THE CONCURRENT VALIDITY OF LEARNING POTENTIAL AND PSYCHOMOTOR PERFORMANCE COMPARED TO SAFE WORKING BEHAVIOR OF MACHINE OPERATORS IN A PLATINUM MINE

by

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DECLARATION

I, Karin Keyser (Student number 4257-676-8) declare that **The concurrent validity of learning potential and psychomotor performance compared to safe working behaviour of machine operators in a platinum mine** is my own work, that it has not been submitted before for any degree or examination at any other university, 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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Karin Keyser March 2012

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SUMMARY

The researcher selected a quantitative cross-sectional design to test the concurrent validity of learning potential and psychomotor ability by evaluating the relationships between mining machine operators' learning potential and psychomotor ability as well as their work safety behaviour. Work safety behaviour was considered indicative of their capability to operate a moving machine. The utilization of measuring instruments capable of measuring their learning potential and psychomotor ability and measuring safety behaviour by means of their safety score cards provided the required measurement data. The study involved a quantitative investigation into the relationship between learning potential and psychomotor ability as independent variables and safety behaviour as dependent variable.

De Vos, Strydom, Fouche and Delport (2002, p.79) defined quantitative research as "based on positivism, which takes scientific explanation to be nomothetic. Its main aims are to measure the social world objectively, to test hypotheses and to predict and explain human behaviour. A quantitative study may therefore be defined as an inquiry into social or human problems based on testing a theory composed of variables, measured with numbers and analysed with statistical procedures in order to determine whether the predictive generalization of the theory holds true."

The aim of the study was to determine the learning potential and psychomotor ability of mining machine operators as well as compare the following sub-groups (based on the biographical variables): age, years' experience, educational level and gender. The respondents' work safety behaviour was measured and the relationship between the two measures of the independent variables (learning potential and psychomotor ability) and work safety behaviour determined.

Key words: Learning potential, psychomotor ability, safe working behaviour, intelligence, dynamic assessment, cognitive ability, mechanised mining

CHAPTER 1
ORIENTATION TO THE STUDY

1.1 INTRODUCTION

South Africa is a mineral-rich country and mining has played an important role in the South African economy for more than one hundred years (Saylor & Fraikue, 2011). In 2008, the mining sector in South Africa directly contributed 8% to the national gross domestic product (Saylor & Fraikue, 2011). The industry also directly employed more than 500 000 employees in the same period, accounting for 6.1% of the total non-agricultural employment in the economy (Hattingh, Sheer & Du Plessis, 2010).

Since most organisations regard educational qualifications as an indicator of a person's skill levels or productivity they frequently use it as a prerequisite in hiring decisions (Benson, Finegold, & Mohrman, 2004). According to the Anglo Twickenham Platinum Mine (2009), there are two main prerequisites in the platinum mining industry, namely:

- Psychomotor ability performance – to determine which machine an operator is allowed to operate.
- Learning potential – to determine the potential of the candidate for future development.

Since it is essential in the field of industrial psychology to determine whether the tools used to assess employees' potential and psychomotor ability performance are valid in predicting safe working behavior and useful to business in contributing to achieving business goals, there is a need in the research organisation, to determine whether or not there is a correlation between the results of the learning potential test psychomotor ability test and the safety performance rating.

This study focused on the concurrent validity of learning potential and psychomotor performance compared to safe working behaviour of machine operators in a platinum mine, using safety performance as a criterion measure.

1.2 BACKGROUND TO THE STUDY

Political change in South Africa, followed by the demand to implement affirmative action as a compensatory measure for previous deprivation, stimulated many attempts at identifying training and development potential among employees who had been exposed to an inferior educational system (Abrahams, 1994). In these efforts, the South African mining industry, in particular, sought to identify psychological tests to measure various abilities among employees with a view to identifying "successful" candidates for adult education, advancement and upliftment (Watkins & Elliot, 1997).

Mining is a hazardous occupation by nature, and the issue of safety is of the utmost importance to the industry (Bhattacherya, Dunn & Egger, 2006). Since the 1970s, mobile underground equipment in mining has increased as the industry moves and continues to move towards increased mechanisation and automation. Both workers and mining companies have benefited from mobile equipment technology through increased productivity and significantly lower total physical demands on workers (Bhattacherya, et al., 2006).

Mechanisation, in its broadest sense, refers to the use of machines to do the work. Machines have been used in mines since mining began, primarily to improve working conditions, safety and productivity (Hattingh, Sheer & Du Plessis, 2010).

The validity of psychological tests and other similar assessments used by an organisation to make any decisions affecting an individual's career status is a legal requirement in terms of the Employment Equity Act (1998). The Act has a direct impact on the legal responsibilities of the company and stipulates that the use of psychological tests or any similar assessments is prohibited, unless they meet the requirements of being valid, reliable, fair and not biased.

The rationale for using psychometric tests in the selection process lies in the purported ability of the testing instruments to accurately and objectively assess an applicant's ability to perform the work required by the job (Ritson, 1999).

With regard to the use of personnel selection procedures, the Society for Industrial Psychology (1992, p.6) states that the "underlying assumption of any personnel selection procedure is an important and relevant behavioural requirement or job performance aspect of the position". Accordingly, if an organisation uses psychometric assessment in its selection of employees, it should be because it assists in accurately predicting whether the applicant possesses the behavioural requirements and competencies necessary to perform the particular job (Muller & Schepers, 2003). Ritson (1999, p.35) emphasised that if there is any doubt "regarding the ability of a test to provide an accurate idea of an applicant's future performance in the job, then the test itself should be analysed for suitability of purpose".

Certain selection methods are employed to select individuals who will contribute to the effectiveness of organisations. These selection methods need to remain within the ambit of the law as well as have the ability to potentially select the most productive employees for an organisation (Gilmore, 2008; Mauer, 2000a; 2000b; Schmidt & Hunter, 1998).

Valid selection procedures should translate into productivity and improved performance levels, and ultimately, into the overall effectiveness of an organisation (Anastasi, 1988; Gilmore, 2008; Schmidt & Hunter, 1998).

It is important to note that personnel selection is successful and hence, useful, only to the extent that the measurements of the differences between individuals and job requirements referred to are accurate or valid. If they are not valid, they are useless as predictors of safe performance, on the one hand, and as criterion measures on the other – hence, the extreme significane of validity in the selection process.

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For leaders to create capable and competitive organisations, the focus has shifted from structure, forms, rules and roles to capability (Ulrich, Zenger & Smallwood, 1999). Technological advancements are reducing the workforce and the remaining employees now require a different set of skills and abilities than before (Chowdhury, 2000; Foot & Stoffman, 1996). The complexities and competitiveness of the global market require a collective and collaborative environment and not simply a grand strategist at the top (Senge, 1990). Employees should not only be able to adapt to the changing work environment but should also have the necessary ability to use new and complex equipment (Senge, 1990).

Continuous investment should thus be made in terms of training and competence improvement (Lessing & Maritz, 2001). Education levels and aspirations of the workforce are changing, and business qualifications in addition to a first degree are often required (Pearn, Roderick & Mulrooney, 1995). Hands-on operating has changed to advanced systems and information management, which require different skills and abilities (Toffler, 1981).

These fundamental changes in the marketplace require higher levels of cognitive ability or intelligence. Intelligence can be defined as the capacity to learn from experience and adapt to one's environment and cognitive assessment is widely used for selection and placement purposes as well as for the prediction of performance or success (Gregory, 1996; De Beer, 2000a). As educationally disadvantaged learners do not form a homogeneous group, there is a need to differentiate between those who truly possess potential and happen to be classified as disadvantaged and those who are disadvantaged but do not possess the same levels of learning potential (Murphy & Maree, 2006).

Continuous change and competition in the work environment necessitate increased efficiency and productivity, which require different and enhanced skills and abilities. It is therefore important that the right people with the right skills are selected and employees are developed to enable them to meet the organisational and national demands of the future (Gilmore, 2008).

The validity of a personnel measure (or combination of measures) used in hiring is directly proportional to the practical value of the method – whether measured in monetary value of increased output or percentage of increase in output (Schmidt & Hunter, 1998). The implication, then, is that the higher the validity coefficient of a selection measure, the greater the economic utility in financial terms over the period in which the candidates who are ultimately selected, work for the organisation in question. The opposite is also true, namely the lower the validity coefficient of the selection measure, the greater the potential economic loss for the organisation in financial terms (Schmidt & Hunter, 1998). To maximize the potential economic benefit that can be derived from selecting the candidates most likely to add value to the business, therefore, the organisation should investigate the validity of the various selection methods used in the organisation as well as those available for use.

In order to understand the context of this study, it is necessary to move from the macro perspective of the need for the use of valid selection procedures in South African organisations to the micro perspective of the need for a valid selection procedure for the selection of operators in the platinum mine in which this study was undertaken.

1.3 PROBLEM STATEMENT

It is essential to determine whether there is a statistically significant relationship between learning potential and psychomotor performance of mining employees on the one hand, with their safety performance on the other hand. A positive relationship between an employee's learning potential and psychomotor performance might contribute to the productivity of the mine if it is positively related to the safety behavior of the employee.

In the platinum mining industry, there is increasing competition between the various platinum producers to supply the emerging shortfall of the precious metal at the largest profit margins possible (Gilmore, 2008). To ensure high competitiveness, the cost curve needs to decline. This translates into a need for a more productive workforce, working more efficiently (Gilmore, 2008). It is essential to determine whether there is a statistically significant relationship between learning potential and psychomotor performance of mining employees and their safety performance.

The organisation in which this study was conducted makes use of a standard in-house selection procedure for machine operators, which is revised once a year. This procedure includes the Learning Potential Computerised Adaptive Test (LPCAT) and the Vienna Testing System (VTS) assessment for every job applicant. Each machine requires a different "score". Because of the low literacy levels amongst applicants, the assessment of appropriate employees for appointment, training and development is a very challenging process for both applicant and organisation.

In order to investigate whether the organisation's preferred selection procedure can be considered valid in the particular context, the aim of the study was to answer the following questions:

- Is there a statistically significant relationship between learning potential (LPCAT) and psychomotor performance (VTS) scores and safety performance?
- Is safety performance statistically significantly related to learning potential (LPCAT) and psychomotor (VTS) scores?

1.4 PURPOSE AND AIMS OF THE STUDY

The aim of the study was to determine the learning potential and psychomotor ability of mining machine operators as well as compare the following sub-groups (based on the biographical variables): age, years' experience, educational level and gender. The respondents' work safety behaviour was measured and the relationship between the two measures of the independent variables (learning potential and psychomotor ability) and work safety behaviour determined. The study thus had general, theoretical, and empirical aims.

1.4.1 General aim

The general aim of the study was to determine whether learning potential and psychomotor performance are valid predictors of safe working behaviour of machine operators in a platinum mine. Accordingly, the researcher formulated the following hypotheses:

(1) Learning potential and psychomotor results are statistically significantly related to safe working behaviour.

(2) Learning potential is a statistically significantly related to safety behaviour of machine operators in a mechanised platinum mine.

(3) Psychomotor ability is a statistically significantly related to safety behaviour of machine operators in a mechanised platinum mine.

(4) There is a statistically significant correlation between learning potential and psychomotor ability scores.

1.4.2 Theoretical aims

The theoretical aims were to

- Determine what is meant by "learning potential" and describe how it is measured.
- Determine what is meant by "psychomotor ability" and describe how it is measured.
- Review literature on the theoretical relationship between learning potential and psychomotor ability with specific reference to the mining environment.
- Determine what is meant by "safety behavior" and how it is measured.

1.4.3 Empirical aims

The empirical aim was to determine whether learning potential and psychomotor performance are valid predictors of safe working behavior of machine operators in the organisation under study. The study, therefore, wished to determine whether there are statistically significant correlations between

- Learning potential (LPCAT) and psychomotor (VTS) scores and a measure of safe work behaviour
- Learning potential (LPCAT) scores and a measure of safe work behavior
- Psychomotor performance (VTS) and a measure of safe work behavior
- Learning potential (LPCAT) and psychomotor (VTS) scores.

1.5 PARADIGM PERSPECTIVE

Mouton and Marais (1996) stated that it is possible for research to be conducted in a context broader than particular paradigms and disciplines and social science research is a collaborative human activity thus implying that each discipline in the social sciences consists of a variety of paradigms. This study was conducted in the field of personnel psychology encompassing the sub-disciplines of psychometrics and organisational and personnel psychology. Industrial and Organisational Psychology is an applied field of psychology. Muchinsky, Kriek and Schreuder (1998) described it as the field concerned with behaviour in the workplace. Different paradigm perspectives were used for the variables of this study. Learning potential is based on humanism (every organism has an inherent growth potential or self-actualising tendency) because it is regarded as changeable (De Beer, 2000; Meyer, Moore & Viljoen, 1989). Psychomotor ability is based on positivism. Pure positivism assumes that only observable behaviour can be studied (Meyer, Moore & Viljoen, 1989). Safety behaviour is also based on positivism. However, Mouton (1997) indicated that positivism in the 20th century has relaxed its rigid empiricist criteria. According to him, the quantitative methodological approach in twentieth century psychology can be regarded as positivist. Modern positivism differs from pure positivism in that modern positivism accepts that certain theoretical constructs need to be used.

