concrete material (Madge, 1981, Part I, pp.13-23). The JSAIS was developed to assess the general intellectual levels (intelligences) of Afrikaans-speaking, English-speaking and Hindu children (Madge, 1981, p. 65). The test can also be used to identify strengths and weaknesses in some important facets/areas of intelligence and these scores can be used in description and prediction. This psychological test can be administered to children or learners aged between 3 and 8 years.

3.4.1.1 The development of the instrument

Previous research indicated that a need arose to assess children from the age of four years old and a request was made for an intelligence scale for five and six year old children during 1967 (Madge, 1981, p. 1). Unfortunately, the “Nuwe Suid-Afrikaanse Individuele Skaal” (now known as the Senior South-African Individual Scale) did not sufficiently assess intelligence therefore the JSAIS was developed. The assumption was made that intelligence is a composite of related mental abilities, where some are more closely associated with efficient functioning at school, with the resulting prediction of school performance, than others (Madge, 1981, reprint 1996, p. 5). The assumption that these abilities are not totally independent of one another implies that the total score on the subtests included in the JSAIS, represents a broader, underlying factor of general intelligence. With regard to the JSAIS, both the verbal subtests (verbal intelligence, ‘gc’) and non-verbal subtests (performance intelligence, ‘gf’) grouped together measure one underlying general factor ‘g’ (see sections 2.5 and 2.5.1, where theories of intelligence and theories emphasising structures of intelligence, is provided, for more detail).

A relatively large number of tests were constructed for item analysis to ensure that the important facets of mental functioning in the final battery are represented satisfactorily (Madge, 1981, pp. 5-6). Two facets were included, namely the content facet, that involves the nature of the test tasks (consisting of verbal, quantitative and spatial stimuli) and the process facet, that involves the execution of a task. Five elements were included in the process facet, namely concept attainment, convergent production, evaluation, divergent production and memory.

3.4.1.2 The composition of the JSAIS

The manual for the JSAIS was compiled by Elizabeth M. Madge in 1981 and the (JSAIS) norms were revised during November 1984 by A.R. van den Berg and Maryna Robinson. Both books were distributed by the Human Sciences Research Council (Madge, Van den Berg & Robinson, 1985, p. 1).

After an assessment the JSAIS will provide an overall measure of global intelligence and the participant's score can vary from below 69 (children in this group are being called 'Cognitively handicapped') to 130 and above (thus 'Very superior').

Madge (1981, pp. 13-23) contends that the 12 tests in the GIQ scale can be grouped into four subscales, such as:

a) A Verbal Intelligence Scale (VIQ) comprises of the following five subtests; Vocabulary, Picture riddles, Word association, Ready knowledge and Story memory;

b) A Performance Intelligence Scale (PIQ) consists of the following five subtests; Form board, Absurdities A and B, Block designs and Form discrimination;

c) A Numerical scale that includes the Number A and B and, Digit memory subtests, and

d) Story memory subtests, with Absurdities A and Digit memory that form part of the Memory scale. The subtests contain different amounts of items or questions for two different age groups.

3.4.1.3 Administration of the JSAIS

Before the JSAIS could be administered to participants, ethical clearance was obtained (see section 3.4, where ethical aspects, is discussed for further detail). A child-friendly venue with chairs and tables, adequate lighting and minimal noise was allocated near the Grade R classes for the assessments. Specific arrangements were made with the teachers with regards to the participants' assessments. Thereafter the (pre)test was administered to all the participants during school mornings during the course of first term of 2009. Before administering the structured JSAIS to the participants, questions were answered and participants were re-assured of the practitioner's assistance. Participants were assessed according to the manual and all responses (such as test behaviour and delays) were recorded in the response booklet, and with due allowance made for all the specific conditions associated with individual tests such as time restrictions. To reduce anxiety, practice examples were completed with the participant where indicated in the manual. Furthermore, breaks were given between subtests to keep participants from becoming inattentive.

It was important that both Afrikaans and English were used interchangeably during the assessments, as some children were exposed to both languages in different preparatory schools prior to Garsieland and were exposed to a home language (Afrikaans) and to English. This was done to prevent any communication problems between the assessment practitioner and the participants that could invalidate a measure (Kanjee, as cited in Foxcroft & Roodt, 2005, p. 88). After participants were assessed, they were thanked for their contributions and accompanied back to the classroom.

The JSAIS was administered to all the participants in the same manner and under the same physical conditions. These conditions were carefully controlled and highly standardised, when the instructions and procedural steps were followed as dictated by the manual of the JSAIS. By paying careful attention to above mentioned administrative procedures, the internal consistency of the global scale of the JSAIS will remain high and thereby one ensures valid data.

3.4.1.4 The reliability of the JSAIS

Researchers differ from one another regarding the optimal reliability coefficient in order to render a test reliable. Therefore Foxcroft and Roodt (2005, p. 46) suggested that it depends on what the measure is being used for, namely when standardised measures are being used reliabilities should range from 0.80 to 0.90 and higher (Anastasi & Urbina, 1997). The following researchers (Foxcroft & Roodt, 2005, p. 46) proposed that reliabilities ranging from 0.70 to 0.95 are also acceptable. Furthermore, for decisions about groups, namely for research purposes (such as exploring the differences between groups as in this study), Nunnally and Bernstein (1994) contend that a reliability of 0.80 is adequate.

When using existing measuring instruments, their reliability and validity are usually known and reported in the manual, and this is the case with the JSAIS, namely:

- The 12 subtests' reliabilities were calculated by the Küder-Richardson Formula 8 and the results for the internal consistency was as follows; the subtests showed reliabilities of 0.74 to 0.97 for age groups 3-5 years (calculated by the Küder-Richardson Formula 8), except for a few subtests, such as the Picture series, where no values were given in the manual (Madge, 1981, Part I, pp. 55-58). For the age groups 6-7 years, reliabilities varied from 0.67 to 0.91, excluding a few subtests, such as the Picture association subtest where no values for this age group were given.

- With reliabilities of 0.96 to 0.97 for all the age groups (from 3 to 7 years), the 12-test GIQ provides an adequate measure of global intelligence (Madge, Van den Berg & Robinson, 1985, pp. 21-22).

- Reliabilities of the VIQ and PIQ scales varied between 0.91 to 0.96 from the age groups, 3-7 years, though,

- Reliabilities for the Numerical scale ranged between 0.87 and 0.89 for all age groups.

The formula of Mosier was used to calculate the stated reliability coefficients (Guilford, 1954, p. 393). The composite scale, the GIQ of the 12-test JSAIS with accompanying reliability coefficients of 0.96 and higher meets all the stated requirements.

The intercorrelations of four of the five composite scales GIQ, VIQ, PIQ and Memory Scales vary from 0.59 – 0.91 (for ages 4 to 7 years old) and for the Numerical scales intercorrelations from 0.52 to 0.80 (for ages 4 to 7 years old).

Madge (1981, pp. 57 and 64) argues that the intercorrelations (from 0.52 to 0.77) are high enough to indicate quite an amount of common variance, but also low enough to propose that the abilities measured by each of the individual scales, cannot readily be inferred from each other. Though, George and Mallery (2003) contend that intercorrelations below 0.7 are rather low and not generally regarded as satisfactory (except for when tests are used for preliminary rather than final decisions), but this was the only available standardised instrument to assess intelligence of Afrikaans-speaking children.

Researchers (Tramontana, Hooper & Selzer, 1988) are of the opinion that by the age of five years old, intelligence tests are predictive of later performance in adolescence and adulthood. This predictive power improves with age and by the age of seven years old intelligence scores are now predictive of later performance across the lifespan. Intelligence Quotients begin to stabilise at the age of seven years old and remain relatively stable across one’s life span (Bourne, Fox, Deary & Whalley, 2007).

3.4.1.5 The validity of the JSAIS

Madge (1981, pp. 65-75) proposes different types of validity for the JSAIS, such as content validity, construct validity, criterion related validity and predictive validity. Content validity will first be discussed as one of the four types of validity of the JSAIS and thereafter validity in the study.

3.4.1.5.1 Content validity

The JSAIS has evidence of content-description procedures, as in content and face validity (or a priori validity), not only due to the colourful and bright pictures of objects in the JSAIS representing childrens' worlds, but also due to a meaningful content analysis and judgements made by a panel of competent people (Wolfaardt, as cited in Foxcroft & Roodt, 2005, p. 49).

3.4.1.5.2 Construct validity

Previous research indicated that there is evidence for the construct validity of the various tests of the JSAIS, because when factor analysis was used to validate the instrument, all the individual subtests had a satisfactory loading of 0.3 or higher (varied from 0.3 to 0.77) on the unrotated first factor, regarded as *g* or general intelligence (Madge, 1981, p. 71-75). Though, with a more strict cut-off point of 0.50 the subtests Form Board (0.40 for 4/5 year age group and 0.47 for 6/7 year age group) and Memory for Digits (0.32 to 0.49 for all age groups) did not meet the criteria to permit inclusions of these tests in a battery for the evaluation of the level of general intelligence, but were still included due to various reasons.

3.4.1.5.3 Criterion-related or empirical validity

According to researchers (Colman, 2006:, p. 58 and 593; Madge, 1981, p.66) the JSAIS is generally taken to have evidence of two examples of criterion-related validity, namely, predictive and concurrent validity. With regards to predictive validity, the primary criterion to be predicted with GIQ is probably future school achievement.

3.4.1.6 Validity in this research study

In this study there is sufficient evidence for different types of validity, namely content, construct and criterion related validity of the measuring instrument, but an experiment is only regarded as trustworthy when there is a high degree of internal and external validity. Subsequently, such a high validity can be obtained when intelligence is being measured by the JSAIS, but a lower degree of internal validity is relevant in the study, due to less control over extraneous variables (for example the amount of hours participants engaged in chess playing at home or elsewhere) other than chess instruction. In this study, there was no randomisation, but there is still an amount of external and ecological validity, but less than in a full experimental design.

3.5 Summary

The research design, sample and sampling process were described, as well as the gathering of data and data capturing. The measuring instrument, the JSAIS, used to measure Grade R learners' performance (intellectual development) in this study, has been discussed and rendered to be a reliable questionnaire and by administering the JSAIS and the capturing of data were discussed, as well as limitations in this study. In the next chapter statistical data analyses of the collected data will be performed to investigate the model.

Chapter 4
Results

4.1 Introduction

In the current study, a group of young children received chess instruction for a period of a year, and the researcher investigated the possible effects of learning chess on their cognitive and intellectual development. The five hypotheses (H1-H5) were tested using Oneway ANOVA (analysis of variance) (GLM 1) and Two-way ANOVA with repeated measures (GLM 5) on one factor (see section 2.8, where the hypotheses were formulated). A mixed design with one between factor and one within factor was employed with the repeated measures design. Field (2005, pp. 571-572) contends that multivariate analysis of variance (MANOVA), a complicated (non-standard) technique, should rather be performed in situations where there are several dependent variables (outcomes), because the simple ANOVA model (that involves only one dependent variable) is inadequate (see also Colman, 2006, p. 485). MANOVA is an extension of the ANOVA technique, therefore the principles of ANOVA also apply to MANOVA. The latter cannot be used to examine one or several independent variables simultaneously only, but also interactions between independent variables. When MANOVA is used, a probable Type I error is reduced and the MANOVA technique can take into account the relationships between the outcome variables. MANOVA possesses great power to detect an effect, because it can detect whether groups differ along a combination of variables. A MANOVA can also inform the researcher whether groups of participants can be distinguished by a combination of scores on several dependent measures.

Therefore, for various reasons, namely the existence of several dependent variables (and group means) in this study, MANOVA was used to determine the significance of the differences among these group means. The following variables were created for the purpose of data analysis:

- treatment or chess instruction (with two levels, no treatment or 20 hours of treatment);
- groups (the experimental group and the control group);
- intelligence or cognitive development (as represented by scores on the subscales and global scale of the JSAIS) of the two groups;
- periods or time (at two levels, namely the pre-test condition at the onset of the investigation and the post-test condition at the end of the period during which the treatment was administered).

4.2 Testing of the Assumptions

At the beginning of the study, the sample consisted of 64 participants whose ages varied from four-and-a-half years to seven years at the end of period of chess instruction. At the onset of the study, none of the 34 participants (19 boys and 15 girls) in the experimental group knew how to play chess; therefore they were taught (from scratch) the basics of the chess game and the principles upon which the game is based during weekly chess classes at the school (see section 3.2.4.1). The control group of 30 participants (16 boys and 14 girls) did not receive any chess instruction at the school.

The experimental group was designated the title “E” when referred to in tables or graphs and the control group was labelled “C”. The first assessment period is called the Pre-test condition or the first period, and the second assessment is called the Post-test condition or the second period.

In the next section, the collected data as well as the results of all the statistical tests performed to test the research questions are described.

4.2.1 Testing the parameter assumptions

In the case of the parametric tests used in this study (i.e., ANOVA and MANOVA) four basic assumptions must be met in order to render the tests to be accurate (see Field, 2005, pp. 63-65). In this section, details of the parameter assumptions pertaining to MANOVA are reported, beginning with the assumption of normality. Summaries of the statistics for the two groups and each test are presented in Appendix B under the appropriate heading. These summaries serve as the basis for the analyses of the comparison of means and other statistical techniques.

The four assumptions required for the use of the parametric statistical techniques, ANOVA and MANOVA, are:

- Normality of distribution;
- Homogeneity of variances of the data and variables across groups;
- The use of interval data; and

- Independence of data.

4.2.1.1 Testing the assumption of the normality of distribution

Data points were plotted on a normal distribution and when the histograms were examined, a few outliers were observed where they formed the extreme points (Field, 2005, pp. 67-68 & 75). Five outliers were identified on the pre-test, namely four participants in the experimental group and another one in the control group. When graphs on the post-test condition were examined, no outlying data points were identified. Therefore, the outliers identified on the pre-test level, were found not to be problematic and no outliers were excluded from the study.

After examining the outliers, the Shapiro-Wilk test was performed for two different periods in order to assess whether the distribution of the variables (scores or data) to be analysed would be normal for the two independent groups (N=64) at the two conditions or periods. Simple comparisons of the mean as well as the Shapiro Wilk statistic were drawn in order to make decisions regarding the normality (see Appendix B, Table B2, where the test *Shapiro-Wilk Test* is set out). The intelligence scores (of the global scale and subscales of the JSAIS) for the two groups (experimental and control groups) and for the two periods were normally distributed at a 95 % level of confidence ($p>0.05$), except for the VIQ mean scores of the experimental group at the pre-test condition (VIQ1) and the GIQ mean scores of the experimental group of the second period or at the post-test condition (GIQ2). The p-values (for the VIQ1 and the GIQ2) derived from the Shapiro-Wilk test are smaller than 0.05 (VIQ1, $p = 0.022$* and for GIQ2, $p = 0.027$*) at a 95 % confidence level. To test for normality, a level of 0.05 alpha-level should be applied. This was performed in order to detect deviations and to guard against a Type 2 error, due to the low power resulting from the small sample size used in this study. MANOVA is robust and was developed to deal with deviations such as the lack of normality, as mentioned above.