1.6 LITERATURE REVIEW

The researcher conducted a literature review on learning potential, psychomotor ability and work safety behaviour, including definitions, theory and measuring instruments.

1.7 RESEARCH DESIGN

The research design is “an exposition or plan of how the researcher has decided to execute the research to answer the formulated research question. The aim of the research design is to plan, structure and execute the project concerned in such a way that the validity of the findings are maximized” (Mouton & Marais, 1996, p.193).

De Vos, Delport, Fouche and Strydom (2002, p.79) defined quantitative research as “based on positivism, which takes scientific explanation to be nomothetic. Its main aims are to measure the social world objectively, to test hypotheses and to predict and explain human behaviour. A quantitative study may therefore be defined as an inquiry into social or human problems based on testing a theory composed of variables, measured with numbers and analysed with statistical procedures in order to determine whether the predictive generalization of the theory holds true.”

Cross-sectional designs are used to examine groups of subjects in various stages of development simultaneously (Burns & Grove, 1993). Information collected from the sample is used to describe the population at that moment. According to Shaughnessy and Zechmeister (1997), this design can also be used to assess interrelationships among variables. In addition, this design is best suited to address the descriptive and predictive functions associated with the correlation design, whereby relationships between constructs are examined (Shaughnessy & Zechmeister, 1997).

The researcher selected a quantitative cross-sectional design to test the concurrent validity of learning potential and psychomotor ability by evaluating the relationship between mining machine operators’ learning potential and psychomotor ability as well as work safety behavior. The capability to operate a moving machine, was indicative of their work safety behaviour. The utilization of measuring instruments capable of measuring their learning potential and psychomotor ability and measuring safety behavior by means of their safety score cards provided the required measurement data. The study involved a quantitative investigation into the relationship between learning potential and psychomotor ability as independent variables and safety behaviour as dependent variable.

1.8 POPULATION AND SAMPLE

A research population includes all members who are under study. In this study the population consisted of machine operators working at the organisation. In the particular sample of convenience (n=200) from a specific mine that were used in this study, 195 were males and 5 were females. All the participants were Black and operators with at least one year experience or more. The sample group of 200 machine operators working at this particular mine participated in the study and they were assessed over a period of two months.

The respondents were obliged to complete the work-related testing to determine on what level they are and what machines they are allowed to operate at the mine. Instructions for both tests were given in English and Sepedi, because most of the respondents were Sepedi speaking.

The 200 operators were all from the same area in the Limpopo Province. The ages varied from 21 to 60 and the mean age was 34.57. At the age of 60 the employee must retire. The work-related experience varied from a minimum of one year work-related experience to a maximum of 26 years work-related experience. The mean work-related experience was 9.90 years. The employees' levels of education ranged between a minimum of 6 years and a maximum of 13 years' education. The mean level of education was 9.99 years. This was expected from this sample group, because most of them lived in a rural area, where the general level of education is very low and poverty is rife.

1.9 DATA COLLECTION

Data was collected by means of the learning potential computerised adaptive test (LPCAT) and Vienna Test System (VTS). Biographical data (age, experience, educational level and gender) was obtained from the personnel files and records. The tests were administered in small groups on the premises on pre-arranged dates.

The line managers completed a safety score card for each respondent. The safety score cards were handed in at the safety department. Safety behaviour was measured by the information provided on the safety score cards. The results were reported in terms of the respondents' learning potential, psychomotor ability test results and work safety behaviour score. The relationship between the variables to test the relationship between learning potential and psychomotor results were also reported.

Three categories of variables were assessed for the study, namely moderator-, predictor-, and dependent variables.

1.9.1 Moderator variables

Biographical data have been described by Owens as permitting the respondents to describe themselves in terms of demographic, experiential or attitudinal variables presumed or demonstrated to be related to personality structure, personal adjustment or success in social, educational or occupational pursuit (Owens, cited in Drakeley, 1989). It is common practice in applied psychological research to investigate the effects of biographical variables such as age, gender and education in terms of possibly moderating the relationship between the predictor and criterion variables (Cascio, 1991).

Whilst cognitive ability tests are generally accepted to provide the best indication of future performance in terms of predictive validity, biographical data can be equally effective (Hunter & Hunter, 1984). Anastasi (1988) stressed the need to include only those variables for which there is evidence of moderating effects. Accordingly,in this study, age, education and experience were investigated as potential moderators in the predictor-criterion relationships.

1.9.1.1 Age

Young (18–25), middle (26-34) and older (35–50) male and female drivers were compared in their perception of driving risk and confidence in driving ability. All three groups provided responses to a questionnaire on accident risk and driving ability and further generated subjective ratings of risk to a series of videotaped sequences depicting various elements of driving behavior (Matthews & Moran, 2002).
In their meta-analyses, Hunter and Hunter (1984) and Schmidt and Hunter (1998), found validity for age as a predictor of job performance. However, Oehlschlagel and Moosbrugger (as cited in Schuhfried, 1996) and Wagner (as cited in Schuhfried, 1996) found that as age increases, performance in psychomotor tests decrease.

1.9.1.2 Years of education

Education and work experience are the two forms of human capital individuals are most likely to acquire during their careers (Myers, Griffith, Daugherty & Lusch, 2004; Singer & Bruhns, 1991; Strober, 1990). It should be noted, though, that in numerous cases educational level and amount of work experience are likely to be negatively correlated. Those younger employees who spend more years in school will have less time available in which to accumulate work experience, whereas those who enter the labor market early typically accumulate less formal education (Thomas, Feldman & Daniel, 2009). Because most organisations use education as an indicator of a person's skill levels or productivity (Benson, Finegold, & Mohrman, 2004), they frequently employ it as a prerequisite in hiring decisions.

1.9.1.3 Years of operating experience

Schmidt, Hunter, and Outerbridge (1986) argued that the effects of job experience may decrease over time. Schmidt et al. (1986) noted that although both cognitive ability and job experience influence work performance through their effects on job knowledge and that experience differences between incumbents tend to decline. Job experience is essentially a measure of practice on the job and hence a measure of opportunity to learn. The major direct causal effect of job experience is on job knowledge, just as is the case for mental ability (Schmidt & Hunter, 1998). Increasing job experience leads to increasing job knowledge (Schmidt, Hunter & Outerbridge, 1986), which, in turn, leads to improved job performance. Schmidt, Hunter, Outerbridge and Goff (1988) found that if experience does not exceed 5 years, the validity coefficients are as high as 0,33 when measured by supervisor ratings and 0,47 when measured using a work sample test. From these findings it is concluded that for the first five years, job experience predicts job performance – thereafter it has less utility as a predictor.

1.9.2 Predictor variables

Predictors were selected according to the Society for Industrial Psychology's (1992) guidelines for the selection of predictors, namely

- Predictors should be reliable and valid.
- Predictors should be chosen on the basis that there is a logical, empirical or theoretical reason for them to be included.
    - Predictors should be selected based on scientific knowledge rather than expedience.
- Predictors should be as objective as possible.

Two instruments were used, namely the Learning potential computerised adaptive test (LPCAT) and Vienna Test System (VTS), to collect data on predictor variables.

1.9.2.1 Learning potential computerised adaptive test (LPCAT)

The LPCAT is specifically aimed at measuring learning potential by making use of non-verbal figural items only, focusing on learning potential in the non-verbal figural domain and using Item Response Theory (IRT) methods to improve the psychometric features of the test (De Beer, 2006). In addition, it is very suitable for screening together with other measures (De Beer, 2000). The LPCAT makes use of a dynamic test-train-retest format and is based on Vygotsky's concept and theory of the zone of proximal development referring to the difference in performance levels with and without help. By means of computerised adaptive test techniques (based on Item Response Theory), test items are selected during the pre-test as well as the post-test according to the appropriate level of difficulty to match the estimated ability level of the particular individual during the assessment (De Beer, 2004).

The results from the LPCAT will be presented as standard scores making use of T-scores, stanines and percentile rankings. The norm comparison group is approximately Grade 10, which means that a T-score of fifty would compare a person with that of a Grade 10 school learner. T-scores have a mean of fifty and a standard deviation of ten equaling a range between twenty and eighty. Stanines are a normalized nine-point scale with a mean of five and a standard deviation of 1.96. Percentiles range from one to one hundred and represent the percentage of learners who obtain a score equal to or below that particular score (De Beer, 2000c).

De Beer (2000c) emphasized the concern raised by Grigorenko and Sternberg (1998) that reliability and validity are often not given sufficient attention in dynamic assessment and she intended to cover this extensively in her design of this dynamic assessment instrument. The LPCAT's internal consistency reliability indices range between 0.925 and 0.987 (De Beer, 2002).

The computerised format of the test contributes towards reliability and validity (Murphy, 2002), because of the accuracy in measurement. The use of standardized training and universal figural items contributes to the face validity of the LPCAT. In the standardization of the LPCAT, the correlation between the LPCAT and other cognitive tests was investigated to ensure construct validity. For a group of 92 first-year science and technology students, the LPCAT post-test score had a higher correlation with the General Scholastic Aptitude Test (GSAT) than the pretest score. The overall results showed that the two tests measured similar constructs, indicating construct validity (De Beer, 2000a).

The following correlation scores were obtained for the LPCAT post-test for various groups:

TABLE 1.1 CORRELATIONS OF LPCAT POST-TEST SCORES WITH DIFFERENT CRITERIA RESULTS (De Beer, 2003).

Group	Description of criteria	N	r
Adults – low literacy	ABET Literacy Level 1	182	0.44**
	ABET Numeracy Level 2	182	0.49**
	ABET Literacy Level 3	111	0.46**
	ABET Numeracy Level 3	26	0.61**
Grade 8	English proficiency	128	0.61**
	Mathematics proficiency	128	0.67**
	Academic average results	116	0.69**
Grade 12+	Numeracy scores (non-standardised)	146	0.39**
	Language scores (non-standardised)	146	0.41**
	Matriculation Mathematics	158	0.53**
	Matriculation Science	158	0.45**
	Matriculation Biology	58	0.31**
	Matriculation Average	158	0.51**
Technikon 1st year	Academic average semester 1	89	0.32**
	First year average	89	0.23**
University 4th year	Academic average	46	0.05

** statistically significant at $p<0.01$

r=0.1 small effect   r=0.3 medium effect   r=0.5 large effect

Table 1.1 summarises the correlation between the LPCAT post-test-scores and various criteria for groups with different levels of education. There are statistically significant correlations for all groups, except for fourth-year university students where there was no statistically significant correlation between LPCAT post-test scores and the academic average mark that students obtained. The magnitude of correlations, interpreted as effect size, ranged between medium and large for all groups except for the fourth-year university students (De Beer, 2003). For this group the criterion (academic) results were obtained from seven different academic institutions and this might have affected the results. A statistically significant correlation was also found between the LPCAT and the following matric subjects: English, Mathematics and Science, according to De Beer (2000b).

De Beer (2000b, p.93) states that for multicultural groups, “the LPCAT seems to be a reasonably equitable measure of learning potential within the non-verbal reasoning ability domain”. De Beer (2000b) suggests further validity investigations of the LPCAT. The current study provides additional results in this regard.

1.9.2.2 The Vienna Test System (VTS)

The VTS is a computerised psychological assessment that consists of various personality, intelligence, and special ability assessments (Schuhfried, 1996). The VTS was developed by the SCHUHFRIED Company in the early 1980s and has years of research in the support of the utility of the test system (Schuhfried, 1996). The company was founded in 1947 in Austria and the VTS is now used in 65 countries, on all 5 continents (Schuhfried, 1996).

The VTS assessment tools selected for operators relate directly to the critical tasks required of operators, including monotonous concentration, estimation of speed and distances, multi tasking in times of emergencies, and two-hand co-ordination. To cancel the habitual effect of training and experience that has an effect on operators’ performance, the VTS assesses the same underlying abilities required by the operator for safe equipment operating but without these influences.

The fact that the system requires no prior driving experience to yield predictions of driving ability makes this test ideal for use in the selection of potential mining operators.

For the purpose of this study, four of the psychomotor tests were assessed for their validity so as to determine their relationship with the LPCAT assessment as co-predictor and safety behavior as dependent variable. The four psychomotor tests used were: *Cognitrone* (in this study, referred to as “Cognitrone efficiency”); *Determination unit* (referred to as “Determination unit efficiency”); *Two-hand coordination test* (referred to as “Two-hand coordination speed” and “Two-hand coordination accuracy”, respectively), and *Time/Movement Anticipation (ZBA)* (only linear progressions were included since they relate to the operating activities required for the operation of moving machinery) (Schuhfried, 2000b).

i) Cognitrone

The test yields various options in terms of differentiated results. In this study “sum correct reactions” was utilized. It gives an indication of performance quality and, to some extent, also provides data on processing speed (Schuhfried, 2000a). In this study, this measure was referred to as “Cognitrone efficiency”.

The test has a split-half reliability of 0,95 (Schuhfried, 2000a). Criterion-related validity studies found significant correlations between test results and safety criteria, such as accident frequency and driver errors (Bukasa, Wenninger & Brandstätter as cited in Schuhfried, 2000a; Cale as cited in Schuhfried, 2000a). However, no criterion-related studies are available with the Cognitrone as predictor and operator or driver performance as criterion. A correlation of 0,48 was reported with the Determination unit subtest of the Vienna Test System, discussed in the following sub-section (Wagner as cited in Schuhfried, 2000a). This could be due to both tests tapping similar needs for sustained concentration, efficient information processing and quick reaction time. Negative impacts for age were reported in two studies (Oehlschlagel & Moosbrugger& Wagner as cited in Schuhfried, 2000a).

ii) Determination Unit

The measure used in this research is the “overall results correct” result, which reflects the total number of appropriate timely and delayed responses for the entire test (encompassing the slow, medium and fast phases of the test). This measure will be referred to in this study as “Determination unit efficiency” (Schuhfried, 2000b).

The Determination Unit demonstrates internal consistency of 0,99 (Schuhfried, 1996). Various criterion related validity studies found significant correlations between test results on the Determination unit and driving performance criteria. Correlations have been reported for the Determination Unit results with driving behavior during a test drive as well as results of a driving test (Klebelsberg & Kallina; Karner & Neuwirth as cited in Schuhfried, 2000a). Encouraging correlations between test results on the Determination unit and driving safety criteria have also been reported in terms of frequency of accidents and driver errors (Cale; Wenninger & Brandstatter as cited in Schuhfried, 2000b).

iii) Two-hand coordination test

The results yielded are “total mean duration” (speed dimension) and “total percentage error duration” (accuracy dimension). These variables are referred to as “Two-hand coordination speed” and “Two-hand coordination accuracy”, respectively in this study.

Internal consistency (Cronbach's Alpha) of the standardised variables lies between 0,847 and 0,968 (Schuhfried, 2000c). No criterion-related validity studies could be located in the literature review.

iv) Time/Movement Anticipation (ZBA)

For the purpose of this study only linear progressions were included. Sine wave progressions were omitted, since they relate to operating activities more complex than the operating activities required for the operation of moving machinery (Schuhfried, 2000b).

Internal consistency is 0,92 for the ZBA time estimation measure and 0,69 for the ZBA motion estimation measure (Schuhfried, 2000b). Validity studies on the previous version of this test (the Distance Estimation Test) indicate that drivers who overestimate distance (i.e. who stop too late) are more problematic than drivers who underestimate distance (Schuhfried, 2000b). This relates to the prediction of safety criteria. No validity studies relating the test to operator or driver performance criteria were reported for the previous version of the test. There are no validity studies available on the current version of the test (ie, the ZBA). No studies on the relative effects of age or any other potential moderator variable have been reported.

1.9.3 Dependent variables

Dependent variables are human factors or the various types of errors that people make in performing their tasks (Sagan, 1993). The work in a mine is challenging and those working in physical environments (i.e., processing plants and underground) naturally require some degree of physical fitness and strength (Singer, 2002; Wynn, 2001). Furthermore, employees in a mining context work with explosives, test geological formations, operate load-haul-dump machines, scraper winches, and heavy-duty machines, and maintain mining machinery in conventional mines. The equipment and techniques used are varied and complex, with many areas requiring significant safety and skills training (Calitz, 2004).
The respondents' safety records were used. In normal circumstances the operator's supervisor will record any unsafe behaviour of the operator. These recordings go to the safety department where they are entered onto a spreadsheet. For the purpose of this study, the spreadsheet was used as safety performance records for the respondents. No criterion-related validity studies could be located in the literature review.

The data entered onto the spreadsheet are given in the following way:

1. Green – good behaviour – score 3
2. Orange – average behaviour – score 2
3. Red – poor behaviour – score 1

The brief was to determine whether operators, with good learning potential and high psychomotor performance will be more likely to act in a good safety behaviour way. This relationship, will at the same time imply that those with low scores on learning potential and psychomotor ability are more likely to show poor safety behavior.

No attempt was made to compare operators amongst shifts because of the unreliability that could potentially be caused by different supervisors not being familiar with the performance of all the operators.

1.10 DATA ANALYSIS

Data analysis is conducted to reduce, organise and give meaning to the data. A statistician analysed the data using the Statistical Program for the Social Sciences (SPSS, version 19). Cronbach's alpha coefficients were used to assess the reliability of the constructs that were measured in this study. Descriptive statistics (e.g., means, standard deviations, skewness and kurtosis) and inferential statistics were used to analyse the data.

Pearson product-moment correlation coefficients were used to specify the relationship between the variables. In terms of statistical significance, it was decided to set the value at a 95% confidence interval level ($p \leq 0.05$). Effect sizes were used to decide on the practical significance of the findings (Steyn, 1999). Cut-off points of 0,30 (medium effect) and 0,50 (large effect) were set for the practical significance of correlation coefficients (Cohen, 1988).

Discriminant analysis (DA) was used to analyse the quantitative variable (safety behaviour) to examine the relationship to the independent variables (learning potential and psychomotor performance). DA is a statistical technique which allows the study of the differences between two or more groups of objects with respect to several variables simultaneously (Klecka, 1980). The aim of discriminant analysis is to combine (weight) the variable scores so that a single new composite variable, the discriminant score, is produced (Agresti, 1996). The degree of overlap between the discriminant score distributions can then be used as a measure of the success of the techniques, so that there can be two different groups, such as good and poor (Agresti, 1996). The ANOVA was utilized to evaluate the statistical significance of differences of mean values between groups.

1.11 ETHICAL CONSIDERATIONS

Ethics deals with matters of right and wrong. *Collins English Dictionary* (1991, p.533) defines ethics as "a social, religious, or civil code of behaviour considered correct, esp. that of a particular group, profession, or individual". In this study, the researcher upheld the ethical considerations of permission, anonymity and confidentiality. The researcher respected the respondents' rights to confidentiality and anonymity. The nature of confidentiality was verbally explained to all candidates by the test administrator, before the test session started.

1.12 KEY WORDS

For the purposes of this study, the following words were used:

- **Learning potential**
- **Psychomotor ability**
- **Safe working behaviour**
- **Intelligence**
- **Dynamic assessment**
- **Cognitive ability**
- **Mechanised mining**

1.13 CHAPTER SUMMARY

This chapter outlined the study, including the purpose, paradigm perspective, research design and methodology, and definitions of key words.

In Chapter 2 discusses the literature review conducted for the study will be discussed.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

The business environment in which organisations have to operate has become increasingly complex (Kilduff, 2000). Business organisations are faced with ever-increasing uncertainty, turbulence and changes in the external environment. These changes are due to increased international and local competition, technological advances and increased stakeholder and customer expectations, among other things. To survive in this ever-changing external organisational environment, management must use its awareness of these forces to improve its internal business operations (De Villiers & Slabbert, 1996).

The South African mining industry forms the hub of the country's economy and many individuals and families would be stranded without it. At the same time, however, it is an environment in which many people's lives are put at risk due to the nature of the job. The work in a mine is challenging and those working in demanding physical environments (i.e., processing plants and underground) naturally require some degree of physical fitness and strength (Singer, 2002; Wynn, 2001). Mining employees work with explosives, test geological formations, operate load-haul-dump machines, scraper winches and heavy-duty machines, and maintain mining machinery used in conventional mines. The equipment and techniques used are varied and complex, with many areas requiring significant safety and skills training (Calitz, 2004).

Since 2003 there has been a steady increase in trackless mining in platinum mines underground narrow reef operations. By narrow reef method first platinum group metals is extracted where miners make use of handheld pneumatic drills in order to make holes in the reef which explosives can be loaded (Pickering, 2006). Seventeen sites currently apply trackless mining to various degrees (Harrison, 2008).. Increased mechanisation can create opportunities to achieve injury-free sustainable production and drive down unit cost (Harrison, 2008).

In the South African *Mine Health and Safety Act (29 of 1996)*, employers are required to assess the risks to the health and safety of their employees and persons affected by their undertakings. In order to select individuals who will contribute to the effectiveness of organisations, certain selection methodologies are employed. These selection methods need to remain within the ambit of the law as well as have the ability to potentially select the most productive employees for an organisation (Gilmore, 2008; Mauer, 2000a, 2000b; Schmidt & Hunter, 1998).

Valid selection procedures should translate into productivity and improved performance levels, and ultimately, into the overall effectiveness of any organisation (Anastasi, 1988; Schmidt & Hunter, 1998). The ability to assess and identify employees who have the potential to learn new tasks, rather than only being able to demonstrate the skills they have learnt, should have an impact on the prediction of the manner in which employees ultimately perform in the workplace (Sternberg & Grigorenko, 2002).

Hunter and Hunter (1984) examined the validity and ability of alternative predictors of job performance such as cognitive tests, job tryouts, interviews, biographical data forms, interest tests, age, and education in a wide variety of occupations. For entry-level jobs, Hunter and Hunter (1984) found that ability tests were generally the most accurate single predictors. Ability tests can include a combination of cognitive tests (tests of verbal and numerical reasoning) and psychomotor tests, among other elements. Hunter and Hunter (1984, p.80) maintain that "ability tests are valid across all jobs in predicting job proficiency". In over four hundred studies, the mean correlation of ability with supervisors' ratings of performance was 0.53. Tests of cognitive ability were the most accurate for thinking jobs (e.g. manager, salesperson), while psychomotor skills were most accurate for jobs requiring manual skills. Job tryouts and biographical inventories were also valid predictors (Dakin & Armstrong, 1989).

Given the socio-economic and educational disadvantages that many individuals in South Africa did and still do experience, there is a need for assessment strategies that focus on future potential rather than current ability (Murphy & Maree, 2006).

For the purpose of this study, the literature review covered definitions and descriptions of cognitive ability, dynamic assessment, learning potential, psychomotor ability, cognitive ability/intelligence, mechanised mining, mechanised ability and safety behaviour.

2.2 DEVELOPMENT OF PSYCHOLOGICAL TESTS FOR MEASURING INTELLIGENCE

Psychological tests were first developed for the purpose of measuring intelligence (Nevid, Rathus & Greene, 1997). In the early nineteenth century there was strong interest in classifying types of mental disorders, such as autism and Down syndrome, and distinguishing between mental disabilities and mental illness (Stengel, 1959).

Sir Francis Galton (1909) proposed the development of measures of central tendency and variability to summarize data and also developed the concept of correlation. James McKeen Cattell, a student of Galton's, was the first to use the term "mental test". He developed a set of tests able to predict a child's scholastic achievement. Cattell's (1987) goals were to strengthen psychology's scientific credentials.

Karl Pearson, also a student of Galton's, developed several techniques still used in modern statistics, such as the standard deviation and the normal curve. His most well-known statistical concept is the product moment correlation coefficient, or Pearson's r (Fancher, 1985).

Alfred Binet was the first to formulate a test for children with mental challenges. He believed that intelligence could be nurtured, and was not simply the product of nature. Binet (1983) developed cognitive exercises called “mental orthopaedics” to increase the intelligence level of children.
David Wechsler, a student of Pearson’s, developed two widely used intelligence scales: the Wechsler Adult Intelligence Scales (WAIS) and the Wechsler Intelligence Scale for Children (WISC). Wechsler (1958) defined intelligence as “the global capacity to act purposefully, to think rationally and to deal effectively with the environment”.

Anne Anastasi (1981), one of the best known psychologists in the field of testing, stated that psychological tests are tools that can be instruments of good or harm, depending on how they are used. She defined a test as an “objective” and “standardised” measure of a sample of behaviour.
Anastasi and Urbina (1997, p.4) defined a psychological test as essentially “an objective and standardized measure of a sample of behaviour”. This definition would imply the likelihood that people from different cultural backgrounds would behave differently from the culture of the standardisation sample. In a cross-cultural clinical psychological assessment of Hispanic Americans, Cuellar (1998) found that as the tests are samples of behaviour, it is difficult to identify why the test-takers perform as they do. Anastasi and Urbina (1997) maintained that if tests cannot remove cultural influences from test scores, greater value may be derived by identifying the extent to which specific cultural variables, such as language, education, and acculturation, affect specific test scores. Gregory (1996) and Aiken (1979) described assessment as an estimation of one or many specific attributes or traits that an individual may possess. Assessment involves activities such as interviews, observations, checklists, projectives and other psychological tests to gather more information about an individual (Aiken, 1979; Friedenberg, 1995; Gregory, 1996).