4.2.1.2 Testing the assumption of homogeneity of variances

A one-way ANOVA was conducted to examine whether there were statistically significant differences among different levels of chess instruction in relation to the mean intelligence performance scores. ANOVA indicated that intelligence (represented by scores on the JSAIS) met the assumption of equal variances between the two groups, at the PRE level or pre-test condition, prior to manipulation of treatment (chess instruction). The results revealed no significant differences between the intelligence scores (mean PIQ, VIQ, GIQ and Num scale scores) of the two groups for different chess levels at a 95 % level of confidence as the *p*-values were all larger than 0.05 ([PIQ, $F_{1,62} = 0.176$ ns; VIQ, $F_{1,62}=0.329$ ns; GIQ, $F_{1,62} =0.600$ ns and Num scale, $F_{1,62} = 0.403$ ns] see Appendix B Table B.4, where the test for the Equality of Means, ANOVA, is set out).

Levene’s tests also indicated that intelligence scores met the assumption of equal variances for the two groups at the PRE level. In a series of Levene’s tests, the *p*-values of the PRE level are all greater than 0.01 ([PIQ, $F_{1,62}=0.479$ ns, VIQ, $F_{1,62}=0.9741$ ns, Num scale, $F_{1,62}=0.966$ ns and GIQ, $F_{1,62} =0.478$, ns]), hence also indicating no significant differences at a 99 % level of confidence (see Appendix B, Table B5 where the tests of Homogeneity of Variance are displayed). At the POST level or post-test condition, the *p*-values from the Levene's test are also greater than 0.01 ([PIQ, $F_{1,62}$=0.426 ns; VIQ, $F_{1,62}$ =0.216 ns; Num scale, $F_{1,62}$=0.085 ns and GIQ, $F_{1,62}$=0.375 ns]) at a 99 % level of confidence. Therefore, one can conclude that the intelligence scores for the different chess levels (control and experimental groups) met the assumption of equal variances. This assumption is especially important in a repeated measures design, because when testing variances for equality, one can ensure that no group starts off with an advantage prior to the manipulation of the treatment to the experimental group.

4.2.1.3 The use of interval data

In this study, interval data, with equal distances and equal differences between points on scales, were used as displayed in the profile plots (see section 4.3).

Lastly, independence of data is also an important assumption when analysing data in a repeated measures design, therefore this aspect is discussed in the next section.

4.2.1.4 Independence of data

Field (2005, p. 64) notes that in the case of a repeated-measures design in both ANOVA and MANOVA, it can be expected that scores in the experimental condition will not be independent for a specific participant, but this does not hold true for different participants because the behaviour of one participant should not have an effect on the other participants. With regard to this study, the independence requirement entails that the intelligence scores of the different participants in each group should not exert an influence on one another, and therefore the scores should be statistically independent.

4.3 Results of the Investigation

4.3.1 Testing H1

The assumptions required for ANOVA and MANOVA such as the assumptions of normality and homogeneity were tested and dealt with in the previous section (see section 4.2).

In order to test if there are significant improvements in cognitive or intellectual developments (Global intelligence) of both groups (Grade R learners in the control or experimental group) after the period of 40 weeks or between the pre- and post test levels (as measured on the JSAIS scales), a two-way ANOVA with repeated measures was used to analyse the results and thereby further explore the relation between chess instruction and the development of cognition and intelligence.

Table 4.1 presents a summary of the MANOVA analysis of the interaction between groups and time, displaying the within-subjects effect for time.

Table 4.1
MANOVA Summary Table of the Analysis of Groups and Time, Displaying the Within-subjects Effect for Time

Source	Numenator DF	Denominator DF	F	P-*value*
Within subjects:				
Time	1	62	97.41	<0.000*
Group by Time interaction	1	62	6.25	0.015*

n=64

The following conclusions can be drawn from the data in Table 4.1.

The *p*-value for the factor time is less than 0.05 ($F_{1,62}$=97.41, *p*<0.0001*) indicating a significant effect at a 95 % level of confidence. The *p*-value for the interaction is less than 0.05 ($F_{1,62}$=6.25, *p*=0.0151*) indicating a significant difference for the interaction term at a 95 % level of confidence.

The 0.05 alphalevel was used when drawing conclusions regarding the significance of interactions between chess and time as reflected by the intelligence scores. This notion was applied in order to guard against a Type 2 error, which could occur due to the lower power resulting from the small sample used in this study. The results were analysed using a two-way ANOVA with repeated measures on one factor.

The SAS JMP program used in the empirical analyses does not provide effect sizes; therefore a General Linear Model (GLM 5) in the SPSS standard version was used to calculate effect sizes for significant values (see Table 4.2 below, where the results of the tests of within-subjects effects for GIQ are set out)**.** Prior to the calculation of the effect sizes, the null hypothesis stating that the observed covariance matrices of the dependent variables are equal across groups, was tested (see Appendix B, Table B7 Box's Test of Equality of Covariance Matrices). No significant values at a 95 % level of confidence were obtained from this test.

Table 4.2
Results of Tests of Within-Subjects Effects for GIQ

Source		**Type III Sum of squares**	**Df**	**Mean Square**	**F**	**Sig**	**Partial Eta Squared**
Time	Sphericity Assumed	1298.809	1	1298.809	97.41	.000	.611
	Greenhouse -Geisser	1298.809	1.000	1298.809	97.41	**.000***	.611
	Huynh-Feldt	1298.809	1.000	1298.809	97.41	.000	.611
	Lower bound	1298.809	1.000	1298.809	97.41	.000	.611
Time Group	Sphericity Assumed	83.309	1	83.309	6.25	.015	.092
	Greenhouse-Geisser	83.309	1.000	83.309	6.25	**.015***	.092
	Huynh-Feldt	83.309	1.000	83.309	6.25	.015	.092
	Lower bound	83.309	1.000	83.309	6.25	.015	.092
Error	Sphericity Assumed	826.683	62	13.334			
	Greenhouse-Geisser	826.683	62.000	13.334			
	Huynh-Feldt	826.683	62.000	13.334			
	Lower bound	826.683	62.000	13.334			

n = 64

The following conclusions can be drawn from the data presented in Table 4.2.

There was a statistically significant main effect (time) at a 95 % level of confidence ($F_{1,62}$=97.41, *p*<.000*) with a large contribution of 61 % variance to GIQ (eta square is .611).

Multivariate tests such as the Pillai's trace and the Greenhouse-Geisser *F* test were used to draw conclusions regarding the within-subject effect, as well as the interaction involving the within-subjects factor. The Pillai's trace was used owing to the small sample size in the study and because the values were similar to those obtained by the SAS JMP program. All the results were confirmed by the output in the GLM program (see tables 4.1 and 4.2, as well as Appendix B, Table B8, MANOVA Summary of the Tests of Within-subjects Effects for VIQ and the Multivariate Tests).

The null hypothesis for GIQ therefore cannot be accepted, as the results indicate that both groups (the control and experimental groups) displayed improved cognitive development and intellectual development over time as reflected in the groups' statistically significant scores on the GIQ scale (see section 2.8, where the formulation of the hypotheses is discussed).

4.3.1.1 Testing H1.1

In order to test if there is a significant difference between the mean scores of the two groups on the PIQ (intelligence) after the 40 week period, a two-way ANOVA with repeated measures was used to analyse the results and thereby further explore the relation between the variables in the model.

Table 4.3
MANOVA Summary Table of the Analysis of Groups and Time, Displaying the Within-subjects Effect for Time

Source	Numerator DF	Denominator DF	F	P-value
Within subjects: Time	1	62	55.46	<0.000*
Group by Time: Interaction	1	62	4.15	0.046*

n=64

The following conclusions can be drawn from the data displayed in Table 4.3. The *p*-value for the factor time is less than 0.05 ($F_{1,62}$=55.46, *p*<0.000*) indicating a significant effect at a 95 % level of confidence.

The *p*-value for the interaction is less than 0.05 ($F_{1,62}$=4.15, *p*=0.046*) indicating a significant difference for the interaction term at a 95 % level of confidence.

Results were analysed using a two-way ANOVA with repeated measures on one factor.

As previously stated, the SAS JMP program employed in this study does not provide effect sizes therefore the GLM program was used to calculate the effect sizes (see Table 4.4). Results were analysed using a two-way ANOVA with repeated measures on one factor.

Table 4.4
Results of Tests of Within-Subjects Effects for PIQ

Source		Type III Sum of squares	Df	Mean Square	F	Sig	Partial Eta Squared d
Time	Sphericity Assumed	1469.653	1	1469.653	55.46	.000	.472
	Greenhouse -Geisser	1469.653	1.000	1469.653	55.46	**.000***	.472
	Huynh-Feldt	1469.653	1.000	1469.653	55.46	.000	.472
	Lower bound	1469.653	1.000	1469.653	55.46	.000	.472
Time Group	Sphericity Assumed	109.903	1	109.903	4.15	.046	.063
	Greenhouse-Geisser	109.903	1.000	109.903	4.15	**.046***	.063
	Huynh-Feldt	109.903	1.000	109.903	4.15	.046	.063
	Lower bound	109.903	1.000	109.903	4.15	.046	.063
Error	Sphericity Assumed	1642.816	62	26.497			
	Greenhouse-Geisser	1642.816	62.000	26.497			
	Huynh-Feldt	1642.816	62.000	26.497			
	Lower bound	1642.816	62.000	26.497			

n = 64

The results displayed in Table 4.4 reveal a statistically significant main effect (time) ($F_{1,62}$=55.46, p<.000*) at a 95 % confidence level, with a contribution of 47 % to the variance in PIQ (eta square is .472). The results were analysed using a two-way ANOVA with repeated measures on one factor.

Multivariate tests such as the Pillai's trace and the Greenhouse-Geisser *F* test were used to draw conclusions regarding the within-subject effect, as well as the interaction involving the within-subjects factor. The Pillai's trace was used and the values were similar to those obtained by the SAS JMP program. All the results were confirmed by the output in the GLM program (see Appendix Table B8 Multivariate Tests).

Therefore, the null hypothesis for PIQ is rejected because the results indicate that both groups exhibit improved cognitive and intellectual development as seen in mean scores of the PIQ scale after the 40 week period (see section 2.8, where the formulation of hypotheses is discussed).

4.3.1.2 Testing H1.2

In order to test if there is a significant difference between the mean scores of the two groups on the VIQ scale (intelligence) after exposure to chess instruction (of the experimental group) a two-way ANOVA with repeated measures was used to analyse the results and thereby further explore the relation between the variables in the model.

Table 4.5 presents a summary of the MANOVA results of the analyses of the interaction between the groups and time (and thereby displays the within-subjects effect for time).

Table 4.5
MANOVA Summary Table of the Analysis of Groups and Time, Displaying the Within-subjects Effect for Time

Source	**Numerator DF**	**Denominator DF**	**F**	**P-value**
Within subjects:				
Time	1	62	60.650	<0.000*
Group by Time interaction	1	62	1.210	0.276

n=64

The following conclusions can be drawn from the data presented in Table 4.5.

The *p*-value for the factor Time is less than 0.05 ($F_{1,62}$=60.65, *p*<0.000*) indicating a significant effect at a 95 % level of confidence.

The *p*-value for the interaction is greater than 0.05 ($F_{1,62}$=1.21, *p*=0.276) indicating no significant difference for the interaction term at a 95 % level of confidence.

Table 4.6 below presents the results of the analysis of the tests of the within-subjects effects of VIQ which were provided when the GLM program was used.

Table 4.6
Results of Tests of Within-Subjects Effects of VIQ

Source		Type III Sum of squares	Df	Mean Square	F	Sig
Time	Sphericity Assumed	1420.419	1	1420.419	60.65	.000
	Greenhouse-Geisser	1420.419	1.000	1420.419	60.65	**.000***
	Huynh-Feldt	1420.419	1.000	1420.419	60.65	.000
	Lower bound	1420.419	1.000	1420.419	60.65	.000
Time Group	Sphericity Assumed	28.294	1	28.294	1.21	.276
	Greenhouse-Geisser	28.294	1.000	28.294	1.21	.276
	Huynh-Feldt	28.294	1.000	28.294	1.21	.276
	Lower bound	28.294	1.000	28.294	1.21	.276
Error	Sphericity Assumed	1451.948	62	23.419		
	Greenhouse-Geisser	1451.948	62.000	23.419		
	Huynh-Feldt	1451.948	62.000	23.419		
	Lower bound	1451.948	62.000	23.419		

n=64

The following conclusions can be drawn from Table 4.6.

The GLM program was used to calculate effect sizes and all the tests used in this program revealed similar results as provided by the SAS JMP program and thereby confirms all the results of the SAS JMP (see tables 4.5, 4.6 and Table B8 in Appendix B, MANOVA Summary of the tests of within-subjects effects for VIQ and the multivariate tests). The results indicated a statistically significant main effect (time) ([$F_{1,62}$=60.650, p<.000*]) at a 95 % confidence level, with a large contribution of 49 % to the variance in VIQ (eta square is 0.495).

The results were analysed using a two-way ANOVA with repeated measures on one factor. Therefore, the null hypothesis for VIQ cannot be accepted in view of the significant results indicating no relation between chess instruction and Grade R learners’ intelligence (VIQ) (see section 2.8). Both groups displayed improved cognitive development and intellectual development over time as reflected in the VIQ scale.

4.3.1.3 Testing H1.3

In order to test if there is a significant difference between the mean scores of the two groups on the Numerical scale (intelligence) after the 40 week period, a two-way ANOVA with repeated measures was used to analyse the results and thereby further explore the relation between the variables in the model.

The MANOVA summary of the results of the analysis is presented in Table 4.7.

Table 4.7
MANOVA Summary Table of the Analysis of Groups and Time, Displaying the Within-subjects Effect for Time

Source	Numerator DF	Denominator DF	F	P-value
Within subjects:				
Time	1	62	14.90	0.000*
Group by Time interaction	1	62	1.72	0.194

n = 64

The following conclusions can be drawn from the data presented in Table 4.7.

The *p*-value for the factor Time is less than 0.05 ($F_{1,62}$=14.90, *p*=0.000*) indicating a significant effect at a 95 % level of confidence. The *p*-value for the interaction is greater than 0.05 ($F_{1,62}$=1.72, *p*=0.194) indicating no significant difference for the interaction term at a 95 % level of confidence.