According to Carretta and Ree (2000, p.229), the “measurement and structure of abilities have been a topic of speculation and study since the time of Aristotle, who distinguished ability from emotional and moral faculty”. In the field of personnel selection, intelligence is the most researched predictor (Salgado, 2000; Schmidt & Hunter, 1998). Intelligence is widely regarded as the most valid indicator of job performance (Hunter & Hunter, 1984; Ree & Carretta, 1996a; Ree & Earles, 1992; Schmidt & Hunter, 1998). Learning potential as a measurement in the cognitive domain is seen as related to though different from the measurement of intelligence. .

Theories differ on the nature, definitions and assumptions of intelligence and the measures used to assess it (Suzuki, Meller & Ponteretto, 1996). The term “IQ” (intelligence quotient – also referred to as intelligence coefficient) refers to a complex concept, and researchers differ on the various theories of intelligence and learnable intelligence (Perkins, 1995). For the purpose of this study, intelligence was defined as “that which intelligence tests measure” (Reber, 1995, p.2). There is no consensus on a definition of what exactly constitutes intelligence. Some researchers regard intelligence as a single, general ability while others state that intelligence encompasses a range of aptitudes, skills and talents. Galton, Cattell, Binett, Simon, Wechsler, and Anastasi were among the major people who influenced the development of intelligence theory and testing.

2.2.1 Sir Francis Galton (1822-1911)

In 1865 Galton began to study heredity after reading his cousin, Charles Darwin's publication, *Origin of Species* (Clayes, 2001). Galton soon discovered that his true passion was studying the variations in human ability. In particular, he was convinced that success was due to superior qualities passed down to offspring through heredity (Clayes, 2001). Galton used supporting data he collected by analyzing the obituaries of the *Times* newspaper, where he traced the lineage of eminent men in Europe. His quest for data and accountability led to a series of studies and books on the heredity of mental faculties specifying that "human mental abilities and personality traits, no less than the plant and animal traits described by Darwin, were essentially inherited" (Seligman, 2002, p.53).

Ultimately, these findings sparked the eugenics movement, which called for methods of improving the biological make-up of the human species through selective parenthood (Allen, 2002). Galton even advocated human breeding restrictions to curtail the breeding of "feeble-minded" individuals (Clayes, 2001; Irvine, 1986). Galton is recognized for his heredity studies and his proliferation of eugenics ideology, as well as many notable contributions to the fields of biology, psychology, statistics, and education. Galton is called the "father of behavioural genetics" for his foundation breaking twin studies on the differences between mono- and dizygotic twins (Allen, 2002, p.26).

In order to quantify the passing down of characteristics, qualities, traits, and abilities from generation to generation, Galton formulated the statistical notion of correlation, which led to his understanding of how generations were related to each other (Bynum, 2002). Galton established that "numerous heritable traits, including height and intelligence, exhibited regression to the mean - meaning that extreme inherited results tended to move toward average results in the next generation" (Seligman, 2002, p.54).

Galton was the first to demonstrate that the Laplace-Gauss distribution or the "normal distribution" could be applied to human psychological attributes, including intelligence (Simonton, 2003). From this finding, he coined the use of percentile scores for measuring relative standing on various measurements in relation to the normal distribution (Jensen, 2002). He established the world's first mental testing centre, in which a person could take a battery of tests and receive a written report of the results (Irvine, 1986).

2.2.2 James McKeen Cattell (1860-1944)

James McKeen Cattell was an important figure in psychology and the study of human intelligence (*Biographical Dictionary of North American and European Educationists,* 1997). While at Leipzig, working under Wundt, he was the first American to publish a dissertation, *Psychometric investigation*. After his return from Europe, perhaps no other person contributed more to the strengthening of American psychology in the late 1890s and early 1900s. He was the co-founder and co-editor of *The Psychological Review* (1894-1903), editor and publisher of the *Journal of Science* (1894-1944), and founder of the Psychological Corporation (1921) and the Science Press (1923). He was also involved with the American Psychological Association, the American Association of University Professors, and the American Association for the Advancement of Science (*Biographical Dictionary of North American and European Educationists*, 1997).

Cattell was interested in the measurement of individual differences of intelligence (Anastasi, 1988). He maintained that an individual's culture promotes certain specialized skills and knowledge required for functioning in that culture. These skills and knowledge are learned, internalized, and known as crystallized intelligence (Taylor, 1994). Cattell proposed a theory that intelligence consists of two major types of cognitive abilities: crystallized intelligence and fluid intelligence (Cohen & Swerdlik 2002). Crystallized intelligence (G*c*) refers to acquired skills and knowledge that are dependent on exposure to a particular culture, as well as formal and informal education, for example, vocabulary. The abilities that make up fluid intelligence (G*f)* are nonverbal, relatively culture-free, and independent of specific instruction, for example, memory for digits. Fluid and crystallized intelligence are discrete factors of general intelligence, or *g* (Cattell, 1987).

Although it is widely believed that Cattell's goal was to measure intelligence or a similar construct with these tests, his goals appear to have been related largely to strengthening psychology's scientific credentials. According to Cattell and Farrand (1986, p.648):

> *We do not at present wish to draw any definite conclusions from the results of the tests so far made. It is of some scientific interest to know that students entering college have heads on the average of 19.3cm long … that they have an average reaction time of 0.174 sec., that they can remember seven numerals heard once, and so on with other records and measurements. These are mere facts, but they are quantitative facts and the basis of science. Our own future work and that of others must proceed in two directions… (a) To what extent are the several traits of body, of the senses and of mind interdependent? … What can we learn from the tests of elementary traits regarding the higher intellectual and emotional life? (b) On the other hand we must use our measurements to study the development of the individual and of the race, to disentangle the complex factors of heredity and environment.*

Although crystallized and fluid intelligence are highly correlated and often indistinguishable in test populations that are homogenous in terms of culture and education levels, the implication is that this correlation is not necessarily prevalent in test populations where there is heterogeneity in these variables (Budoff, 1987; Laughton, 1990; Taylor, 1994; Walsh & Betz, 1990). For this reason, in this theory it is argued that the assessment of fluid intelligence will give a clearer picture of intellectual potential, particularly in culturally and educationally diverse test populations. This educational diversity is expected to be relevant in a country such as South Africa where educational opportunities were assigned on the basis of race for a great part of its history (Pelser, 2002).

2.2.3 Alfred Binet (1857-1911) and Theodore Simon (1873-1961)

After receiving his law degree in 1878, Alfred Binet began to study science at the Sorbonne (Wolf, 1973). However, he was not overly interested in his formal schooling, and started educating himself by reading psychology texts at the National Library in Paris (Wolf, 1973). He soon became fascinated with the ideas of John Stewart Mill, who believed that the operations of intelligence could be explained by the laws of associationism. Binet eventually realized the limitations of this theory, but Mill's ideas continued to influence his work (Siegler, 1992).

Binet published more than 200 books, articles, and reviews in what now would be called experimental, developmental, educational, social, and differential psychology (Siegler, 1992). Bergin and Cizek (2001) suggested that this work may have influenced Jean Piaget, who later studied with Binet's collaborator, Theodore Simon in 1920. Binet's research with his daughters helped him to further refine his developing conception of intelligence, especially the importance of attention span and suggestibility in intellectual development (Wolf, 1973).

In developing the Binet-Simon Scale, Binet and Simon collated a variety of tasks they considered representative of typical children's abilities at various ages (Fancher, 1985). This task-selection process was based on their many years of observing children in natural settings. They then tested their measurement on a sample of fifty children, ten children in each of five age groups. The children selected for their study were identified by their school teachers as being average for their age. The purpose of this scale of normal functioning, which would later be revised twice using more stringent standards, was to compare children's mental abilities relative to those of their normal peers (Siegler, 1992).

The scale consisted of thirty tasks of increasing complexity (Fancher, 1985). The easiest of these could be accomplished by all children, even those who were severely retarded. Some of the simplest test items assessed whether or not a child could follow a lighted match with his eyes or shake hands with the examiner. Slightly harder tasks required children to point to various named body parts, repeat back a series of 3 digits, repeat simple sentences, and define words like “house”, “fork” or “mama”. More difficult test items required children to state the difference between pairs of things, reproduce drawings from memory, or construct sentences from three given words, such as “Paris”, “river” and “fortune”. The most difficult test items included asking children to repeat back 7 random digits, and find three rhymes for the French word *obeisance* (Fancher, 1985).

For the practical use of determining educational placement, the score on the Binet-Simon scale would reveal the child's mental age. For example, a 6 year-old child who passed all the tasks usually passed by 6 year-olds -- but nothing beyond -- would have a mental age that exactly matched his chronological age, 6.0 (Fancher, 1985).

Lewis Terman, who followed Goddard in the US mental testing movement, standardized the Binet-Simon Scale using a large American sample. The new Stanford-Binet scale was no longer used solely for advocating education for all children, as was Binet's objective. A new objective of intelligence testing was illustrated in the *Stanford-Binet Manua*l with testing ultimately resulting in “curtailing the reproduction of feeble-mindedness and in the elimination of an enormous amount of crime, pauperism, and industrial inefficiency" (White, 2000, p.42).

2.2.4 David Weschler (1896-1981)

David Wechsler is best known for developing several widely-used intelligence tests, including the Wechsler Intelligence Scale for Children (Wechsler, 1997) and the Wechsler Adult Intelligence Scale (Wechsler, 2003). Updated versions of these tests remain popular in the 21st century (WAIS-III®, 1997; WISC-IV®, 2003;). Wechsler is also noted for his use of the deviation quotient (DQ), a technical innovation that replaced the use of mental ages in computing IQ scores (Fancher, 1985). This greatly improved the utility of normative comparisons when intelligence tests were used with adult examinees (Edwards, 1994).

When the United States entered the First World War, David Wechsler was completing his master’s degree in psychology. He joined the Army, and this circumstance brought him into contact with several pioneers in the field of intelligence theory, including Karl Pearson, Edward Thorndike and Robert Mearns Yerkes (Edwards, 1994). While awaiting his induction Wechsler volunteered to score the Army Alpha test, one of the two group intelligence tests developed by the Committee on the Psychological Examination of Recruits, and here he met Yerkes and Thorndike. Later Wechsler became an individual psychological examiner, and was charged with administering the Stanford-Binet to recruits who had performed poorly in the group intelligence tests (Fancher, 1985).

Wechsler found Spearman’s theory of general intelligence (*g*) too narrow. Unlike Spearman, Wechsler viewed intelligence as an effect rather than a cause, and asserted that non-intellective factors, such as personality, contribute to the development of each person’s intelligence (Wechsler, 1940). His broader view was reflected in his personal definition of intelligence as “the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment” (Edwards, 1994, p.1135).

The Wechsler Intelligence Scale for Children – Fourth Edition® (WISC-IV®) was published in 2003. It has been normed for use with children aged six to sixteen years and eleven months. It yields a full-scale IQ score and four index scores: Verbal Comprehension (e.g. similarities, vocabulary and comprehension activities), Perceptual Reasoning (e.g. matrix reasoning, block design and picture concepts), Working Memory (e.g. letter-number sequencing and digit-span) and Processing Speed (e.g. symbol search and coding). The Wechsler Adult Intelligence Scale, 3rd edition (WAIS-III®), was published in 1997, and can be used with adults between the ages of 16 and 89 years.

2.2.5 Anne Anastasi (1908-2001)

Anne Anastasi, the only child of Sicilian parents, grew up in New York City (Reznikoff & Procidano, 2001). Her father died when she was an infant, and she was raised by her mother, grandmother and uncle. Her grandmother was a domineering woman who maintained stewardship over most issues in family life, including young Anne's education (Reznikoff & Procidano, 2001). She believed herself to be a true aristocrat, and categorized all those whom she met as either aristocrats or peasants (Anastasi, 1989). Anastasi's uncle was a man of superior classical education, but was ill prepared for real-world employment. In contrast, Anastasi's mother was a practical, resourceful woman, and she shouldered the burden of supporting the family (Reznikoff & Procidano, 2001; Sexton & Hogan, 1990). Anastasi believed that the juxtaposition of these three personalities might have been the reason for her later professional interest in the psychology of individual differences (Anastasi, 1989).

Anastasi entered college as a Mathematics major. During her sophomore year she enrolled in an elective psychology class taught by HL Hollingworth. His enthusiasm and intensity impressed her, as did his sharp criticism of sloppy research practices (Anastasi, 1989; Sexton & Hogan, 1990). Later Anastasi read a Charles Spearman article on correlation coefficients, and realized that she did not need to abandon mathematics to pursue her emerging interest in psychology (Anastasi, 1972, 1989; Reznikoff & Procidano, 2001; Spearman, 1904). She switched majors and completed a bachelor's degree in psychology at the age of nineteen. After graduation from Barnard, she entered Columbia University, requesting that her undergraduate work be accepted in lieu of a master's degree. She completed her doctorate in two years (Anastasi, 1972, 1989).

Anastasi's research focused on understanding and measuring the factors underlying the development of individual differences in psychological traits (Anastasi, 1972, 1989). She argued against the strictly hereditarian position, emphasizing the role of experiential and environmental influences on intelligence test scores and psychological development (Sexton & Hogan, 1990). According to Anastasi (1972, p.13), intelligence test scores are not pure measures of innate ability:

> *...not only does the nature of one's antecedent experiences affect the degree of differentiation of "intelligence" into distinct abilities, but it also affects the particular abilities that emerge, such as verbal, numerical, and spatial abilities. Thus, experiential factors affect not only the level of the*

individual's intellectual development, but also the very categories in terms of which his abilities may be identified.

Anastasi (1981) maintained that most claims about "culture-free" and "culture-fair" testing are untrue. She stressed that different cultures have different concepts of what an "intelligent person" is, and traditional psychometric tests measure only those skills which are valued in academic and work circles in modern, industrialized social contexts. The dominant intelligence test paradigm presupposes that intelligence tests should assess the individual's ability to succeed in this environment. However, the value of these tests is ephemeral; new tests will have to be developed as society advances and new technology demands cultivation of different cognitive skills. Anastasi emphasized that there is an alternative to this testing model. Other assessments could be developed to measure “how well individuals have acquired skills and knowledge valued in [their own] culture” (Anastasi, 1981, p.18). According to Anastasi (1981), although both types of tests can be valid as intelligence tests, the way in which intelligence is defined would necessarily be different for each construct.

Anastasi's research increased awareness of what intelligence tests should and should not be used for. She cautioned test users against misinterpreting results, emphasizing that intelligence is changeable over time, and that intelligence (not just intelligence test scores) can improve with experience. Therefore, intelligence test scores should never be used to label a student indelibly (Anastasi, 1992). According to Anastasi (1981, p.8),

Tests can serve a predictive function only insofar as they indicate to what extent the individual has acquired the prerequisite skills and knowledge for a designated criterion performance. What persons can accomplish in the future depends not only on their present intellectual status, as assessed by the test, but on their subsequent experience.

Anastasi (1981, p.8) stated that intelligence tests

1. Permit a direct assessment of prerequisite intellectual skills demanded by many important tasks in our culture.
2. Assess availability of a relevant store of knowledge or content also prerequisite for many educational and occupational tasks.
3. Provide an indirect index of the extent to which the individual has developed effective learning strategies, problem-solving techniques and work habits and utilized them in the past.

When intelligence test scores are used properly, they are valuable descriptive tools that allow teachers and counsellors to determine a student's current level of academic performance (Anastasi, 1992). Although an intelligence test score cannot tell *why* students scored as they did, the score can make it easier to meet students at their level, and to design educational experiences that will improve intelligence (Anastasi, 1981).

Sergei Rubinstein (1946), a Russian psychologist, held that in order for an educator to evaluate students' ability to learn, the educator needs to teach students something and then to observe their learning. People draw conclusions about other people's ability to learn, their learning potential (Sternberg & Grigorenko, 2002). Embretson (1987b) delineated three main goals of dynamic testing, namely to

1. provide a better estimate of a specified ability construct;
2. measure new abilities, and
3. improve mental efficiency.

Learning potential measures fall within the framework of the learning/dynamic theories of intelligence or cognitive ability. The distinguishing characteristic of learning potential tests is that respondents learn a new skill or competency while doing the tasks set out in the test. Some individuals become more competent than others and the differences in competency are captured in test scores (Taylor, 1999).

The views on cognitive or mental ability evolved, and along with the developing theories, different methods of measurement were required. As noted above, despite the acknowledgment of contextual influences on one's cognitive ability, the cognitive tests that were developed focused mainly on the measurement of crystallised intelligence. Dynamic assessment was introduced to assess learning potential.

2.3 DYNAMIC ASSESSMENT

As a more modern approach to assessment in the cognitive domain, dynamic assessment is an interactive approach to conducting assessments within the domains of psychology, speech/language, or education, and focuses on the learner's ability to respond to intervention (Haywood & Lidz, 2007). Dynamic assessment is both a model and philosophy of conducting assessments. Although there are variations on several dimensions of the model, the most consistent characteristics are (Haywood & Lidz, 2007):

- The assessor actively intervenes during the course of the assessment with the learner with the goal of intentionally inducing changes in the learner's current level of independent functioning.

- The assessment focuses on the learner's processes of problem solving, including those that promote as well as obstruct successful learning.

- The most unique information from the assessment is information about the learner's responsiveness to intervention.

- The assessment also provides information about what interventions successfully promote change in the learner (connecting assessment with intervention).

- The assessment is most often administered in a pre-test-intervention-post-test format

- The assessment is most useful when used for individual diagnosis, but can also be used for screening of classroom size groups

- The model is viewed as an addition to the current, more traditional, approaches, and is not a substitute for existing procedures. Each procedure provides different information, and assessors need to determine what information they need.

Haywood (1997, p.16) identified three major groups of dynamic assessment approaches, namely “restructuring the test situation”, “learning within the test”, and “metacognitive intervention, teaching generalisable cognitive operations”. Sternberg and Grigorenko (2002) further divided the various approaches into the following groups:

- Structural Cognitive Modifiability
- Learning Potential Testing
- Testing via Learning and Transfer
- *Lerntest* Approach
- Testing the Limits
- Information Processing

The underlying assumption of dynamic assessment is that all learners are capable of some degree of learning (change; modifiability) (Burden, 2002). This contrasts with the basic assumption of standardized psychometric testing that the learning ability of most individuals is inherently stable (Burden, 2002). Research with dynamic assessment indicates that determination of the current levels of independent functioning of learners is far from a perfect predictor of their ability to respond to intervention (Sternberg & Grigorenko, 2002).

Dynamic assessment procedures vary on several dimensions, but primarily with regard to degree of standardization of interventions as well as content. Three basic models fit most of the procedures (Haywood & Lidz, 2007):

- An open-ended, clinical approach that follows the learner, using generic problem-solving tasks such as matrices. The approach to intervention focuses on principles and strategies of problem solution and aims to promote independent problem solving.

- Use of generic, problem-solving tasks, but offering a standardized intervention. All learners are provided with the same intervention involving principles and strategies for problem solution. These approaches tend to focus on classification of learners, attempting to reduce the negative results of cultural bias.

- A graduated prompting procedure where learners are offered increasingly more explicit hints in response to incorrect responses. All learners progress through the same menu of prompts or hints, varying with regard to the number of prompts required for task solution.

A dynamic assessment measure has the following characteristics (Lidz & Elliot 2000, p.6):

- **Interaction.** The assessment measure is interactive in nature with interaction between the assessor and the assessed. The assessor is not a neutral observer but is actively involved in producing change within the learner. This takes into consideration the notion that an individual's abilities are not stable but rather change over time. How much an individual changes and responds to a learning situation is dependent on the individual, and this is the focus of the assessment procedure.
- **Intervention.** Built into the assessment measure is intervention within the procedure. Assessment and intervention can therefore be linked in dynamic assessment.
- **Unlimited.** Dynamic assessment is not limited to a specific domain or content or to any particular age group.

Dynamic assessment is the testing procedure used to measure learning potential and generally includes a test-train-retest or test-teach-retest strategy where the training subsection generally includes some kind of assisted help that forms part of the assessment process (De Beer, 2006).

Generally, dynamic learning potential assessment procedures and instruments adhere to the following graduated processes (Jooste, 2004):

- measurement of an initial base of competency in a given area of intellective functioning
- training in the given area of intellective functioning
- subsequent assessment of the application of the newly acquired intellective competencies.

The dynamic aspect of the assessment procedure pertains to the second process, namely that of training. The influence of this training or mediation process is estimated by computing the difference between the initial and subsequent measures of intellective functioning; that is, between the initial measurement and subsequent assessment. The degree of this difference is regarded as a learning potential score indicating an individual's potential to develop intellective competencies in the context of appropriate mediation (Bendixen, 2000; Swanson & Lussier, 2001).

The following paragraphs underpin the core tenet of the dynamic cognitive assessment of learning potential:

a) Intelligence potential

Although the level of endowed intelligence potential may be fixed, no individual completely explores this potential (Hamers & Resing, 1993). Dynamic assessment procedures highlight the relationship between what Vernon (1962) and De Groot (1985) referred to as "intelligence-as-inborn-capacity" and "intelligence-potential". The ability of traditional static instruments to formulate a summative representation of past learning is relatively sound. The ability to investigate the intelligence-potential, even within the context of potentially limited intelligence-as-inborn-capacity, represents the qualitative assessment evolution presented by dynamic assessment procedures. In the context of dynamic assessment philosophy, intelligence is considered to be the capacity (or indeed, potential) of the individual to utilize experience (Feuerstein, 1979). The measurement of what has been experienced is deemed secondary to underlying cognitive faculties that would mediate any future experience.

b) Actual performance

The best assessment for any performance is a sample of the actual performance (Elliott, 2003). Rather than attempting to generalize future task capability on the basis of broad and presumed indexical summative products (as in the case of most traditional assessment philosophies), dynamic assessment procedures pursue a sample of requisite underlying cognitive facets (Murphy, 2002).

c) Impediments and differences in individuals

In the context of impediments and differences in individuals' application and development of specific intellective competencies, an emphasis on potential yields more valuable data on possible future competencies (Jitendra & Kameenui, 1993; Murphy, 2002; Skuy, Zolezzi, Mentis, Fridjhon & Cockcroft, 1996). In contexts where there is significant cultural heterogeneity or disadvantagement, the development of intellective and meta-intellective structures and strategies will differ between individuals (Haywood & Tzuriel, 2002). Assessment procedures that are able to account for and reduce the influence of such potentially spurious contextual factors afford a better indication of potential to perform intellective tasks in the future than to do those geared to past learning experiences and opportunities (Jitendra & Kameenui, 1993; Zollezzi, 1995).

Dynamic assessment challenges conventional views on teaching and assessment by contending that these should not be seen as separate activities but instead be fully integrated. This integration occurs as intervention and is embedded in the assessment procedure in order to interpret individuals' abilities and lead them to higher levels of functioning (Lidz & Gindis, 2003, p.99).

Vygotsky's (1978) socio-cultural theory and Feuerstein's (1991) mediated learning experience theory are two approaches to dynamic intelligence assessment, which rely on some form of appraisal of intellective process.

2.3.1 LS Vygostky (1896-1934) – Socio-cultural theory

Vygotsky's (1978) theory is based on the difference between the actual developmental level as determined by independent problem solving and the notion of a zone of proximal development (ZPD). Vygotsky (1978, p.86) described ZPD as "the distance level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" .

The breadth of the "zone" varies not only across individuals, but also within each individual across different domains of learning (Campione, Brown, Ferrara & Bryant, 1984). Vygotsky (1978, p.90) maintained further that learning and development are not the same, and that learning not only leads development, but "creates the zone of proximal development".

Vygotsky's theory (cited in Rieber, 1997) made a distinction between experiences produced by the immediate contact of the individual with environmental stimuli and experiences shaped by interactions mediated by symbolic tools. Vygotsky's research into the development of cognitive functions revealed that this process is not a matter of innate abilities growing into a mature state but the emergence of new ways of thinking, acting, and being that result from individuals' engagement in activities where they are supported by cultural artefacts and by interaction with others (Poehner, 2008).

Lidz and Gindis (2003, p.100) pointed out that for Vygotsky, abilities are not innate but are emergent and dynamic. This means that abilities must not be considered stable traits that can be measured; rather, they are the result of an individual's history of social interactions in the world. Vygotsky holds that cognitive skills and patterns of thinking are not primarily innate factors, but rather the products of activities practised in the social institutions of the culture in which the individual grows up. As such, the history of the society in which a child grows up and the child's personal history are crucial determinants of the way in which the child will think (Thomas, 1993). According to Vygotsky's theory, an individual's actual level of development as determined by independent performance "not only does not cover the whole picture of development, but very frequently encompasses only an insignificant part of it" (Vygotsky, cited in, Rieber & Hall, 1998, p.200).

Vygotsky (1978, p. 91) referred to what children can do on their own as the "level of actual development". In his view, it is the level of actual development that a standard IQ test measures. Such a measure is undoubtedly important, but also incomplete. Two children might have the same level of actual development, in the sense of being able to solve the same number of problems on some standardized test. Given appropriate help from an adult, still, one child might be able to solve an additional dozen problems while the other might be able to solve only two or three more. What the child can do with the help is referred to as the "level of potential development" (Vasta, Haith & Miller, 1995).