Table 4.8 presents the tests of within-subjects effects (with effect sizes) summary table of the results of the analysis, as provided by the GLM program.

Table 4.8
Results of Tests of Within-Subjects Effects for the Numerical Scale

Source		Type III Sum of squares	Df	Mean Square	F	Sig	Partial Eta Squared
Time	Sphericity Assumed	32.503	1	32.503	14.90	.000	.194
	Greenhouse -Geisser	32.503	1.000	32.503	14.90	**.000***	.194
	Huynh-Feldt	32.503	1.000	32.503	14.90	.000	.194
	Lower bound	32.503	1.000	32.503	14.90	.000	.194
Time Group	Sphericity Assumed	3.753	1	3.753	1.72	194	.027
	Greenhouse-Geisser	3.753	1.000	3.753	1.72	194	.027
	Huynh-Feldt	3.753	1.000	3.753	1.72	194	.027
	Lower bound	3.753	1.000	3.753	1.72	194	.027
Error	Sphericity Assumed	135.216	62	2.181			
	Greenhouse-Geisser	135.216	62.000	2.181			
	Huynh-Feldt	135.216	62.000	2.181			
	Lower bound	135.216	62.000	2.181			

n = 6

Based on the data contained in Table 4.8, the following conclusions can be drawn.

Multivariate tests such as the Pillai’s trace and the Greenhouse-Geisser *F* test were used to draw conclusions regarding the within-subject effect, as well as the interaction involving the within-subjects factor (see Appendix B, Table B8). The results produced by the GLM program confirm the results provided by the SAS JMP program. The results revealed one statistically significant main effect (time)

([$F_{1,62}$=14.90, p <.000*]) at a 95 % confidence level, with a contribution of 19 % to the Numerical scale (eta square is .194).

The results were analysed using a two-way ANOVA with repeated measures on one factor. In view of the statistically significant results, the null hypothesis for Num scale was rejected, because there was a significant cognitive and intellectual improvement in the numerical intelligence of both groups' after the 40 week period (see section 2.8 for further detail).

4.3.2 Testing H2

The assumptions required for ANOVA and MANOVA such as those of normality and homogeneity were tested and dealt with in the previous section (see section 4.2).

In order to test if there is a significant difference between the mean scores of the two groups on the GIQ scales (intelligence) after exposure to chess instruction (of the experimental group) a two-way ANOVA with repeated measures was used to analyse the results and thereby further explore the relation between the variables in the model.

The GIQ profile plot in Figure 4.1 based on the analysis displays the interaction between the groups (control, experimental) and time (pre, post).

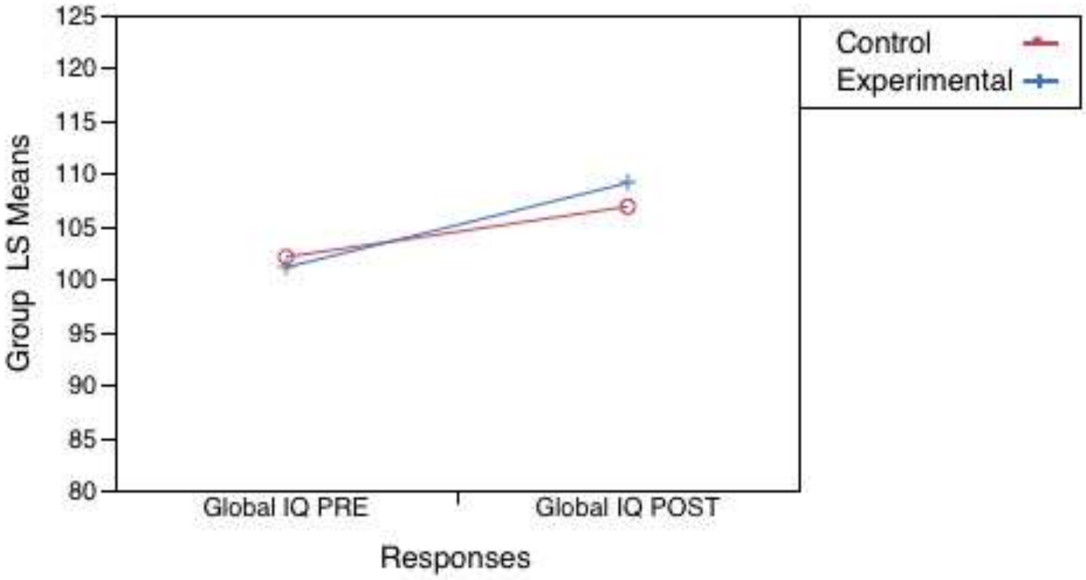

***Figure 4.1* The GIQ profile plot from the two-way ANOVA analysis displaying the interaction between the groups and time.**

The plot in Figure 4.1 indicates that a possible interaction between group and time exists. The experimental group obtained a lower score than the control group at the pre-test level, but increased more over time than that of the control group (see Appendix B, Table B6). The post-test GIQ mean score of the experimental group was 109.12, whereas the post-test mean score of the control group was 106.12. Table 4.9 presents a summary of the MANOVA results of the analysis of the interaction between the groups and time.

Table 4.9
MANOVA Summary of the Analysis of the Interaction between the Variables, Groups and Time

Source	Numerator DF	Denominator DF	F	P-value
Between subjects:				
Group	1	62	0.13	0.715
Within subjects:				
Time	1	62	97.41	<0.000*
Group by Time: Interaction	1	62	6.25	0.0151*

n=64

The following conclusions can be drawn from the data in Table 4.9.

The *p*-value for the interaction is less than 0.05 ($F_{1,62}$=6.25, *p*=0.0151*) indicating a significant difference for the interaction term at a 95 % level of confidence. The *p*-value for the factor Group is greater than 0.05 ($F_{1,62}$=0.13, *p*=0.715 ns) indicating no significant effect at a 95 % level of confidence.

Tests for simple effects revealed that the mean GIQ score for both the control group ($F_{1,62}$=25.69, *p*<0.000*) and experimental group ($F_{1,62}$=81.23, *p*<0.0001) displayed significant differences across time. The results were analysed using a two-way ANOVA with repeated measures on one factor.

A corrected model of the effects of the between subjects (groups) was used (due to unequal group sizes) to investigate whether the groups differed on the dependent variables (in terms of the PIQ, VIQ, Num scale and the GIQ scales), but there were no significant effects at the 95 % confidence level (see Appendix B, Table B9). No significant values were obtained from the corrected model regarding the between-groups effect.

As already stated, the GLM program was used to calculate the effect sizes. Multivariate tests such as the Pillai's trace were used to draw conclusions regarding the interaction involving the within-subjects factor (see Appendix B, Table B8). All the results were confirmed by the output in the GLM program and the Pillai's trace values were similar to those obtained by the SAS JMP program.

The following conclusions can be drawn from the data presented in Table B8.

The Pillai's Trace revealed a statistically significant between-subjects interaction effect ($F_{1,62}$=6.25, p<.015*) at a 95 % confidence level, with a very small contribution of 9 % to the variance in GIQ (eta square is .092).

Therefore, the null hypothesis for GIQ cannot be accepted, as the results indicate that there is a significant relation between chess instruction and Grade R learners' intelligence (GIQ) (see section 2.8, where the formulation of the hypotheses is discussed).

4.3.3 Testing H 3

In order to test whether there is a significant difference between mean scores of the two groups on the *PIQ* (intelligence) after exposure to chess instruction, a two-way ANOVA with repeated measures was used to analyse the results.

The following PIQ Profile Plot (Figure 4.2) using data from the two-way ANOVA analysis portrays the interaction between the groups (control, experimental) and time (pre, post).

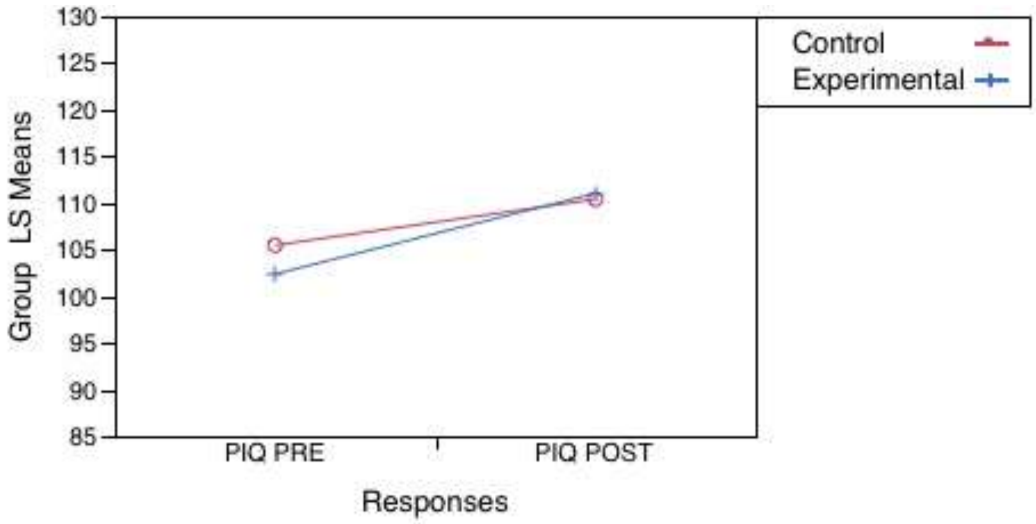

Figure 4.2 **The PIQ profile plot from the two-way ANOVA analysis displaying the interaction between the groups and time.**

In Figure 4.2, it is evident that there is an interaction between group and time. At the pretest (see Appendix B, Table B6) the experimental group obtained mean scores lower than those of the control group, but those of the experimental group increased more across time than the scores of the control group. Sampling in this study was not carried out on a random basis, but rather based on convenience (see section 3.2.3). However, the experimental group did score slightly higher than the control group in the pre-test measurement of PIQ, but this difference was not statistically significant.

Nonetheless, in a future study, it would be important to pair participants based on intelligence, meaning that the IQ of a participant in the control group must be paired or coupled with another participant's IQ in the experimental group, on the same level of intelligence at the pre-test condition.

Table 4.10 presents a summary of the PIQ MANOVA results of the analysis of the interaction between the groups and time.

Table 4.10
MANOVA Summary of the Analysis of the Interaction between the Variables, Groups and Time

Source	Numerator DF	Denominator DF	F	P-value
Between subjects:				
Group	**1**	**62**	**0.38**	**0.537**
Within subjects:				
Time	**1**	**62**	**55.46**	**<0.000***
Group by Time: Interaction	**1**	**62**	**4.15**	**0.046***

n=64

The following conclusions can be drawn from the data displayed in Table 4.10.

The *p*-value for the factor Group is greater than 0.05 ($F_{1,62}$=0.38, *p*=0.537) indicating no significant effect between values are at a 95 % level of confidence. The *p*-value for the interaction (group by time) is less than 0.05 ($F_{1,62}$=4.15, *p*=0.046*) indicating a significant difference for the interaction term at a 95 % level of confidence. The *p*-value for the factor Time is less than 0.05 ($F_{1,62}$=55.46, *p*<0.000*) indicating a significant effect at a 95 % level of confidence. Tests for simple effects indicated that the mean PIQ score for both the control group ($F_{1,62}$=13.47, *p*<0.000*) and experimental group ($F_{1,62}$=48.95, *p*<0.000*) displayed significant differences across time. Results were analysed using a two-way ANOVA with repeated measures on one factor.

A corrected model of the effects of the between subjects (groups) was used to further investigate whether the groups differed on the dependent variables (here in terms of the PIQ), but there were no significant effects at the 95 % confidence level (see Appendix B, Table B9). No significant values were obtained from the corrected model regarding the between-groups effect.

A General Linear Model (GLM 5) in the SPSS standard version was used to calculate effect sizes for significant values. Prior to the calculation of the effect sizes, the null hypothesis stating that the observed covariance matrices of the dependent variables are equal across groups was tested (see Appendix B, Table B7 Box's Test of Equality of Covariance Matrices). No significant values at a 95 % level of confidence were obtained from this test. Multivariate tests such as the Pillai's trace tests were used to draw conclusions regarding the interaction involving the within-subjects factor. The values of the Pillai's trace were similar to those obtained by the SAS JMP program (see Appendix B, Table B8 Multivariate Tests).

The results displayed in Table 4.10 reveal a statistically significant main effect (time) ($F_{1,62}$=55.46, p<.000*) at a 95 % confidence level, with a contribution of 47 % to the variance in PIQ (eta square is .472).

The Time*Group interaction effect was also statistically significant ($F_{1,62}$=4.15, p <.046*) at a 95 % confidence level, but contributed to only 6.3 % of the variance in PIQ (eta square is .063).

Therefore, the null hypothesis for PIQ is rejected because the results indicate that there is a significant relation between chess instruction and Grade R learners' intelligence (PIQ) (see section 2.8).

4.3.4 Testing H4

In order to test if there is a significant difference between the mean scores of the two groups for the VIQ (intelligence) after exposure to chess instruction, a two-way ANOVA with repeated measures was used to analyse the results. The analysis data plotted in Figure 4.3 portrays the interaction between the groups and time.

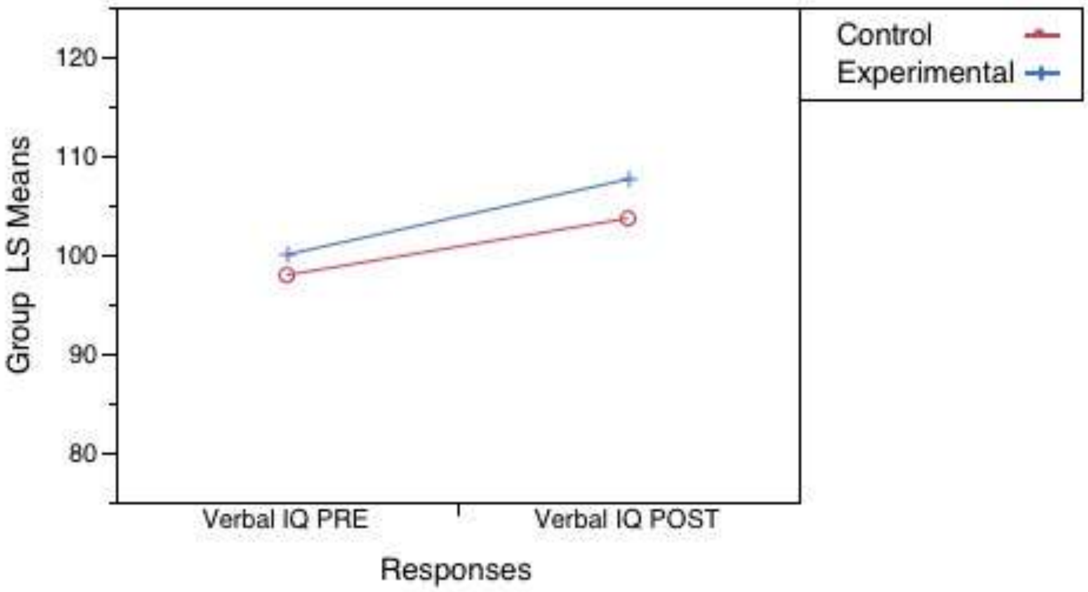

Figure 4.3 **The VIQ profile plot from the two-way ANOVA analysis displaying the interaction between the groups and time.**

The VIQ profile plot (Figure 4.3) indicates that both the control and experimental groups increased equally over time (see Appendix B, Table 6 Difference between means of the PRE and POST IQ levels of groups). Table 4.11 presents a summary of the MANOVA results of the analysis of the interaction between the groups and time.