For Vygotsky, language has a particular role in learning and development. By acquiring a language, a child is provided the means to think in new ways and gains a new cognitive tool for making sense of the world. Language is used by children as an additional device in solving problems, to overcome impulsive action, to plan a solution before trying it out, and to control their own behaviour (Jones, 1995).

Dynamic assessment is an interactive approach to psychological or psycho-educational assessment that embeds intervention within the assessment procedure. Most typically, there is a pre-test then an intervention and then a post-test. This allows the assessor to determine the response of the client or student to the intervention. There are a number of different dynamic assessment procedures that have a wide variety of content domains (Luria, 1961).

One purpose of dynamic assessment is to determine if a student has the potential to learn a new skill (Thomas, 1993).

Luria (1961) modified Vygotsky's developmental assessment procedure into an assessment of learning potential. The interaction between child and adult was transformed into a training phase that became part of the assessment procedure. By comparing pre- and post-test scores, Luria differentiates between a child's actual development and his/her potential performance level.

2.3.2 R Feuerstein (1921-) - Mediated learning experience theory

Feuerstein's mediated learning experience (MLE) theory focuses on the interaction that occurs between individuals and their socio-cultural environment (Feuerstein & Feuerstein, 1991). More specifically it is concerned with individuals' interaction with their environment via a human mediator (Feuerstein & Feuerstein, 1991).

Feuerstein and Feuerstein (1991, p.7) define the mediated learning experience as:

> A quality of interaction between the organism and its environment. This quality is ensured by the interposition of an initiated, intentional human being who mediates the stimuli impinging on the organism. This mode of interacting is parallel to and qualitatively different from the more generalized and more pervasive modality of interaction between world and organism referred to as direct exposure to stimuli.

Feuerstein and Feuerstein (1991) used the Piagetian school of thought to explain that this process of direct exposure to stimuli is the modality by which the development of intelligence and cognitive processes become possible. However, more than just the properties of the stimulus are responsible for the development of intelligence. The characteristics of the organism and its maturation introduced because of the activity play an equally important role. Other factors also need to be taken into consideration in this process. For example, other people or cultural determinants need to be considered. This theoretical approach takes into consideration individual differences that exist between people including their individual capacities to modify themselves, cognitive structure, knowledge base and operation functioning with regard to stimulus exposure. It is evident in the daily observation of people's behaviour that even after exposure to a stimulus, behaviour change does not necessarily occur (Tzuriel, 2000a). While some individuals may require a single experience of exposure to a stimulus to result in generalization to other stimuli, others require repetitive exposure before any permanent changes occur within them. In the MLE theory such variations are variations in modifiability. Tzuriel (2000a) interpreted Feuerstein's MLE as a process during which a teacher (whether a parent, grandparent, etc.) places themselves between the individual and the set of stimuli. This mediator then mediates the stimuli to the child. This may include various strategies, such as changing the frequency or order of the stimuli presented, relating them to contexts that are familiar to the individual, and so forth. It is the mediator's role to motivate the individual by arousing their curiosity, vigilance and challenge. In other words, the mediator, in effect, tries to improve the individual's cognitive functions that are required for them to determine the temporal, spatial and cause-effect relationship. It is expected or hoped that the individual will gradually internalize these motivation strategies to become part of the change mechanism within the individual. These strategies should allow the individual to develop later on, independently, to gain meaning from learning experiences, to be able to self-mediate in similar but new learning situations and ultimately be able to actively modify their own cognitive systems (Tzuriel, 2000a).

As discussed above, many tests have been developed on the basis of Vygotsky's learning potential concept, both internationally and nationally. For the purpose of placing this research in context, it is imperative to ensure a proper understanding of the concept and measurement of learning potential.

2.4 LEARNING POTENTIAL

Hamers and Resing (1993) stated that learning ability or learning potential is equivalent to the simplistic definition of intelligence, viewing it as the ability to learn, while traditional IQ tests measure current cognitive abilities.

Babad and Budoff (1974) described learning potential as the trainability, that is, the ability of an individual to improve performance in reasoning problems, after a learning experience.

Learning potential is related to that which the individual could be capable of and is very much determined by the possibility of change. Learning potential refers to the individual's overall cognitive capacity and is composed of both present and future projected performance. Learning potential, in effect, refers to intelligence, but intelligence that changes (De Beer, 2006).

To ensure that training and education are aimed at potentially the most responsive and deserving individuals, it is essential that such individuals have the potential to develop the required skills and abilities (Schoeman, De Beer & Visser, 2008). Many standard cognitive tests are problematic, because they measure current cognitive abilities, and do not assess individuals' capacity to apply acquired skills, strategies and operations in new situations (Feuerstein, Feuerstein & Gross, 1997; Foxcroft, 1997; Schoeman, De Beer & Visser, 2008).

Guthke and Beckmann (2000, p.18) stated that measurement of learning potential results in a fairer measurement of intelligence compared to standard intelligent quotient static psychometric tests. This is especially so for those who have been underprivileged or come from cultures that have not been taken into consideration in the standard traditional intelligence tests. In this context, Whitely and Dawis (1975) used the concepts "aptitude" and "ability" for learning potential and intelligence, respectively. Intelligence, in their opinion, is reflected in the actual score on an intelligence test, whereas learning potential can only be measured if the environmental conditions have been optimal for the development of intelligence. Intelligence tests are best suited for selection and prediction purposes and only to a lesser extent for the description of individual performance. This is because the test scores represent the product of cognitive activity but do not provide information about underlying cognitive processes (Hamers, Hessels & Van Luit, 1991).

Learning potential measures fall within the framework of the learning/dynamic theories of intelligence or cognitive ability. The distinguishing characteristic of learning potential tests is that respondents learn a new skill or competency while doing the tasks set out in the test. Some individuals become more competent than others and the differences in competency are captured in the test scores (Taylor, 1999). When learning potential tests are presented primarily in non-verbal diagrammatical format (except for the instructions), cultural bias that would be prevalent if candidates were to be required to respond to items in a second or third language, is limited to a degree (Lopes, Roodt, & Mauer, 2001; Taylor, 1999). In validity studies for the use of learning potential measures in the South African mining industry, the criterion measures have always been academic outcomes (Taylor, 1999).

2.4.1 Process of learning

The previous section on learning potential and its theories, as well as dynamic assessment outlined what these theories regard as essential conditions for learning to take place. It also indicated how the environment, the individual and the interaction that occurs determine the quality of what is learnt. This section discusses the various learning theories.

Sternberg (2001, p.197) stated that for years learning was defined as “any relatively permanent change in the behavior, thoughts and feelings of an organism that results from previous experience”. For instance, Pavlov’s classical conditioning and Thorndike’s operant conditioning theories explain how individuals learn through exposure to the environment and the feedback they receive.

Neurobiological theories explain the learning process as the link to neural events in the brain and changes that occur at the molecular and structural level. Social theories explain learning as a function of the social environment where individuals learn through observation or vicariously (Sternberg, 2001, p.199). The underlying mechanisms involved in the learning process link directly to theories of memory. Sternberg (2001, p. 230) defined memory as “the process by which past experience and learning can be used in the present”. At the same time, the process of learning and memory involves numerous aspects including the ability to perceive objects and recognize patterns, the individual’s attentional resources and capacity, the process where new traces are formed and used in memory, problem solving and reasoning (Galotti, 2004). Various theories attempt to explain these aspects. To perceive objects and recognize patterns, individuals may use methods of template matching, featural analysis and prototype matching. The filter theory, the attenuation theory and the late-selection theory are among the theories that explain processes of attention (Mac Donald, 2009). The process required for development of new traces and their use involves aspects such as the coding process, what determines what an individual retains and forgets, and how the individual perceives that information in the future. Lastly, various techniques are employed, including means-ends analysis, reasoning by analogy backtracking, deductive and inductive reasoning, when an individual thinks, solves problems and reasons (Galotti, 2004).

2.5 PSYCHOMOTOR ABILITY

Like cognitive ability, psychomotor ability has been studied for more than a century (Carretta & Ree, 1997). Research findings generally support the validity of psychomotor tests in the prediction of job performance in positions requiring operating or driving skills (Carretta & Ree, 2000; Martinussen, 1996; Schoeman, 1995; Wheeler & Ree, 1997). The findings also seem to indicate that as job complexity decreases, the validity of psychomotor skills increases (Hartigan & Wigdor, 1989; Hunter & Hunter, 1984; Levine, Spector, Menon, Narayanan & Cannon-Bowers, 1996).

Psychomotor tests have traditionally been composed of electromechanical apparatuses (e.g., a rotary pursuit apparatus, finger or stylus mazes, tapping boards, etc.) and associated equipment (e.g., stop clocks, impulse counters, stopwatches, etc.). Psychomotor testing has historically required exorbitant fabrication costs, low examiner:examinee ratios, substantial training of examiners, and frequent recalibrations of equipment

(Melton, 1947). Even though psychomotor abilities appeared to be important determinants of individual differences in skilled performance, it was generally impractical to evaluate or, from an applied perspective, to recommend psychomotor testing as cost effective for selection purposes (Ackerman & Cianciolo, 2000).

The term “psychomotor” denotes a combination of physical and psychological activities (Plug, Meyer, Louw & Gouws, 1989). Measures of psychomotor coordination or hand-eye coordination are commonly included in selection batteries for two apparent reasons, namely (a) they have an obvious relation to the task and (b) the results of validation research support their inclusion in selection batteries (Hilton & Dolgin, 1991).

Psychomotor skills research has a long history in pilot selection (Griffin & Koonce, 1996).Damos (1996) examined the shortcomings and perspectives of pilot selection batteries. Damos (1996) found that when psychomotor tasks were added to a USAF selection battery already including the Air Force Officer Qualifying Test (AFOQT) scores, the predictive validity of the battery increased from 0.168 to 0.207. In their study, Burke, Hobson and Linsky (1997) found that psychomotor tests were predictive of pilot training success and that its validity generalised across samples. They used Validity Generalisation Analysis (VGA) with three samples from different national air forces, with a large sample (N = 1760). Furthermore, Ree and Carretta (1996a) reported that measures of psychomotor abilities were able to increase predictive validity of a battery already measuring *g* in military pilot selection.

2.5.1 Relationship between cognitive ability and psychomotor ability

General cognitive ability and psychomotor ability are frequently regarded as independent (Ree & Carretta, 1994). In a study to investigate the nexus of cognitive and psychomotor tests for personnel selection and assessment, Ree and Carretta (1994) administered a multiple aptitude cognate test battery and a psychomotor test battery to 354 United States Air Force recruits. The average multiple correlation of the cognitive tests and each psychomotor score as a criterion was 0.34, corrected for range restriction (Ree & Carretta, 1994).

Individuals’ psychomotor performance and cognitive abilities vary from person to person and can be affected by certain factors. These abilities can also slow down due to aging. In their study on aging, motivated cognition and the positivity effect in attention and memory, Mather and Carstensen (2005) found that cognitive capacities in older age groups were lower than in younger age groups.

It is generally agreed that cognitive abilities have a hierarchical structure with general cognitive ability, *g*, at the apex, lower-order common factors such as verbal, math and spatial, with test scores at the lowest level (Caretta & Ree, 1996a). The hierarchical model demonstrates that *g* accounts for a major portion, frequently more than half, of the variance of the lower-order common factors and the test scores. Caretta and Ree (1995) found that the hierarchical structure did not differ across gender and racial/ethnic groups.

Like cognitive ability, psychomotor ability has been studied for about a century (Carretta & Ree, 1997). Fleishman and Quaintance (1984) identified eleven conceptually separate domains of psychomotor performance. Historically, psychomotor abilities have been seen as lower order factors not influenced by a higher order factor (Cronbach, 1970; Fleishman, 1964). Ree and Carretta (1994) examined the relationship of a limited battery of cognitive tests and psychomotor tracking tests. They found both lower-order and higher-order cognitive and lower-order and higher-order psychomotor factors. However, their cognitive tests were limited to verbal and mathematical abilities and their psychomotor tests to tracking tasks only (Carretta & Ree, 1997).

Similarly, cognitive tests and psychomotor tests bear little superficial similarity (Carretta & Ree, 1997). Cognitive tests require answering questions on an answer sheet while psychomotor tests are usually computer-administered and use control sticks, the computer pointing device called the mouse, and foot pedals. The dissimilarity between cognitive and psychomotor tests has caused several researchers to consider them unrelated to one another (Carretta & Ree, 1997).