Table 4.11

MANOVA Summary of the Analysis of the Interaction between the Variables, Groups and Time

Source	Numerator DF	Denominator DF	F	P-value
Between subjects:				
Group	1	62	2.480	0.121
Within subjects:				
Time	1	62	60.650	<0.000*
Group by Time interaction	1	62	1.210	0.276

n=64

The following conclusions can be drawn from the data presented in Table 4.11.

The *p*-value for the interaction is greater than 0.05 ($F_{1,62}$=1.21, *p*=0.276) indicating no significant difference for the interaction term at a 95 % level of confidence. The *p*-value for the factor Time is less than 0.05 ($F_{1,62}$=60.65, *p*<0.000*) indicating a significant effect at a 95 % level of confidence. The *p*-value for the factor Group is greater than 0.05 ($F_{1,62}$=2.48, *p*=0.1205) indicating no significant effect at a 95 % level of confidence, therefore a corrected model of the effects of the between subjects (groups) was used to further investigate whether the groups differed on the dependent variables (here in terms of the VIQ), but there were no significant effects at the 95 % confidence level (see Appendix B, Table B9). No significant values were obtained from the corrected model regarding the between-groups effect.

A General Linear Model (GLM 5) in the SPSS standard version was used to calculate effect sizes for significant values. Prior to the calculation of the effect sizes, the null hypothesis stating that the observed covariance matrices of the dependent variables are equal across groups was tested (see Appendix B, Table B7 Box’s Test of Equality of Covariance Matrices). No significant values at a 95 % level of confidence were obtained from this test. Multivariate tests such as the Pillai's trace tests were used to draw conclusions regarding the interaction involving the within-subjects factor. The values of the Pillai's trace were similar to those obtained by the SAS JMP program (see Appendix B, Table B8 Multivariate Tests).

The results were analysed using a two-way ANOVA with repeated measures on one factor. The Group by Time interaction was not significant, $F_{1,62}=1.21$, $p=0.276$. Therefore, the null hypothesis for VIQ is accepted in view of the insignificant results indicating no relation between chess instruction and Grade R learners' intelligence (VIQ) (see section 2.8).

4.3.5 Testing H5

In order to test if there is a significant difference between the mean scores of the two groups for the numerical intelligence scale after exposure to chess instruction, a two-way ANOVA was performed to analyse the results. The numeric profile plot (Figure 4.4) of the analysis results portrays the interaction between the groups and time.

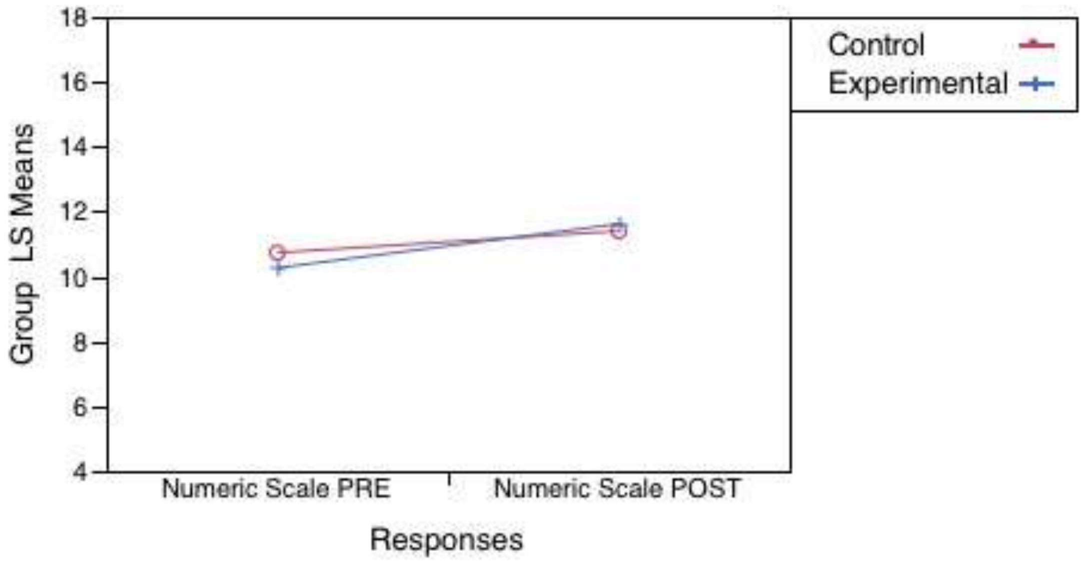

Figure 4.4 **The Numeric profile plot from the two-way ANOVA analysis displaying the interaction between the groups and time.**

The plotted data in Figure 4.4 indicates that not only did the control and experimental groups both increase over time, but also, the experimental group exhibited a slightly higher increase in the Numeric mean score than the control group did. The experimental group obtained a lower mean score than the control group at the pre level (see Appendix B, Table B6, which displays the difference between means of the PRE and POST Test IQ levels of groups), but the post-test mean score on the Num scale of the experimental group was 11.62, whereas those for the control group was 11.40 (see section 4.3.5, Figure 4.4).

The MANOVA summary of the results of the analysis of the interaction between the groups/group and time is presented in the following table (Table 4.12).

Table 4.12
MANOVA Summary of the Analysis of the Interaction between the Groups and Time

Source	Numerator DF	Denominator DF	F	P-value
Between subjects:				
Group	1	62	0.0518	0.8207
Within subjects:				
Time	1	62	14.90	0.000*
Group by Time interaction	1	62	1.72	0.194

n=64

The following conclusions can be drawn from the data presented in Table 4.12.

The *p*-value for the interaction is greater than 0.05 ($F_{1,62}$=1.72, *p*=0.194) indicating no significant difference for the interaction term at a 95 % level of confidence. The *p*-value for the factor Time is less than 0.05 ($F_{1,62}$=14.90, *p*=0.000*) indicating a significant effect at a 95 % level of confidence. The *p*-value for the factor Group (the between-subject effect) is greater than 0.05 ($F_{1,62}$=0.0518, *p*=0.8207) indicating no significant effect at a 95 % level of confidence.

A corrected model of the effects of the between subjects (groups) was used to investigate whether the groups differed on the dependent variables (in terms of the subscales and the global scale of the JSAIS), but there were no significant effects at the 95 % confidence level (see Appendix B, Table B9). No significant values were obtained from the corrected model regarding the between-groups effect.

Multivariate tests such as the Pillai's trace were used to draw conclusions regarding the within-subject effect, as well as the interaction involving the within-subjects factor. The values of the Pillai's trace were similar to those obtained by the

SAS JMP program. All the results were confirmed by the output in the GLM program (see Appendix B, Table B8 Multivariate Tests).

Results were analysed using a two-way ANOVA with repeated measures on one factor. The Group by Time interaction was not significant, $F_{1,62}$=1.72, p=0.194. In view of the results, the null hypothesis for Num scale was accepted as there was no significant relation between chess instruction and Grade R learners' intelligence (Num scale) (see section 2.8 for further detail).

4.4 Conclusion

In order to explore the relation between chess instruction and intelligence (as represented by scores on scales and subscales of the JSAIS), differences between the control and experimental groups (after exposure to chess instruction) were investigated by making use of various statistical analyses such as ANOVA and MANOVA. Results in the study revealed statistically significant differences between the group means of the PIQ and GIQ scales at a 95 % level of confidence ([PIQ, $F_{1,62}$=4.15, p=0.046* and GIQ, $F_{1,62}$= 6.25, p=0.015]), which indicates a relation (interaction) between chess instruction (across time) and intelligence. However, the magnitude of this relation is small (eta square is .063) and the time factor contributes mainly to these two interactions, but not the chess factor. Both groups increased over time, in terms of the within-subjects effects for PIQ, VIQ, GIQ and Num scales ([PIQ, $F_{1,62}$=55.46, p=<0.000*; VIQ $F_{1,62}$=60.65, p=<0.000*; GIQ $F_{1,62}$=97.41; p<0.000*; Num scale, $F_{1,62}$=14.90 p=0.000*]), at a 95 % confidence level. The time factor contributed 47 % towards the variance in PIQ; 49 % variance to VIQ; a large contribution of 61 % to GIQ and a very small contribution of 19 % variance to the Numerical scale.

The significant results in the study on the relation between chess exposure over time and intelligence (for the PIQ scale) falls in line with the study conducted by Frydman and Lynn (1992) in which a link was found between chess skill and performance intelligence (see section 2.4.1.1 for further detail, where visual imagery, visualisation and visuo-spatial abilities, are discussed).

The results of the investigation are discussed in the next chapter and conclusions are drawn with regards to the relation between chess instruction and intelligence. Certain recommendations for future research are made with reference to the obtained results.

Chapter 5
Discussion

5.1 Introduction

In this chapter the contribution made by the research described in the previous two chapters as well as the implications of the results obtained are considered. To recapitulate, the objective of the study was to investigate the relation between chess instruction and the development of cognition and intelligence using a sample of young children.

The study is situated in the theoretical framework of research on the novice-expert shift in cognitive psychology. It was posited that extensive practice in chess deriving from instruction in the game and learning the basic elements of chess would have a positive effect on aspects of cognition and intelligence due to the theoretical construct of transfer between the two domains.

In the light of this theory, it was postulated that chess instruction and chess playing (hereafter simply referred to as ‘chess instruction’) would over time confer a cognitive benefit on the children receiving such instruction, and consequently, they would score better in intelligence tests (i.e., the GIQ of the JSAIS, and its subscales: the PIQ, VIQ, and Num) than learners who did not receive similar exposure to chess instruction. It was further postulated that some effect owing to the treatment factor (i.e., the chess instruction) will be manifested after a reasonably short period of 40 weeks during which the experimental group had received instruction in chess and participated in playing the game.

5.1.1 Results relating to the effects of the within-subjects

In Hypothesis 1 and its sub-hypotheses (i.e., hypotheses 1.1. 1.2, and 1.3) it was postulated that all the children would exhibit cognitive development during the period in which the research was conducted. The MANOVA results revealed a main effect for time on GIQ, and also for the three subscales (PIQ, Num and VIQ), clearly indicating that both groups demonstrated a gain in their performance in the cognitive tests after the 40 week period. Moreover, this increase was statistically significant at a 95 % confidence level, as indicated in the within-subjects effects for the GIQ, PIQ, VIQ, and Num scales ([GIQ $F_{1,62}=97.41$; $p<0.000$*; PIQ, $F_{1,62}=55.46$, $p=<0.000$*; VIQ $F_{1,62}=60.65$, $p=<0.000$*; Num scale, $F_{1,62}=14.90$ $p=0.000$*]).

There is therefore general support for hypotheses 1, 1.1, 1.2, and 1.3 which predicted that some improvement will be manifested in all the children’s cognitive abilities between the pre-test and post-test periods. This cognitive development across time is consistent with psychological theory and expectation; the children participating in this study were in the Piaget’s concrete operations stage, and according to Piagetian theory, children begin to think more logically and become capable of inductive reasoning due to various cognitive skills that emerge during this stage (Ormrod, 2006, p. 28). Thus, cognitive development evidently did occur in all the children (i.e., both the control and the experimental groups) in this sample during the 40 week interval of time.

The cognitive development observed among all the participants can be ascribed to normal cognitive and biological maturation, but the educational environment provided by the Grade R preparatory school, Garsieland*,* could also have had a facilitating effect. Children attending a preparatory school have access to an enriching environment involving inter alia additional computer classes, books, climbing frames and extra mural activities. They follow a prescribed curriculum that can remove some of the characteristics that vary among children stemming from different levels of exposure to relevant environmental stimuli at home, that is, nurture effects (see sections 2.2 and 2.2.1. for further detail). The main educational objective of Grade R classes is to address developmental lags, and thereby facilitate school readiness so that children are prepared for formal schooling. The preparatory schooling environment attendant on the Grade R classes could therefore have made some contribution to the general cognitive improvement reflected in the effects of the within participants. Unfortunately, due to the type of methodology employed in this study (both groups were children in Grade R), no valid inferences can be made about the specific contribution yielded by the Grade R environment. Therefore, the extent of the children’s cognitive improvement remains unclear (the within-subjects effects) can be ascribed to just normal developmental processes resulting from factors such as neural plasticity, general cognitive malleability, and intellectual stimulation received at home, and the extent to which this stems from the additional cognitive benefits (if any) conferred by the Grade R context.

5.2 Results Relating to the Between-Subjects Effects (H2-H5)

Although it was predicted that a general increase in the JSAIS scores would be observed in all the children due to cognitive developmental processes, the specific focus of this study falls on the facilitating effect of chess instruction on cognitive abilities. The research findings pertaining to this between-groups aspect are now discussed.

5.2.1 H2: General cognition

The main hypothesis underlying this research, Hypothesis 2, predicted that chess instruction would confer a cognitive gain and that hence a between-groups effect will be observed on the children's GIQ scores, with the experimental group achieving higher scores in the post-test measurement than the control group. Support for this hypothesis was obtained, and a statistically significant difference in GIQ scores was found between the two groups in the appropriate direction. Thus, the *p*-value obtained in the MANOVA analysis pertaining to GIQ, that is, for the F-ratio ($F_{1,62}$=97.41), was statistically significant (p<0.0001*), because it was less than 0.05 at a 95 % confidence level.

However, although a statistically significant increase was observed in the mean scores of the experimental group on the GIQ scale relative to the control group, the effect size was rather weak, with an eta square of only .092. This suggests that chess instruction had a significant, but small effect on general intelligence over the given period. Of course, the possibility that this effect could also have resulted from other factors (and not just chess) cannot be ruled out; this possibility is discussed further later in this chapter. Furthermore, it should be recognised that this study is best characterised as entailing a rather small-scale research approach that simply explored the effect of chess instruction on cognitive development, and that, due to the quasi-experimental design, the results are purely tentative. Nonetheless, the findings obtained do have some bearing on current debates about the relationship between chess skill and intelligence.

This debate is far from settled. Thus, Bilalić *et al*. (2007) contend that it appears as if intelligence is important and correlates with chess skill at the beginning of chess excellence when children learn to play chess (as in this current study), but that this may not be the case for elite chess players with a restricted range of abilities, who all possess relatively high skills in chess. The Bilalić's study (2007) revealed that the relationship between chess skill and intelligence is complex and they even found that chess skill correlated negatively with intelligence in their sample of elite chess players. In contrast, other studies amongst which, that of Horgan and Morgan (1990) demonstrated a positive relationship between chess and intelligence using Raven's Progressive Matrices to measure intelligence. In their study, the 15 highest rated chess players also scored higher than the average for children of their age on the Raven's intelligence scale. Since there are different and conflicting findings regarding the relationship between chess and intelligence further research on this topic is clearly warranted. This study attempted to contribute to the topic, but the research was concerned with the effect of chess instruction, not chess per se, on intelligence and the focus fell only on the early stages in the development of chess knowledge. No analysis of the effect of higher or lower levels of chess ability on the development of general intelligence could therefore be performed.

To gain further insight into the nature of the specific aspects of intelligence influenced by the treatment factor, chess instruction, hypotheses 3-5 considered the performance, numerical, and verbal dimensions of intelligence. The findings pertaining to these hypotheses are discussed in the next two sections.

5.2.2 H3: Performance intelligence

Hypothesis 3 was concerned with performance intelligence and it was predicted that the experimental group would achieve higher scores than the control group on this subscale. Chess is a strongly visuo-spatial skill requiring the ability to mentally contemplate dynamic changes on a chess board when various possible moves are considered. Alternatively stated, chess players need to construct an image of the game in their mind of how possible moves would transform the configuration of pieces on the board as well as what the logical consequences of different candidate moves are in order to achieve the goal state (i.e., check mate). In the light of the visuo-spatial nature of the game, it was predicted that learning to play chess will produce a positive effect on the experimental group's performance intelligence and consequently that their PIQ scores will exhibit a larger increase from the pre-test to the post-test condition than those of the control group.

Support for this prediction was found. The results obtained in this study regarding the experimental group's performance on the PIQ subscale confirm those yielded in the research conducted by Frydman and Lynn (1992). However, a slightly different interpretation advanced by Frydman and Lynn can also be entertained in this case. Frydman and Lynn (1992) considered the PIQ scale to be an instrument with which to measure visuo-spatial abilities or visual memory (which it does as part of non-verbal reasoning); however, the PIQ scale also measures many other skills such as attention and working memory.

According to Sternberg (2006), very young children experience difficulty with focusing on relevant aspects of school matter and cannot easily concentrate on educational tasks (see section 1.2, for further details). Campitelli and Gobet (2005) contend that chess instruction fosters a child's alertness, attention to detail, concentration, logical thinking and work under pressure, relevant to each child's age level and not only visuo-spatial abilities (for instance, Block designs, as measured by one of the PIQ subtests) (also see Betz & Niesch, 1995; Gobet & Campitelli, 2006). These skills are all measured by the subtests of the PIQ scale and improvements in some of these skills could therefore have contributed to the higher scores obtained on this scale, and not only an increase in visuo-spatial abilities.

It is therefore possible that chess, as a form of additional stimulation or as an instructional technique, could have led to an improvement of concentration skills which subsequently resulted in improved functioning of the children's working memories. The effect of chess on working memory is a factor also discussed by Gobet and Campitelli (2006). Moreover, Sternberg (2006) argues that fluid intelligence is higher in younger children than in adults, and that fluid intelligence relates to the ability to acquire new material and manipulate it in working memory. The increase in the experimental group's PIQ scores over time may therefore also partly stem from an improvement in concentration and working memory, and not just from enhanced visuo-spatial skills.

It is very likely that the improvement in the PIQ scale could have induced the general improvement observed in the experimental group's GIQ scores in relation to those of the control group. The GIQ is a global scale which is a composite of the three subscales, the VIQ, PIQ and Num scales, and as discussed in the next section, no statistically significant differences between the two groups were found in the other two subscales. The only statistically significant difference yielded by the data in this study concerned the PIQ subscale. However, findings in a study conducted by

Bilalić *et al.*, (2007) revealed significant results for a composite scale (representing four different underlying cognitive abilities) and for two of the four subtests (Digit span and Symbol search). However, no significant results were obtained for the subtest, Block designs (see section 5.2.2 for further detail, where H3: Performance intelligence is discussed).

5.2.3 Results from H4 and H5:

The VIQ and Num scales did not display a positive relationship between chess exposure over time and verbal and/or numerical intelligence, thus confirming other research mentioned in the literature (e.g., Peterson, 2002; Frank & D'Hondt, 1979; Doll & Mayr, 1987).

For both these scales the results obtained were not statistically significant. Thus, the *p*-value for the VIQ scale (F-ratio$_{1,62}$=1.210) is greater than 0.05 (*p*=0.276), at a 95 % level of confidence and is therefore not statistically significant. Likewise, the *p*-value for the Num scales ($F_{1,62}$=1.72) was greater than 0.05 (*p*=0.194), at a 95 % confidence level and is not statistically significant. Hypotheses 4 or 5 were therefore not supported by the data yielded by the research in this study, because in both cases the null hypotheses could not be rejected.

With regard to the VIQ scale, numerous studies found that reading in educational settings improved after chess exposure (see section 2.6.2, where transfer to reading and verbal aptitudes, is discussed for further detail). In educational settings and in chess playing, children also learn better when confronted with visual information; this visual information is transformed into some kind of code or language (Schneck, 2005, p. 420; Sutton & Krueger, 2002). In both domains, building of declarative knowledge occurs in children's knowledge bases and an accumulation of experiences emerge from a child's use of fluid intelligence when interacting with society. However, the results obtained on the VIQ in the study were not statistically significant. There could have been some improvement of domain (chess) knowledge in memory, but this was not tested (see section 1.3.2.1, where *Anderson's Adaptive Control of Thought-Rational theory* is discussed, for further detail). In future studies, greater in-depth testing of reading abilities and/or verbal aptitude as measured in educational settings could be included as part of the pre- and post-level assessments to determine whether there was an improvement in verbal skills, and whether more advanced chess abilities such as knowledge of openings are positively associated with verbal knowledge and verbal intelligence. The employment of advanced research designs will enable the researcher to more systematically explore the possibility that chess skill may also have a connection with verbal comprehension skills instead of just performance intelligence.

There was no statistically significant effect due to chess instruction in respect of the Num scale. The experimental group did obtain lower mean scores than the control group in the pre-test condition and slightly higher mean scores in the post-test condition (see Figure 4.4). The change in scores therefore occurred in the direction predicted in Hypothesis 4, but were not statistically significant because measurement error cannot be counted as a factor. The direction of the pattern of results obtained does however indicate that the relationship between chess and numerical ability merit further exploration, particularly because evidence for a positive association between chess ability and mathematical achievement has been found in several research studies (e.g., Smith & Cage, 2000; Aciego *et al*., 2012).

There are three factors to consider with respect to the insignificant results on the Numerical (Num) scale yielded by the data analysis.

- Firstly, one must bear in mind that the participants in the treatment group were exposed to chess instruction for a relatively short period (i.e., only 40 weeks), during which they only learned the basics of the chess game. They had not yet been exposed to difficult problem solving, which fosters mathematical reasoning, and not to the type of mathematical reasoning on a more abstract level measured by the subtest Number B (which is applicable to 6 to 8 year old children) of the Num scale. In this regard, it should be noted that Number A (consisting of colourful pictures and applicable to 3 to 5 year old children) on the Num scale, merely aims to measure understanding of, and skill in, the manipulation of quantitative material in a relatively concrete manner, whereas subtest Number B focuses on the measurement of numerical accuracy in mental arithmetic. It is possible that the positive association between chess and mathematical reasoning found in certain other research develops only after considerable exposure to actually playing the game at a competitive level rather than to merely learning the basics of chess.

- Secondly, the relationship between actual chess skill (e.g., as manifested in an Elo-rating) and mathematical or numerical ability was not tested in this study because all the participants were essentially novice chess players. No distinction between the varying levels of chess skill among the children in the experimental group could be drawn yet, and as a result, chess ability could not be factored in as a variable in the data analysis.

- Thirdly, it should be noted that the statistical evidence for a within-effect pertaining to the Num scale was the lowest for all the subscales, and that there was little variance (only 19 %; see section 4.3.4). Since all the children (i.e., both the experimental and control groups) exhibited only a small increase between the pre-test and post-test conditions, a statistical range effect could have been obtained due to the restricted range within which the scores varied. Hence, a larger more varied sample and a longer period may be needed to establish whether chess instruction does exert an influence on the development of numerical skills in young children.

The research conducted in this dissertation made some contribution to our understanding of the relationship between chess and cognition. It also provided some findings relevant to the question of how useful chess instruction is in a scholastic environment. This is discussed in the next section.

5.3 Value of the Study

The main contribution of this study is to provide some further converging evidence regarding the relationship between chess and cognitive abilities or intelligence. The results obtained show that chess instruction could impact positively, on the cognitive development of young children, albeit with a rather small effect size, and further, that the strongest effect is possibly on the performance intelligence of such children.

In addition, and from a more theoretically substantive point of view, the study provides some support for the notion that some level of transfer could have occurred between the two domains relating to this research (chess and intelligence) due to intensive practice in learning the basics of chess.

5.3.1 Contribution to the general research regarding the role of chess in education

Very few studies have explored the cognitive effects of chess in very young children. Also, there is very little reliable data relating to the assessment of the cognitive abilities of chess players in general (Waters *et al.,* 2002). Therefore, this study does make a contribution to psychological knowledge by exploring the relationship between chess instruction and intellectual development in a scientific manner.

5.3.2 The nature-nurture debate regarding intelligence

This current study may have some relevance for broader debates in psychology regarding the role of nature or nurture in cognitive development. Since the children who received chess instruction exhibited a slight improvement in performance intelligence relative to the children not receiving such instruction, there is some evidence that nurturing could play a role in improving intelligence. However, there was no means by which nature (i.e., genetic factors) could be controlled for in this study, and sampling issues as well as other nuisance variables could have affected the results. Therefore, quite simply, there are only some indirect and very tentative results pertaining to the nature-nurture issue in this study.

5.3.3 The expert-novice theory and issue of transfer revisited

Although the effect size is small, the results do provide some support for the postulated effect of extended practice on the enhancement of cognitive abilities in a particular domain. It should be noted, however, that the pattern of the results obtained can be explained by two different theoretical interpretations of the expert-novice shift (see sections 1.3.2.1 and 1.3.2.2 for further detail) (Ericsson, 1988; Ericsson & Lehman, 1996; Anderson, 1990).

- The results are at least partly in line with Ericsson's expert-novice theory according to which large amounts of (effortful) deliberate practice would be necessary to achieve good chess skills. As already pointed out, one problem with this theory is that it eschews the importance of innate talent, which is also regarded as an important contributing factor to chess excellence by researchers (Eysenck & Keane, 2005, p. 464). The main postulate of Ericson's theory is that extensive practice will exert a direct effect on chess skill or expertise. However, since chess ability, according to the literature reviewed in Chapter 2, is closely associated with specific cognitive skills, an implication of the improvement of chess skill is that some carry over effect to cognition (i.e., aspects of intelligence) can be expected, as formulated in hypotheses 2-5. The results obtained in this research study appear to provide some support for this expectation.

- On the other hand, according to Campitelli and Gobet (2005), chess instruction fosters a child's alertness, attention to detail, concentration, logical thinking and work under pressure, relevant to each child's age level (also see Betz & Niesch, 1995; Gobet & Campitelli, 2006). These skills can all be measured by the subtests of the PIQ scale. Although a slight increase was observed in the mean scores of the experimental group on the two scales PIQ and GIQ, quite small effect sizes were obtained for these interactions (an eta square of .063 for PIQ and an eta square of .092 for GIQ were obtained). This suggests that chess instruction may have had a small effect on performance intelligence, and by implication also on general intelligence over a relatively short period.

- However, while there is some justification for attributing the slight performance increase reflected in the PIQ and GIQ scale measurements to chess instruction, there is of course a possibility that this effect could also be due to other factors. Based on the design and methodology of this research, the contribution of these factors aside from only the chess instruction cannot be ruled out. This possibility is discussed further in the next section.

5.4 Shortcomings and Recommendations

One weakness of the study is that no data were collected regarding the children's relative abilities in chess. Consequently no attempt was made to test for the attainment of a form of excellence in chess. The focus merely fell on instructing children to play chess. As a result, no inferences about the relationship between chess expertise and intelligence can be drawn.

Furthermore, because this was a quasi-experimental rather than a true experimental study, there are a number of aspects that affect the validity, and hence the generalisability of the results obtained. These are briefly discussed below, after which some recommendations for future research on the topic are set out.

5.4.1 General factors due to the quasi-experimental design

Alternative reasons for the yield of significant results regarding slightly higher increases GIQ and PIQ scores of the experimental group relative to the control group are that parents of chess players could also have engaged in frequent chess playing with their children (the amount of chess practice after school hours was not controlled in this study) and these children could have received more exposure to extra-curricular activities than the participants in the control group, possibly because their parents could have been more affluent (see section 2.2.1. for further detail). One could assume that other activities could also have fostered the slightly accelerated development of performance intelligence in the experimental group.

The smarter children in this group who mastered the game quickly could have contributed the most to the slight cognitive gain reflected in the post-test PIQ scores of the experimental group. However, for ethical reasons, relative abilities within the groups were not taken into account in the data analysis. It remains therefore unclear if the higher marks on the PIQ and GIQ scales at the post-test condition could be attributed to most of the children in the experimental group, or whether the increase mostly stems from a smaller subgroup of children in the experimental group with strong cognitive and/or chess abilities.

Lastly, it is also possible that the specific method of chess instruction used by the instructor could have facilitated the learning process. This entailed, for instance, presenting the new material (i.e., chess openings) in a meaningful way by relating it to prior knowledge to facilitate understanding and insight (Eysenck & Keane, 2001, p. 240). The learning process itself could have contributed to the improvement observed in performance intelligence. Furthermore, because the children were given ample opportunity to practise immediately after the instruction, and thus the facilitation of intensive practice could also have contributed to the transfer from chess to aspects of cognition (Ormrod, 2006, pp. 271-273).