Tun and Luchman (2010) studied the association between computer use and cognition across adulthood. Their findings offer new insight into the association between computer activity and cognition across the lifespan in adults from a large national sample with wide range of age, education, and socioeconomic backgrounds. Tun and Luchman (2010) found that frequent computer use is associated with better overall cognitive performance across adulthood, from younger adults through middle-aged and older adults. Furthermore, they found a positive association between computer use and executive function that was seen even after controlling for basic intellectual ability. Specifically, more frequent computer use was associated with better task-switching performance and this association was strongest in adults with lower general cognitive ability.

Previous theories on individual differences in learning, such as Ackerman’s (1988) and Kyllonen and Christal’s (1989) theory, examined changes in between-subject variability, the simplex structure, and changing ability-performance inter correlations.

2.5.2 Ackerman’s (1988) theory

Ackerman (1988) maintained that one needs to first understand the task characteristics and the nature of the ability determinants of performance over practice. Once this is done, a set of predictor measures can be selected that will make it possible to predict individual differences in performance rather than despairing over the lack of predictability for post-practice performance (Ackerman & Cianciolo, 2000). According to Ackerman (1988), ability-performance relations are sensitive to the consistency and complexity of the target task. For example, tasks with predominantly inconsistent stimulus-to-response mappings are expected to show little change in ability demands over practice. In contrast, many real-world tasks (i.e., those with consistent information-processing constraints that allow for the development of automaticity) are expected to show changes in ability demands in a predictable fashion as the learner develops the appropriate task skills.

Ackerman's (1988) theory of ability determinants of skill acquisition concerns changes in ability-performance relations as a function of three task characteristics: a) consistency of information-processing demands, b) task complexity, and c) degree of task practice. In Ackerman's theory, task complexity and degree of task practice refer to the degree of complicated or involved arrangements or procedures necessary to complete a task and the amount of practice necessary to improve task performance, respectively. Ackerman's theory integrates a hierarchical model of cognitive intellectual abilities (from first stage of skill acquisition to last stage), in the context of predicting individual differences in task performance with several phases of skill acquisition (cognitive phase, associative phase, and autonomous phase). The cognitive phase of skill acquisition is characterized by a high cognitive load on a learner in the context of understanding task instruction, general familiarization with task goals, and formulating strategies for task accomplishment. These inconsistent information-processing tasks do not allow for further skill development. Task performance is related to general intellectual abilities in verbal, figural, and numerical content areas. All novel (first-time) experiences require inconsistent information processing. Complex tasks that continually require the processing of new information to complete remain inconsistent and involve the cognitive phase of skill acquisition (Ackerman, 1988). The associative phase of skill acquisition involves strengthening associations between stimuli and responses, resulting in a performance that is quicker and less error-prone. This phase is associated with demands on perceptual speed abilities (the rate at which a task can be accomplished). The autonomous phase of skill acquisition, associated with demands on psychomotor abilities (muscular movements resulting from mental processes), generally proceeds with little or not attentional effort. Tasks are accomplished quickly and accurately (consistent information processing) (Ackerman, 1992).

To date, research on the prediction of individual differences in skill acquisition has focused on consistent tasks, although many tasks in the work environment include substantial inconsistent information-processing demands (Gray & Deem, 2002). According to Ackerman (cited in Kyllonen, Tirre & Christal, 1991), to examine the cognitive determinants of individual differences in inconsistent skill acquisition, the criterion task must

a) represent complex skill acquisition,
b) represent substantial demands for inconsistent information processing throughout task practice, and
c) have substantial overlap with the type of task encountered in the real world.

According to Ackerman's theory, a primary cognitive ability determinant is responsible for performance in complex, inconsistent information-processing tasks. The ability determinant will be different based on the type of task to be performed (Ackerman, 1988).

2.5.3 Kyllonen and Christal's (1989) four-source framework

Kyllonen and Christal (1989) found that task performance is determined by four sources of individual differences, namely "(1) breadth of declarative knowledge; (2) breadth of procedural skills; (3) capacity of working memory, and (4) speed of processing (encoding information into working memory, retrieving knowledge from long-term memory, and executing a motor response)" (Ackerman & Kyllonen, 1991, p.213).

Kyllonen and Christal's (1989) four-source framework is mainly used for the prediction of lower-level skills, but also for the prediction of skilled performance in a logic-gates task and procedural skill acquisition (Kyllonen & Stephens, 1990; Kyllonen & Woltz, 1989; Woltz, 1988). Support for the theory has come from demonstrations that learning-task performance is substantially related to measures of working-memory capacity and, in some cases, to processing speed even after considerable task practice (Kyllonen, Tirre & Christal, 1991).

2.6 SAFETY BEHAVIOUR

According to the Chamber of Mines, South Africa has a 50% worse record on safety than Canada and Australia. Moreover, it is estimated that roughly 80% of the country's mining accidents are caused by human error (*Mail & Guardian*, 2008).
The Mining Industry Occupational Safety and Health Association (2011) reported that in 2008, 171 mining fatalities occurred in South Africa; in 2009, 168 occurred; in 2010, 128 occurred, and between January and August 2011, 76 fatalities occurred.

The National Institute for Occupational Safety and Health (NIOSH) recognizes the hazards associated with complexity and is funding research to develop a complexity assessment methodology that enables the realization of simpler, safer computer-based systems (Sammarco, 2003).

In the *Mines Health and Safety Act, 29 of 1996*, safety is a crucial consideration in the mining industry. The mining industry, then, should identify potential operators who display the least risk from a safety perspective. Despite its importance, however, validity studies on safety criteria are rare. This may be due to the difficulty of obtaining safety criteria that are reliable (accidents are, generally speaking, relatively infrequent events and near-misses are seldom reliably reported) (Pelser, 2002).

2.6.1 Safety and reliability

Safety and reliability are frequently incorrectly equated in the sense that if a system is reliable, it is safe. Reliability alone is not sufficient for safety (Leveson, 2009). For example, a reliable system may have unsafe functions and conditions, or neglect to provide all safety functions. The result is a reliably unsafe system.

Reason (1990, p.29) described safety as “freedom from those conditions that can cause death, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment”. Reliability is “the probability that a piece of equipment or component of a system will perform its intended function satisfactorily for a prescribed time and under stipulated environmental conditions” (Leveson, 1995, p.172). Thus, a system could be reliable but unsafe, or a system could be safe but unreliable.

2.6.2 Faults, errors and failures

According the International Electro-technical Commission (IEC) (1998), there is confusion concerning faults, errors and failures and the terms are used interchangeably. The IEC (1998) defined a failure as “the termination of the ability of a functional unit to perform a required function”. This definition is based on a performance of a function, so failure is a behaviour occurring at a specific instant in time (IEC, 1998). A fault refers to an abnormal condition. Faults are random (hardware) or systematic (hardware or software). Random faults are typically due to physical wear-out, degradation, or defects. Systematic faults concern the specification, design, and implementation. Software faults are systematic. Faults, both random and systematic, may lead to errors (Storey, 1996). An error is a system state that potentially can lead to a failure. When a fault results in an error, the error is then a manifestation of the fault and the fault becomes apparent. Not all faults lead to errors or failures. Some faults are benign or are tolerated in as far as failure does not occur (Sammarco, 2003). Some faults are dormant such that an error state or failure does not occur because the proper conditions do not exist. For example, a fault could reside in a section of software. If that section of software is not used, then neither an error state nor failure will occur (Beizer, 1990).

There is an urgent need to improve safety performance because industrial accidents result in significant harm to people, the environment and the economy (Bain, 1999). Regarding the limits of safety in respect of organisations, accidents and nuclear weapons, Sagan (1993) states that normal accident theory and high reliability theory are among the theories on the management of hazardous technology. Theory of action describes how defensive behaviour is created and sustained in organisations. Argyris and Schoën (1978) provided guidelines for overcoming defences and improving professional effectiveness and performance. When applied to safety, theory of action explains why individuals and companies who are honestly committed to operating in a safe manner end up producing sub-optimal results and are unable to learn how to improve.

2.6.2.1 *Perrow’s (1984) normal accident theory (NAT)*

Perrow (1984) developed the normal accident theory (NAT) after identifying system complexity as a primary accident cause and system complexity attributes. Perrow (1984) defined a system accident as involving the unintended interaction of multiple failures in a tightly coupled system that allows a cascading of failures. He pointed out that these accident types were built-in or inevitable with complex, high technological systems, and were a normal occurrence because of complexity. According to NAT two important system characteristics, namely tight coupling and interactive complexity, make complex software-driven systems especially prone to system accidents (Perrow, 1994). These interactions can be unexpected, unplanned, incomprehensible, and unperceivable to system designers or system users (Perrow, 1994). Abnormal outcomes are more likely and human interventions are less likely to mitigate the abnormal outcomes (Sagan, 1993).

2.6.2.2 LaPorte's (1994) High Reliability Theory

The high reliability theory of high reliability organisations (La Porte, 1994) is based on the belief that accidents can be prevented through good organisational design and management. In contrast to Normal Accident Theory, which claims that it is impossible to prevent severe accidents in sufficiently complex system, High Reliability Theory has a more optimistic approach and emphasises the good things that can be done instead.

Safety is the primary organisational objective for High Reliability Organisations. Redundancies, simulations, a strict organisational structure, decentralised decision-making, learning from mistakes, mindfulness, good training, and experienced personnel are seen as important requisites for being a highly reliable organisation (Rousseau, 1996).

Research on nuclear power plants, chemical plants and air traffic control systems show that safety is not the primary objective (Sagan, 1994). Rather, it is effectiveness due to production pressures. Reason (1990) found that organisations learn, but they learn the wrong things: they learn to cut corners, that disasters are rare, and that they are not likely to be vulnerable as a consequence of their own risky enterprise.

2.6.2.3 Argyris and Schön's (1974) theory of action

Argyris and Schön (1974) defined a theory of action as a theory of deliberate human behaviour, which is for the agent a theory of control but which, when attributed to the agent, also serves to explain or predict his behaviour. They distinguish between two types of theories of action: espoused theories and theories-in-use. The former is the answer given when individuals are asked to describe how they would behave under certain circumstances. The latter is the theory that actually governs individuals' actions. It is not possible to learn what individuals' theory-in-use is by asking them. The theory-in-use must be constructed by observing behaviour. Consequently, studying how theory of action sheds light on safety required adopting ethnographic research techniques and not solely retrospective methods as in most safety studies. Argyris and Schön (1974; 1978) identified a theory-in-use that is endemic throughout business, government and elsewhere. This pattern is called Model I and results in defensive behaviour that creates inefficiencies and prevents double-loop learning. Well-intentioned individuals are trapped by these individual and organisational defences until they are taught how to overcome them. Model I theory-in-use has four governing values: achieve your intended purpose; maximize winning and minimise losing; suppress negative feelings, and behave according to what you consider to be rational (Argyris, 1993). The key action strategies are to advocate your position; evaluate the thoughts and actions of others (and your own thoughts and actions), and attribute causes for whatever you are trying to understand. These action strategies can also be described as selling, persuading and, when necessary, saving one's own and others' face (Argyris, 1990). Model I behavior is particularly common in situations of perceived threat or embarrassment. Since individuals often perceive safety issues as threatening or embarrassing, Model I behavior and its resulting inefficiencies then commonly occur (Bain, 1996).

2.7 MECHANISED MINING

Mechanisation referred to any machine, process or activity that reduces the human effort required to break or move rock or material in a mine (Robbins, 2000).

The following mechanisation technologies, among others, have been implemented in South African platinum mines with varying degrees of success (Willis, Dixon, Cox & Pooley, 2004):

- Trackless equipment for narrow reefs
- Conveyor belts
- Rock cutting technologies
- Drill rigs and jigs
- Hydropower systems
- Monorail transport systems

Mine mechanisation, especially of underground hard rock mines, provides a large potential for reduced costs and improved profitability (Willis & Ashworth, 2002). For many years, machines were used to continuously excavate soft minerals in underground mines. In some cases, this included the soft, or weak, rocks that surround the valuable mineral being extracted. Coal is probably the most common example. Much of the mine development tunnelling in underground coal mines is done in coal. If that is not practical, such as where tunnels must be driven in the over- or underlying rock, the same type of machine can sometimes be used, especially where the rock is shale or soft sandstone (Robbins, 2000).

In Turkey, soft rock is commonly cut by drag bits, or picks, which penetrate the rock fabric with a highly loaded sharp point and rip through the rock in a shearing mode (Pamukcu, 2007). Coal, salt, potash, and trona are among the minerals that can be effectively cut with picks. Roadheader machines and coal mining production machines produce very large tonnages per hour using drag pick cutting. When the rock gets harder, pick wear and breakage increases, and very quickly down time for pick changing makes the use of continuous mechanical excavation much more expensive than drill and blast mining (Robbins, 2000).