As already mentioned (see section 2.8, where hypotheses were formulated) an improvement in the PIQ scale will lead to higher scores on the GIQ as well, because this global scale is a composite of three subscales (namely VIQ, PIQ and Num scale). Therefore the effect of chess instruction on cognition was evident only in the children’s performance, but this effect (although small) was sufficient to produce a slight increase in the chess group’s general intelligence compared with that of the control group. In contrast, the participants in the experimental group did not fare significantly better than those of the control group on the VIQ and Num scale after chess exposure; therefore the null hypothesis could not be reject for these scales. With regards to the Num scale, findings in certain other studies (e.g., Frank & D'Hondt, 1979; Smith & Cage, 2000; Aciego *et al*., 2012) have indicated that a relationship exists between chess playing and numerical aptitude; such a relationship was not found in this study. Findings by Frydman and Lynn (1992) indicate that chess players performed better on the PIQ scale than the VIQ scale, which supports the non-significant results associated with the VIQ scale in this study.

One must bear in mind that performance intelligence refers to non-verbal reasoning and the cognitive processing skills that enable humans (i.e., children in this study) to manipulate abstract symbols (visuo-spatial abilities), as in mathematics (Sternberg, 2003, p. 476). Chess is a visual game, played on a chess board consisting of 64 squares (white and black) and the positions of chess pieces change continuously. Changes in actual and potential or virtual changes due to further possible moves must be visually contemplated by the players. For this reason, Sciammas (as cited in Ezarik, 2003) cogently argues that chess instruction improves visual memory, and that such improvements may be manifested in the ability to judge the correctness of units of figural information (as measured by the subtest Absurdities A of the PIQ scale).

In view of the rather weak effect size obtained in this study it is recommended that the study be replicated by other researchers in future in order to establish whether the relationship between chess and intelligence can be confirmed. In future research, it is also recommended that researchers make use of a larger sample size with greater power and randomisation and that they aim to exert better control over extraneous variables. A larger sample size is necessary to test whether a Type 2 error could have been the reason for the smaller effect from chess instruction in the current study. In addition, it is recommended that future researchers should make use of longitudinal studies stretching over a longer period than that of the current study. Such studies must also attempt to adhere to the requirements of an ideal experiment, which was not feasible given the sample constraints in this study (Gobet & Campitelli, 2006; Redman, as cited in Gobet, 2011).

In subsequent studies, further relevant information which was not available in this study should be collected, for example, intelligence tests (to assess cognitive abilities), academic records, assessments of visual memory, chess ratings and/or chess skill, amount of practice, extra-mural activities and different methods of coaching.

5.4.2 Possible sampling bias and threats to validity

Randomisation, as a method of sampling, is required in experimental studies because it enables researchers to control extraneous variables better, and to ensure that any statistically significant difference observed between groups in an experimental study can be unequivocally attributed to a possible effect of the intervention. However, randomisation in this current study was not feasible for ethical reasons, that is, because children could not be randomly allocated to the two groups. The obvious question: “Why do some parents request chess instruction for their off-spring and others not?” can therefore not be satisfactorily answered. Chess is normally played by smart people, therefore parents of the experimental group, could already be indicating their preference to devote attention and resources to enhancing their children’s future development and education by requesting chess instruction for their children (see section 2.2.1 for further detail).

In addition, it should be recognised that it is difficult to control the “no exposure to chess playing” variable of the control group, because children can teach one another to play chess (or practise chess playing with one another) without anyone even knowing about it. In this study, it was therefore not possible to control extraneous variables (for instance chess practice at home, participation in extra-mural activities, and games and tasks stimulating the development of intelligence). Such control is required for true and rigorous experimental designs due to the potential bias derived from a sampling process based on voluntary participation in chess instruction. External validity can therefore not be guaranteed, but there is at least some reason to assume that the results may also hold true for other Caucasian, Afrikaans-speaking learners in primary schools in South-Africa.

However, even if it is assumed that parental involvement and stimulation at home are possible nuisance factors, it still remains unclear why the effect of such factors was exclusively on the performance intelligence of children. If such factors played a significant role, one would have expected them to affect all three subscales and not just the PIQ subscale.

5.4.3 Lack of pairwise comparisons in terms of intelligence

In the present study, the pairwise matching of the intelligence variable was not controlled. However, statistical analyses performed on children for the pre-test condition showed that there were no statistically significant differences between the experimental and control groups on any of the scales used. Therefore, as far as possible in this study (taking sample restrictions and ethical issues into consideration) the two groups were equated in terms of intelligence. Nonetheless since it was not possible to randomly allocate participants to groups, this aspect should be considered in future; however, it does raise obvious ethical issues which may be difficult to solve.

It is recommended that when intelligence tests are included in future studies the researcher should make use of pairwise comparisons by matching two participants from each group on each intellectual level. For example, after completion of the first intellectual assessments, the researcher in a prospective study could try to match them at each level of intelligence (e.g., by selecting both participants with a GIQ of 100) from one group (namely the experimental group) and pair or match him or her with another participant on the same level of GIQ (100) in the opposite (control) group. The performance of this pair on the different scales and subscales could then be compared to determine whether the experimental group developed more than the control group due to chess instruction. In doing so, better control will be extended over the intelligence, thereby yielding a sound method for determining the effect of the treatment variable.

5.4.4 Instrumentation issues

In the previous chapters, some of the limitations of the measuring instrument, the JSAIS, were discussed. The JSAIS is a rather old psychological test, mostly based on the Western culture and cannot measure certain characteristics important in cognition and chess playing, for instance, persistence, planning, and goal setting (Mouton 2001, p. 102; Ormrod 2006, pp. 143 and 586). There is a general need regarding psychometric testing in this country for a well-rounded measuring instrument with relevant (new) norms with which to assess intelligence (see section 5.4. for further detail) (Sternberg & Kaufman, 1996).

The JSAIS is in need of renewal and/or adaptation, as some parts (content or wording of subtests) are no longer relevant. For instance, different subtests contain outdated pictures of items no longer in use (such as a baby's cot, a fence and a gate), or the appearances of the items have changed. Some of the open questions that were asked were also no longer relevant, and certain phrases or words that were used were outdated (e.g., "grootouers", or grandparents in English) were not understood by the participants and required a synonym or translation to "Ouma en Oupa").

It is possible that there could have been a "carry-over" or transfer effect from one assessment to another (such as practice and memory), but this was taken care of by using a repeated-measurement design (Foxcroft & Roodt, 2005, p. 42). It is also possible that due to maturation and the assumption that children develop at different rates (see section 2.2, and 2.2.1, where theories of human development, and neural and genetic factors in development, is discussed), there could have been variations or spurts in development as reflected in the results of the participants, which is unavoidable. However, all these factors would affect both groups and cannot therefore explain the slightly higher cognitive gain in performance intelligence by the experimental group.

5.4.5 Test conditions

A few participants probably became inattentive while being assessed on the lengthy JSAIS (duration can be up to one and a half hours); however, this could also have occurred due to poor concentration by the learner. The poor concentration levels could have resulted due to internal or external distractibility which would have been reflected in the global scale for each participant.

Learners in grades 1 to 3 were exposed to chess lessons during school hours at the Primary School Garsfontein (until the end of 2013), therefore the participants in the study could not have been assessed during a following year or years. It is possible that the effect of the chess instruction could have been more significant if a longitudinal design was practically feasible, and thus if the children's abilities could be measured again after longer periods such as two years or several years. A longitudinal design would also have helped to establish whether the slight gain in the performance of the experimental group relative to that of the control group was merely transitory or whether it reflected a relatively permanent advantage in visuo-spatial skills. This would be beneficial because in longitudinal designs multiple measures can be taken over several years rather than just once after a treatment so that the long-term effect of the treatment variable can be explored in greater depth.

5.4.6 Improvement in test-wiseness

The abilities of the participants to take tests (in this study) as well as their social skills probably could have improved as a result of exposure to assessments at the pre- and post-level, because assessments at the post-level took place over a shorter period (see section 3.2.4 for further detail).

Test-wiseness is regarded as a very important aspect of intelligence and parents probably unknowingly have contributed to their children's test-taking abilities when they volunteered (and consented) for participation of their children in the two groups in this research. This included the measurement of the participants' intellectual abilities, which also caused them to be more test-wise (Foxcroft & Roodt, 2005, pp. 330-335). However, test-wiseness cannot explain why there was a slight gain in the experimental group's performance intelligence relative to the control group, because both groups were subjected to exactly the same psychometric testing. The experimental group had no advantage in this regard.

5.4.7 The use of sound research designs and methods

Not only the measuring instruments, but also the choice of research design and methods, are of crucial importance in empirical investigations. In the literature review the issue of a sound methodological approach in regard to chess research was mentioned. As such, Gobet and Campitelli (2006) stress that prospective researchers must make use of sound methodological methods in order to make valid decisions about transfer (see section 1.3.4, where the issue of transfer is discussed, for further clarification).

In this study, a quasi-experimental approach was employed and therefore sampling bias could have affected the results. In addition, the effect of a small sample as well as a relatively short period of chess instruction raises the possibility of a lack of power, and hence the possibility of a type two error cannot be excluded. There is certainly still scope for future research that includes adequate samples and rigorous methodologies to explore the complex interaction between chess and cognition, but these are unfortunately difficult to apply in practice owing to time constraints, sampling, and ethical issues. This research provides some converging evidence on the topic, but clearly does not offer a completely rigorous method for addressing the research problem. However, any small contribution to such a complex topic is certainly valuable, and the cumulative research of a particular topic can always be scrutinised using meta-analysis as a research procedure.

5.5 Final Recommendations and Implications

The aim of this study was exploratory in character, with the purpose to guide future investigation in the chess domain. The findings in this study provide direction for future studies, inasmuch that future studies must be undertaken over much longer periods (longitudinal) and that participants need to be paired based on intelligence in order to limit extraneous variables. It is recommended that various relevant variables must be included in future studies.

In view of the significant results between chess skill and performance intelligence in a group of Grade R children it may indicate that additional recreational activities such as chess may have a positive effect on children’s general intellectual development. These results have fairly general implications regarding the use of chess instruction for young children in educational settings in South Africa, an aspect that clearly merits further exploration. It is hoped that the research reported in this dissertation will offer guidance for future research on this topic, and that it will also encourage educationalists to positively consider the use of chess and other intellectually-oriented games designed for cognitive stimulation and scholastic development purposes. In doing so, young children’s learning experiences can be optimised, which could counteract some of the unavoidable negative effects resulting from an unsatisfactory educational system in SA (see section 1.2.1 for clarification).

The previous sections dealt with shortcomings in the current study and subsequent recommendations for future research. In the next section, questions that remain unanswered are discussed briefly.

5.5.1 Questions or debates that remain unanswered

This research has addressed only part of a rather complex issue, and several important questions remain unanswered. Thus the following questions emerge from this research, but have not yet been satisfactorily addressed:

- Why was the interaction in the current study restricted to the general and performance intelligence and why did it not extend to verbal and numerical intelligence?

- Why were the effect sizes for the significant interactions between PIQ and GIQ rather small?

- Are there any differences in terms of parenting style and the home environment among children whose parents who enrol them in extramural classes in chess and those who do not? More specifically, are there any socio-economic environmental variables that could have played a role, and were the chess playing group exposed to a more stimulating environment at home than the children in the control group, which could have fostered the slightly enhanced performance intelligence of the former?

- Would the relationship between chess and cognition have been more pronounced if levels of chess ability were taken into account?
- How permanent is the slight cognitive gain observed between the experimental and control groups? Did the experimental group attain a relatively permanent cognitive advantage following their exposure to chess instruction, or will this advantage disappear over time as the children in the control group catch up?
- Would similar results be obtained in larger and more varied samples that are more representative of the population? External validity was compromised in this study because the research focused on only a small sample from just one cultural group at a single preschool.

From a philosophy of science point of view, science is a problem solving activity that constantly generates new problems to solve, which in turn requires further research (Laudan, 1977), and to the extent that this study has raised several issues that still need clarification, and therefore further research, it has succeeded in this endeavour. Thus, even if there are still many unresolved issues, this research has at least provided some further insight into the puzzling relationship between chess ability and intelligence.

5.6 Final Remarks

The research questions regarding the existence of a relationship between chess and intelligence (as represented by the PIQ, VIQ, Num scale and GIQ of the JSAIS) were addressed. Two weak relationships were identified between chess over time and intellectual development (namely as the PIQ and GIQ) where a group × time interaction was found which can be ascribed to the treatment factor, namely chess instruction.

The study attempted to make some contribution to the topic of chess and intelligence; however, there are still many issues that need further exploration, especially in relation to the many nuisance variables that could have played a role. Nonetheless, the association between aspects of intelligence and chess revealed in this study is certainly of considerable scientific value, particularly in the light of the growing interest in many countries, including South Africa, to exploit chess as a means to offer additional intellectual stimulation and an instrument for enhancing the cognitive development of pupils in educational settings.

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Appendix A: Consent Form

(available in English and Afrikaans)

Informed Consent for participation in the research study

The participants' rights are:

- The purpose of the study is for research purposes and the results will only be used as such, therefore no feedback will be provided to parents.
- Participation is voluntary and participants have the right to withdraw at any time with no consequences.
- Participants' results of assessments would be treated confidentially and only the researcher will have access to the results.
- Although the names of the participants were known to the researcher and entered into statistical programs, anonymity of the names of the participants would be adhered to for their protection, when discussing the results obtained in this study.
- Lastly, both children and parents were thanked for their contributions.

Hereby I declare that I have read the above information and have a clear understanding thereof. I agree with all statements made.

Hereby I (name and surname), ___________________________________ Parent or legal guardian of _______________**(child's name and surname**)

consent to participation of my child in the research study

as part of the experimental group (YES/NO)

or the control group (YES/NO)

I am aware of the fact that this research study entails psychometric assessments at different periods.

Child's age and date of birth:___________________________________

Name of classroom that the child attends:__________________________

Parent's or legal guardian's Signature:_____________________________

Date: _____________________________

Parent's or legal guardian's contact

Details: ______________________________

Researcher’s name and surname: ________________________________

Researcher’s Signature: ________________________________

Appendix B: Data Analysis Tables

B1. Tests of Normality

The histograms display the distributions of the IQ scores of the two groups at the two conditions

B1.1 Distributions of the Control Group

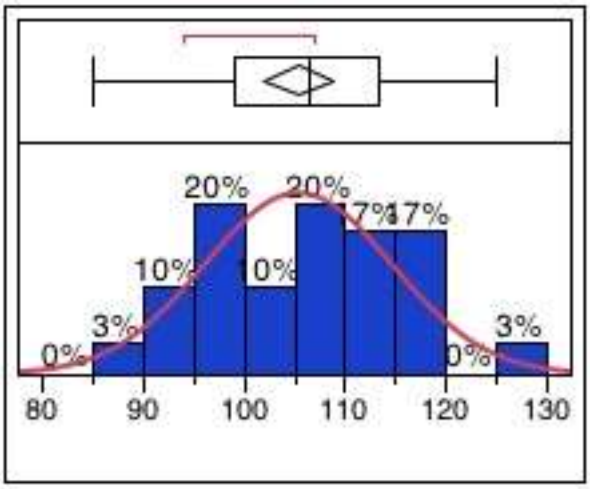

Figure B.1 PIQ at the Pre-test condition

Normal (mean 105.467, standard deviation 9.30233)

Note: H_o = the data from the Normal distribution.

Small *p*-values reject H_o.

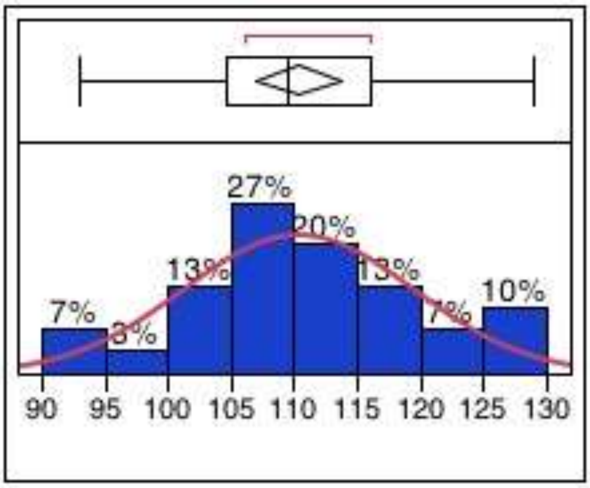

Figure B.2 PIQ at the Post-test condition

Normal (mean 110.4, standard deviation 9.14104)

Note: H_o = the data from the Normal distribution.

Small *p*-values reject Ho.

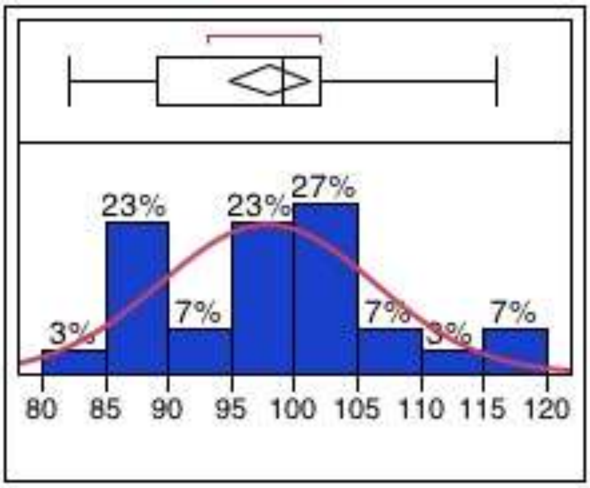

Figure B.3 VIQ at the Pre-test condition

Normal (mean 97.9333, standard deviation 8.50936)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

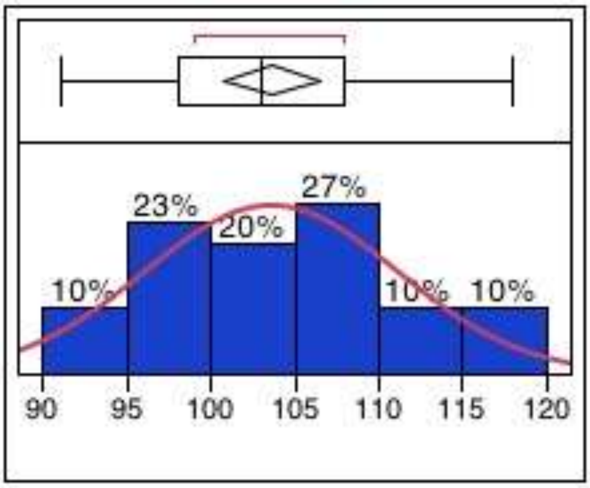

Figure B.4 VIQ at the Post-test condition

Normal (mean 103.667, standard deviation 7.53536)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

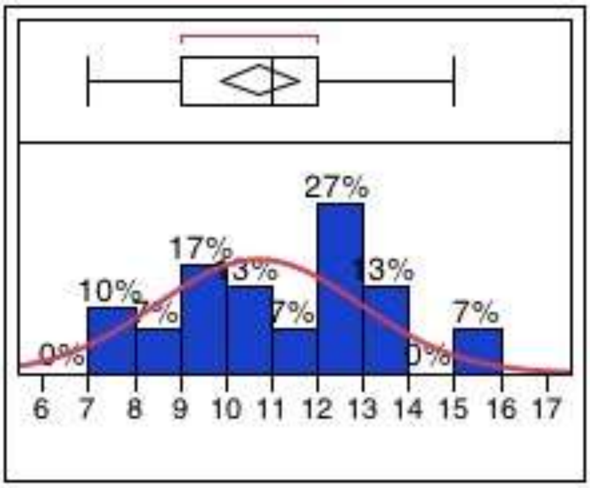

Figure B.5 Num Scale at the Pre-test condition

Normal (mean 10.7333, standard deviation 2.22731)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

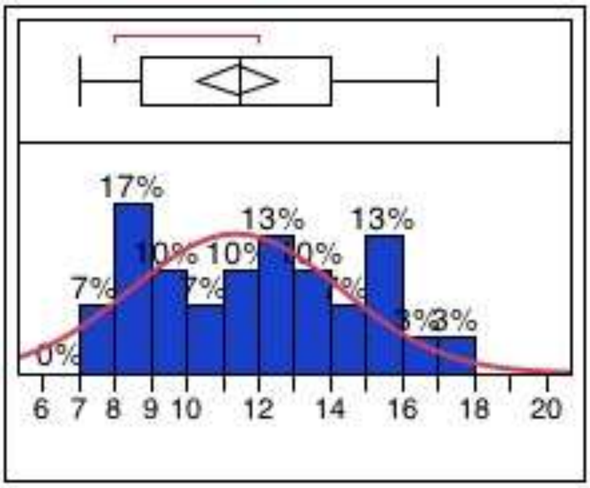

Figure B.6 Numeric Scale at the Post-test condition

Normal (mean 11.4, standard deviation 2.90778)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

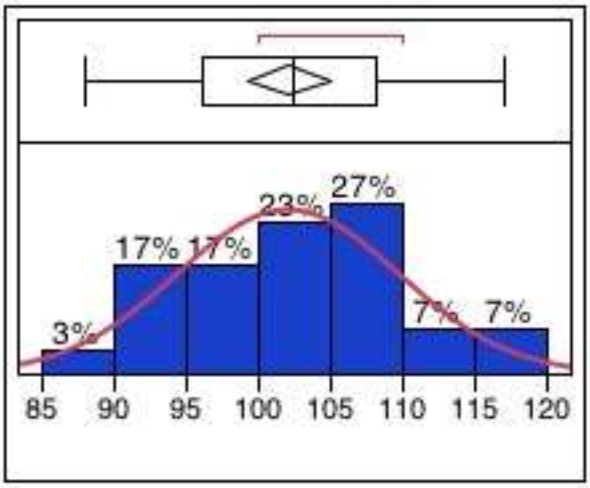

Figure B.7 GIQ at the Pre-test condition

Normal (mean 102.1, standard deviation 7.73862)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

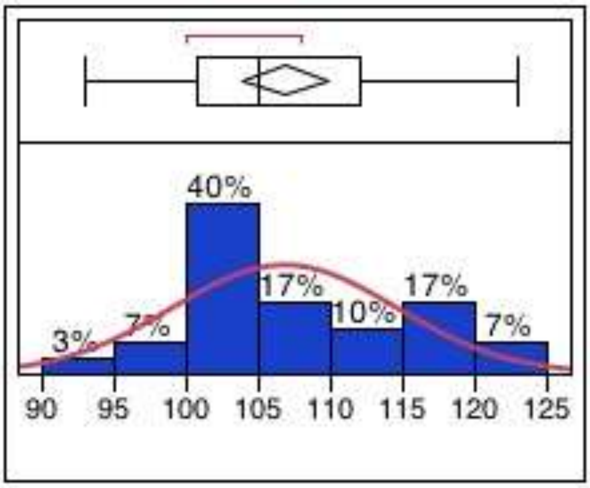

Figure B.8 GIQ at the Post-test condition

Normal (mean 106.867, standard deviation 7.78918)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

B2 Distributions of the Experimental Group

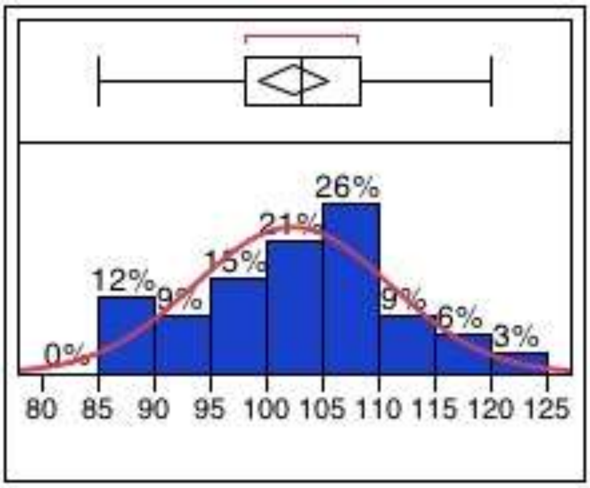

Figure B9 PIQ at the Pre-level condition

Normal (mean 102.382, standard deviation 8.73521)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

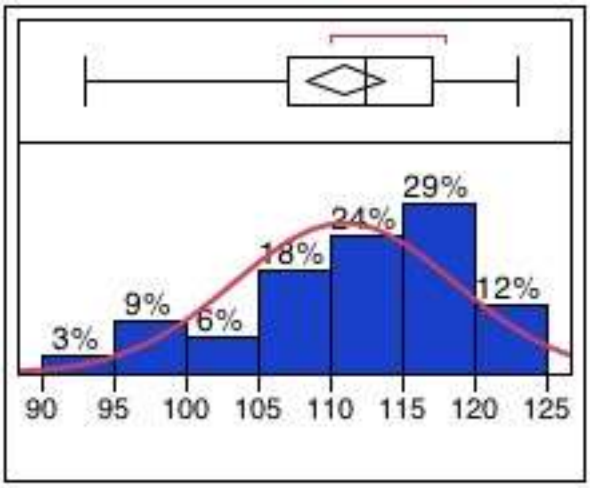

Figure B10 PIQ at the Post-level condition

Normal (mean 111.029, standard deviation 7.64946)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

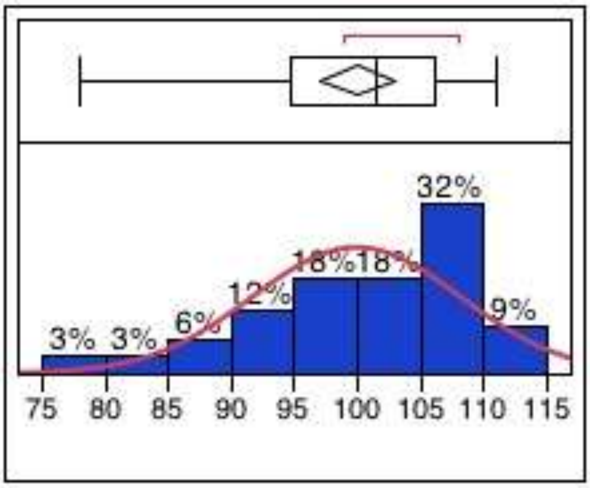

Figure B 11 VIQ at the Pre-test condition

Normal (mean 100, standard deviation 8.28288)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

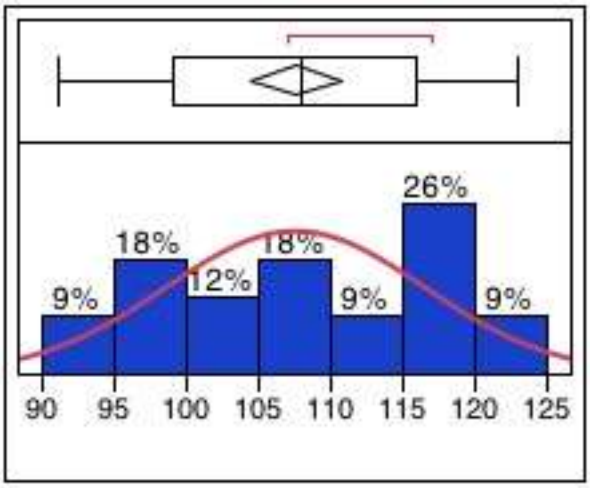

Figure B 12 VIQ at the Post-test condition

Normal (mean 107.618, standard deviation 8.97814)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

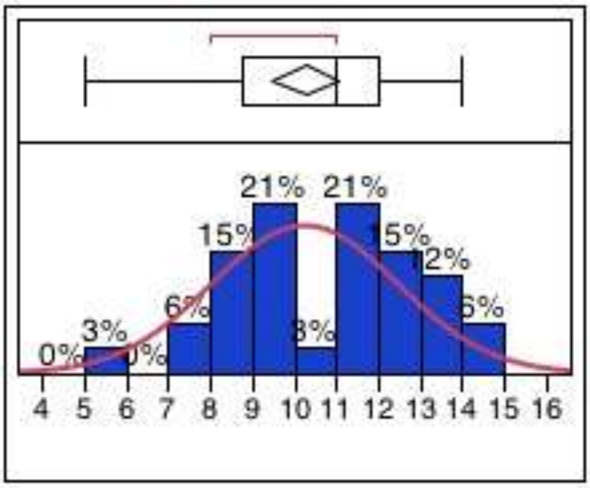

Figure B.13Num Scale at the Pre-test condition

Normal (mean 10.2647, standard deviation 2.21987)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

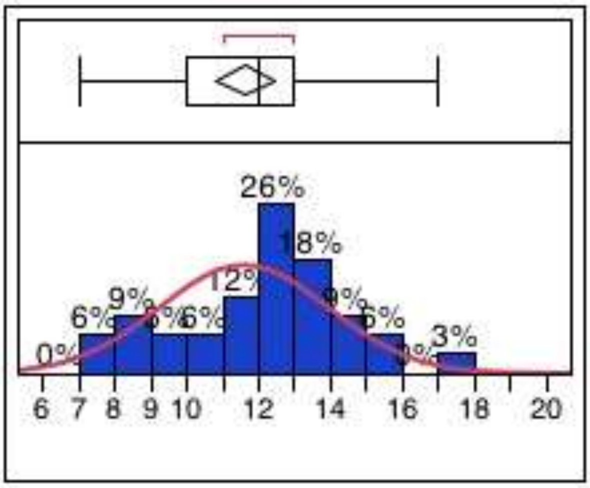

Figure B.14 Num Scale at the Post-test condition

Normal (mean 11.6176, standard deviation 2.36149)

Note: Ho = the data is from the Normal distribution.

Small *p*-values reject Ho.

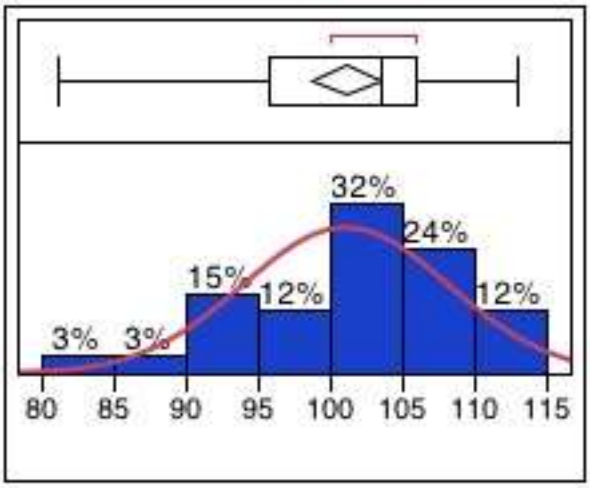

Figure B.15 GIQ at the Pre-level condition

Normal (mean 101.118, standard deviation 7.1595)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

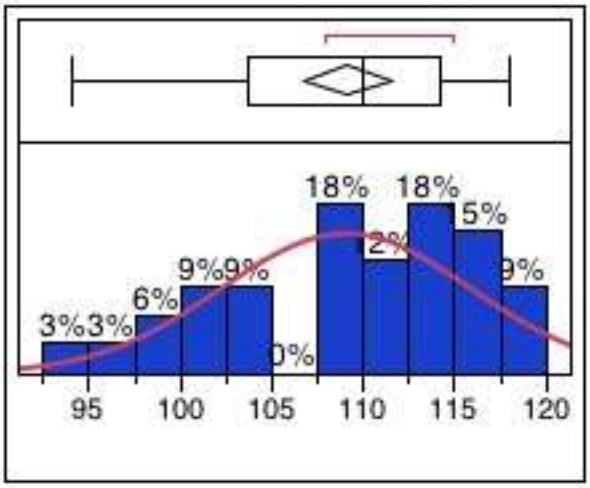

Figure B.16 GIQ at the Post-test condition

Normal (mean 109.118, standard deviation 6.8524)

Note: Ho = the data from the Normal distribution.

Small *p*-values reject Ho.

Table B2.
Test of Normality – Shapiro-Wilk test

			Shapiro-Wilk		
DV	**Group**	**Period**	**Statistic**	**df**	**Sig.**
VIQ	C	PRE	0.957	30	0.267
VIQ	C	POST	0.970	30	0.561
PIQ	C	PRE	0.981	30	0.853
PIQ	C	POST	0.971	30	0.588
Num scale	C	PRE	0.945	30	0.131
Num scale	C	POST	0.946	30	0.138
GIQ	C	PRE	0.976	30	0.722
GIQ	C	POST	0.942	30	0.105
VIQ	E	PRE	0.924	34	0.022*
VIQ	E	POsT	0.956	34	0.187
PIQ	E	PRE	0.971	34	0.492
PIQ	E	POST	0.952	34	0.142
Num scale	E	PRE	0.955	34	0.174
Num scale	E	POST	0.955	34	0.178
GIQ	E	PRE	0.944	34	0.085
GIQ	E	POST	0.928	34	0.027*

Note = *value of *p*=0.022 of the E VIQ of period 1 (at the pre-test condition) and GIQ2 (at the post-test condition) of the experimental group (*p*=0.027) are significant at the 95 % level of confidence

n=64

Table B3.

Test of Homogeneity of Variances: Means for Oneway Anova

DV	Group	N	Mean	Std. Error	95 % Confidence Interval for Mean	
					Lower Bound	Upper Bound
PIQ	C	30	105.467	1.644	102.18	108.75
	E	34	102.382	1.544	99.30	105.47
VIQ	C	30	97.933	1.532	94.871	101.00
	E	34	100.00	1.439	97.124	102.88
Num S	C	30	10.733	0.406	9.922	11.545
	E	34	10.265	0.381	9.503	11.027
GIQ	C	30	102.100	1.358	99.386	104.81
	E	34	101.118	1.275	98.568	103.67

Standard error uses a pooled estimate of error variance

Values based on mean
n=64

Table B4.

Oneway ANOVA - Test for the Equality of Means

DV	Source	df	Sum of Squares	Mean Square	F	Sig.
PIQ	Group	1	151.613	151.613	1.870	0.176
	Error	62	5027.496	81.089		
	Corrected Total	63	5179.109			
VIQ	Group	1	68.071	68.071	0.967	0.329
	Error	62	4363.867	70.385		
	Corrected Total	63	4431.938			
Num scale	Group	1	3.500	3.500	0.708	0.403
	Error	62	306.484	4.943		
	Corrected Total	63	309.984			
GIQ	Group	1	15.380	15.380	0.278	0.600
	Error	62	3428.229	55.294		
	Corrected Total	63	3443.609			

No values are significant at the 95 % confidence level

n=64

Table B5

Tests of Homogeneity of Variance: Tests that the Variances are Equal

DV		Test	F-ratio	DF Num	DF Den	*p*-value
PIQ	PRE	O'Brien [.5]	0.159	1	62	0.691
		Brown-Forsythe	0.485	1	62	0.489
		Levene	0.507	1	62	0.479
		Bartlett	0.120	1	.	0.729
		F Test 2-sided	1.134	29	33	0.723
PIQ	POST	O'Brien [.5]	1.128	1	62	0.292
		Brown-Forsythe	0.648	1	62	0.424
		Levene	0.640	1	62	0.427
		Bartlett	0.966	1	.	0.326
		F Test 2-sided	1.428	29	29	0.322
VIQ	PRE	O'Brien [.5]	0.024	1	62	0.878
		Brown-Forsythe	0.002	1	62	0.963
		Levene	0.001	1	62	0.974
		Bartlett	0.022	1	.	0.882
		F Test 2-sided	1.055	29	33	0.876
VIQ	POST	O'Brien [.5]	1.685	1	62	0.199
		Brown-Forsythe	1.552	1	62	0.218
		Levene	1.559	1	62	0.216
		Bartlett	0.921	1	.	0.337
		F Test 2-sided	1.420	33	29	0.341
Numscale	PRE	O'Brien [.5]	0.000	1	62	0.982
		Brown-Forsythe	0.002	1	62	0.967
		Levene	0.002	1	62	0.967
		Bartlett	0.000	1	.	0.985
		F Test 2-sided	1.007	29	33	0.979
Numscale	POST	O'Brien [.5]	2.129	1	62	0.150
		Brown-Forsythe	3.534	1	62	0.065
		Levene	3.047	1	62	0.086
		Bartlett	1.318	1	.	0.251
		F Test 2-sided	1.516	29	29	0.248
GIQ	PRE	O'Brien [.5]	0.219	1	62	0.641
		Brown-Forsythe	0.670	1	62	0.416
		Levene	0.509	1	62	0.478
		Bartlett	0.184	1	.	0.668
		F Test 2-sided	1.168	29	33	0.662
GIQ	POST	O'Brien [.5]	0.685	1	62	0.411
		Brown-Forsythe	0.676	1	62	0.414
		Levene	0.795	1	62	0.376
		Bartlett	0.500	1	.	0.479
		F Test 2-sided	1.292	29	33	0.475

Note: Tests indicate equal variances at a 99 % level of confidence, except for O'Brien's test, which indicates equal variance at a 0.5 level

n=64

Table B6.

Test difference between means at the Pre- and Post-test IQ levels or conditions of groups

	Group	N	PRE Mean	LEVEL Std. Deviation	POST Mean	LEVEL Std. Deviation
PIQ	C	30	105.47	9.302	110.40	9.141
	E	34	102.38	8.735	111.03	7.649
	Total	64	103.83	9.067	110.73	8.319
VIQ	C	30	97.93	8.509	103.67	7.535
	E	34	100.00	8.283	107.62	8.978
	Total	64	99.03	8.387	105.77	8.503
Num scale	C	30	10.73	2.227	11.40	2.908
	E	34	10.26	2.220	11.62	2.361
	Total	64	10.48	2.218	11.52	2.612
GIQ	C	30	102.10	7.739	106.87	7.789
	E	34	101.12	7.160	109.12	6.852
	Total	64	101.87	7.393	108.06	7.335

n=64

Table B7.

Testing Equality of Covariance across groups: Box’s Test of Equality of Covariance Matrices[a]

	Box’s M	F	df1	df2	Sig.
PIQ	.988	.318	3	1457652.640	.812
VIQ	2.380	.765	3	1457652.640	.513
Num scale	1.626	.523	3	1457652.640	.666
GIQ	.521	.168	3	1457652.640	.918

Note: Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.[a]

a. Design: Intercept + Group
   Within Subjects Design: Time

n=64

Table B8.

Multivariate tests[a] (Output from the GLM program)

Effect			Value	F	Hypothesis df	Error df	*p*-value/Sig	Partial Eta Squared
Time	Inter-cept	Pillai's Trace	.472	55.46b	1.000	62.000	.000*	.472
		Wilks' Lambda	.528	55.46b	1.000	62.000	.000*	.472
		Hotelling's Trace	.895	55.46b	1.000	62.000	.000*	.472
		Roy's Largest Root	.895	55.46b	1.000	62.000	.000*	.472
Time*Group	PIQ	**Pillai's Trace**	.063	4.15b	1.000	62.000	**.046***	.063
		Wilks' Lambda	.937	4.15b	1.000	62.000	.046*	.063
		Hotelling's Trace	.067	4.15b	1.000	62.000	.046*	.063
		Roy's Largest Root	.067	4.15b	1.000	62.000	.046*	.063
Time	Inter-cept	Pillai's Trace	.495	60.65b	1.000	62.000	.000*	.495
		Wilks' Lambda	.505	60.65b	1.000	62.000	.000*	.495
		Hotelling's Trace	.978	60.65b	1.000	62.000	.000*	.495
		Roy's Largest Root	.978	60.65b	1.000	62.000	.000*	.495
Time*Group	VIQ	**Pillai's Trace**	.019	1.21b	1.000	62.000	.276	.019
		Wilks' Lambda	.981	1.21b	1.000	62.000	.276	.019
		Hotelling's Trace	.019	1.21b	1.000	62.000	.276	.019
		Roy's Largest Root	.019	1.21b	1.000	62.000	.276	.019
Time	Inter-Cept	Pillai's Trace	.194	14.90b	1.000	62.000	.000*	.194
		Wilks' Lambda	.806	14.90b	1.000	62.000	.000*	.194
		Hotelling's Trace	.240	14.90b	1.000	62.000	.000*	.194
		Roy's Largest Root	.240	14.90b	1.000	62.000	.000*	.194
Time*Group	Num scale	**Pillai's Trace**	.027	1.72b	1.000	62.000	.194	.027
		Wilks' Lambda	.973	1.72b	1.000	62.000	.194	.027
		Hotelling's Trace	.028	1.72b	1.000	62.000	.194	.027
		Roy's Largest Root	.028	1.72b	1.000	62.000	.194	.027
Time	Inter-cept	Pillai's Trace	.611	97.41b	1.000	62.000	.000*	.611
		Wilks' Lambda	.389	97.41b	1.000	62.000	.000*	.611
		Hotelling's Trace	1.571	97.41b	1.000	62.000	.000*	.611
		Roy's Largest Root	1.571	97.41b	1.000	62.000	.000*	.611
Time*Group	GIQ	**Pillai's Trace**	.092	6.25b	1.000	62.000	**.015***	.092
		Wilks' Lambda	.908	6.25b	1.000	62.000	.015*	.092
		Hotelling's Trace	.101	6.25b	1.000	62.000	.015*	.092
		Roy's Largest Root	.101	6.25b	1.000	62.000	.015*	.092

a. Design: Intercept + Group

Within Subjects Design: Time

b. Exact statistic

* Significant at the 95 % level of confidence

Values of the PIQ (*p*=.046*) and the GIQ are significant (*p*=.015*) at the 95% level of confidence, indicating a statistical significance between the two groups (the between groups factor) in terms of PIQ and GIQ scores on the JSAIS, as well as statistically significant main effects (time) at a 95% level of confidence for all the subscales and global scale.

n=64

Table B.9.

Tests of Between-Subjects Effects – A Corrected model

Source	**Dependent Variable**	**Type III Sum of squares**	**df**	**Mean Square**	**F**	**Sig**	**Partial Eta Squared**
Corrected Model	PIQ	48.024a	1	48.024	.385	.537	.006
	VIQ	288.565b	1	288.565	2.478	.121	.038
	Num scale	.502c	1	.502	.052	.821	.001
	GIQ	12.825d	1	12.825	.135	.715	.002
Inter-cept	PIQ	1468481.024	1	1468481.024	11764.773	.000	.995
	VIQ	1 334439.565	1	1334439.565	11461.375	.000	.995
	Num scale	15438.502	1	15438.502	1593.989	.000	.963
	GIQ	1400350.700	1	1400350.700	14689.303	.000	.996
Group	PIQ	48.024	1	48.024	.385	.537	.006
	VIQ	288.565	1	288.565	2.478	.121	.038
	Num scale	.502	1	.502	.052	.821	.001
	GIQ	12.825	1	12.825	.135	.715	.002
Error	PIQ	7738.851	62	124.820			
	VIQ	7218.615	62	116.429			
	Num scale	600.498	62	9.685			
	GIQ	5910.542	62	95.331			
Total	PIQ	1476267.902	64				
	VIQ	1341946.745	64				
	Num scale	16039.502	64				
	GIQ	14061.242	64				
Correc-ted Total	PIQ	7786.875	63				
	VIQ	7507.180	63				
	Num scale	601.000	63				
	GIQ	5910.542	63				

a. R Squared = 0.001448 (Adjusted R Squared = -0.01466)
b. R Squared = 0.054613 (Adjusted R Squared = 0.039365)
c. R Squared = 0.001756 (Adjusted R Squared = -0.01434)
d. R squared = 0.023823 (Adjusted R Squared = 0.008078)
No values are significant at the 95% level of confidence.
n=64