The introduction of extra low profile (XLP) mechanised equipment in platinum mines is aligned with the overall new mining strategy to focus on continuing modernization of mining operations to achieve injury-free sustainable production and cost-effective mining technologies (Harrison, 2008). Extra low profile (XLP) mechanised equipment should be introduced for the following reasons (Harrison, 2008):

- Improved safety by removing the operator from the sharp end of the production face
- Improved productivity by more accurate drilling, higher face advance and square meters per employee (fully mechanised stoping and development)
- Improved profitability compared to conventional mining
- Replace components of conventional stoping, e.g. dozer face cleaning to replace scrapers.

2.8 MECHANISED MINING AND MECHANICAL ABILITY

Industrial development in South Africa was initially slow, but the discovery of diamonds and gold stimulated the economy and subsequent increase in demand for manufactured goods (Botha, 2007). The mining industry, which has for many decades been the mainstay of the South Africa economy, still provides stimulation for increased demand for manufactured goods (Botha, 2007). This, together with a realization that South Africa will in years to come depend more on manufactured goods for export trade, has created tremendous demands for skilled labour, especially in the mechanical and technical field.
Mechanical ability is a composite ability comprising various other sub abilities (Fleishman & Hempel, 1954; Harrel, 1977; McCormick & Tiffin, 1975; Nunnally, 1970). The particular sub abilities included in a test of mechanical ability depend on the purpose for which the test is to be used, but the concept "mechanical ability" can usually be divided into two broad factors, namely the cognitive and the psychomotor or physical aspects (Lawshe & Balma 1966; Nunnally 1970). McCormick and Tiffin (1975) contended that mechanical ability testing is mainly concerned with the measurement of the cognitive aspects, although they accept that the physical aspects are also important for the successful completion of many mechanical tasks.

Research over the years attempted to identify the various factors or sub abilities in the concept "mechanical ability" (McCormick & Tiffin, 1975). Initially emphasis was placed on the psychomotor aspects of mechanical work (Botha, 2007). Tests of mechanical ability were also of an apparatus type (Keane & O'Connol, 1927). Although the psychomotor aspects of mechanical work should not be discounted, the cognitive factors of mechanical ability have increasingly been emphasized (Fleishman & Gaylard, 1975; McCormick & Tiffin, 1975). Technical jobs have become less dependent on manipulative skills and intellectual factors appear to play an increasing role in mechanical job success. Consequently, investigations into mechanical ability, as in the case of the present study, are concerned with the cognitive aspects of mechanical ability.

The following factors are most frequently represented in mechanical ability tests (Botha, 2007):

- Intellectual abilities
- Spatial relations

- Perceptual ability
- Mechanical comprehension
- Motor dexterity
- Mechanical information (knowledge)

In a factor analysis of mechanical ability, Harell (1977) found that perceptual and spatial abilities, and physical manipulation skills are important. Regarding psychological testing, Anastasi (1961) identified perceptual abilities, mechanical reasoning, mechanical information, as well as mechanical comprehension and arithmetic, which is important in trade training.

The socio-economic progress of any country depends on a sufficient supply of labour (Botha, 2007). South Africa has human resource shortages in many job categories and an acute and growing need for qualified workers. Improving overall productivity (not just labour productivity) is probably the most important driver for increased mechanisation. Increased mechanisation does not necessarily lead to lower unit labour costs. Rather, increased skills are required, resulting in higher paid labour, even with fewer workers being required. Fewer underground workers have important benefits such as easier transport logistics and lower fixed labour overheads (Botha, 2007).

One criticism often levelled at any form of mechanisation is the replacement of labour by machines and its resultant social consequences (Robbins, 2000). Mechanisation can, however, be a powerful driver of increased investment in education and training at all levels of the workforce, with concomitant positive socio-economic benefits. An important consideration is that, while the number of people employed on mines may decrease, the numbers employed in secondary industries such as manufacturing and service industries will increase in order to meet the increasingly high technology demands of mining companies (Robbins, 2000). The overall result of increased mechanisation is therefore often increased opportunity within the broader mining industry (Willis & Ashworth, 2002).

2.9 CHAPTER SUMMARY

In this chapter intelligence was described with different theorists. A discussion on dynamic assessment was also presented. Both learning potential and psychomotor ability, the two predictor variables of this study, were discussed in depth.
.Safety behaviour and mechanised mining was explained and the importance of safety behavior in mechanised mining was emphasized.

In chapter 3, an article was presented.

CHAPTER 3: RESEARCH ARTICLE

THE CONCURRENT VALIDITY OF LEARNING POTENTIAL AND PSYCHOMOTOR PERFORMANCE FOR PREDICTING SAFE WORKING BEHAVIOUR OF MACHINE OPERATORS

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ABSTRACT

The principal aim of the study was to examine the concurrent validity of learning potential and psychomotor performance compared to safe working behaviour of machine operators in a platinum mine. The aim of the study was to determine the learning potential and psychomotor ability of mining machine operators as well as compare the following sub-groups (based on the biographical variables): age, years' experience, educational level and gender. The respondents' work safety behaviour was measured and the relationship between the two measures of the independent variables (learning potential and psychomotor ability) and work safety behaviour determined. A sample of 200 employees participated in this study. The learning potential computerized adaptive test (LPCAT) and the Vienna Test Battery (Dover/VTS) tests were administered on the sample group. In this study a statistically significant relationship was found between the VTS and safe working behaviour.

Key words

Learning potential, psychomotor ability, safe working behaviour, intelligence, dynamic assessment, cognitive ability, mechanised mining.

Background and motivation for the research

The researcher selected a quantitative cross-sectional design to test the concurrent validity of learning potential and psychomotor ability by evaluating the relationship between mining machine operators' learning potential and psychomotor ability as well as work safety behaviour. Work safety behaviour was considered indicative of their capability to operate a moving machine. The utilization of measuring instruments capable of measuring their learning potential and psychomotor ability and measuring safety behaviour by means of their safety score cards provided the required measurement data. The study involved a quantitative investigation into the relationship between learning potential and psychomotor ability as independent variables and safety behavior as dependent variable.

De Vos, Delport, Fouche and Strydom (2002, p.79) defined quantitative research as "based on positivism, which takes scientific explanation to be nomothetic. Its main aims are to measure the social world objectively, to test hypotheses and to predict and explain human behaviour. A quantitative study may therefore be defined as an inquiry into social or human problems based on testing a theory composed of variables, measured with numbers and analysed with statistical procedures in order to determine whether the predictive generalization of the theory holds true."

The aim of the study was to determine the learning potential and psychomotor ability of mining machine operators as well as compare the following sub-groups (based on the biographical variables): age, years' experience, educational level and gender. The respondents' work safety behaviour was measured and the relationship between the two measures of the independent variables (learning potential and psychomotor ability) and work safety behaviour determined.

History of psychological tests for measuring intelligence

Psychological tests were first invented for the purpose of measuring intelligence (Nevid, Rathus & Greene, 1997). In the early 19th century there was strong interest in classifying types of mental disabilities, e.g. autism, down syndrome (Stengel, 1959). It was critical to distinguish between mental disabilities and mental illness.

Sir Francis Galton proposed the development of measures of central tendency and variability to summarize data and also developed the concept of correlation (Galton, 1909).

James McKeen Cattell, a student of Galton, was the first person to use the term "mental test". He developed a set of tests that were able to predict a child's scholastic achievement. Cattell's goals were related to his desire to strengthen psychology's scientific credentials (Cattell, 1987).

Karl Pearson, also a student of Galton, developed several techniques still used today in modern statistics, such as the standard deviation and the normal curve. His most well known statistical concept is the product moment correlation coefficient, or Pearson's r (Fancher, 1985).
Alfred Binet was the first person to formulate a test for children with mental challenges (Binet, 1983). He spoke strongly about the nature-nurture controversy, believing that intelligence could be nurtured, and was not simply the product of nature. Binet developed cognitive exercises called "mental orthopedics" to increase the intelligence level of children (Binet, 1983).

David Wechsler, a student of Pearson, developed two widely used intelligence scales: the Wechsler Adult Intelligence Scales (WAIS) and the Wechsler Intelligence Scale for Children (WISC) (Wechsler, 1958). Wechsler defined intelligence as the global capacity to act purposefully, to think rationally and to deal effectively with the environment (Wechsler, 1958).

Anne Anastasi, one of the best known psychologists in the field of testing, reported that psychological tests are tools that can be instruments of good or harm, depending on how they are used. She defines a test as an "objective" and "standarised" measure of a sample of behavior (Anastasi, 1981). A psychological test, as defined by Anastasi and Urbina (1997, p. 4) is essentially "an objective and standardized measure of a sample of behavior".

Dynamic assessment

Dynamic assessment is an interactive approach to conducting assessments within the domains of psychology, speech/language, or education, and that focuses on the ability of the learner to respond to intervention (Haywood & Lidz, 2007).

The underlying assumption of dynamic assessment is that all learners are capable of some degree of learning (change; modifiability) (Burden, 2002). This contrasts with the underlying assumption of standardized psychometric testing that the learning ability of most individuals is inherently stable (Burden, 2002). Research with dynamic assessment has demonstrated that determination of the current levels of independent functioning of learners is far from a perfect predictor of their ability to respond to intervention (Sternberg & Grigorenko, 2002)

For an assessment measure to be considered a dynamic assessment measure Lidz and Elliot (2000, p. 6) outlined a few criteria. The first, and most defining characteristic , is that the assessment measure is interactive in nature where there exists an interaction between the assessor and the assessed. The assessor is not a neutral observer but is actively involved in producing change within the learner (Lidz & Elliot, 2000). This takes into consideration the notion that an individual's abilities are not stable but rather change over time. How much an individual changes and responds to a learning situation is very dependent on the individual, and this is the focus of the assessment procedure. The second defining characteristic of dynamic assessment is that built into the assessment measure is intervention within the procedure. Assessment and intervention can therefore be linked within dynamic assessment. Dynamic assessment is not limited to a specific domain or content nor is it limited to any particular age group (Lidz & Elliot, 2000; Mac Donald, 2009).

Learning Potential

Learning potential is related to that which the individual could be capable of and is very much focused on the possibility of change. Learning potential refers to the individuals overall cognitive capacity and is composed of both present and future projected performance. Learning potential, in effect, refers to intelligence, but intelligence that changes (De Beer, 2006).

Measurement of learning potential is claimed to result in a fairer measurement of cognitive ability compared to standard intelligent quotient psychometric tests. This is especially so for those who have been underprivileged or come from cultures that have not been taken into consideration within the standard traditional intelligence tests (Guthke & Beckmann, 2000, p.18). In this context, Whitely and Dawis (1975) used the concepts aptitude and ability for learning potential and intelligence, respectively. Intelligence, in their opinion, is reflected in the actual score on an intelligence test. Intelligence tests are best suited for selection and prediction purposes and only to a lesser extent for the description of individual performance as intelligence test scores represent the product of cognitive activity but do not provide information about underlying cognitive processes (Hamers, Hessels & Van Luit, 1991).

Learning potential measures fall within the framework of the learning/dynamic theories of intelligence or cognitive ability. The distinguishing characteristic of learning potential tests is that respondents are afforded a learning opportunity (and learn a new skill or competency) while doing the tasks set out in the test. Some individuals become more competent than others and the differences in competency are captured in the test scores (Taylor, 1999). When learning potential tests are presented primarily in non-verbal diagrammatical format (except for the instructions) cultural bias that would be prevalent if candidates were to be required to respond to items in a second or third language, is limited to a degree (Lopes, Mauer & Roodt, 2001; Taylor, 1999). Validity studies have been conducted for the use of learning potential measures in the South African Mining industry, but the criterion measures have always been academic outcomes (Taylor, 1999).

Psychomotor ability

As with cognitive ability, psychomotor ability has been studied for more than a century (Carretta & Ree, 1997). In general, research findings have been supportive of the validity of psychomotor tests in the prediction of job performance in positions requiring operating or driving skills (Carretta & Ree, 2000; Martinussen, 1996, Schoeman, 1995; Wheeler & Ree, 1997). The findings also seem to point to the fact that as job complexity decreases, the validity of psychomotor skills increases (Hartigan & Wigdor, 1989; Hunter & Hunter, 1984; Levine, Spector, Menon, Narayanan & Cannon-Bowers1996).

Psychomotor tests have traditionally been composed of electromechanical apparatuses and associated equipment (e.g., such tests might involve a rotary pursuit apparatus, finger or stylus mazes, tapping boards, etc.; associated equipment includes stop clocks, impulse counters, stopwatches, etc.) (Ackerman & Cianciolo, 2000). Psychomotor testing has historically (Melton, 1947) required exorbitant fabrication costs, low examiner:examinee ratios, substantial training of examiners, and frequent recalibrations of equipment. Even though psychomotor abilities appeared to be important determinants of individual differences in skilled performance, it was generally impractical to either evaluate this claim, or form an applied perspective. It was similarly impractical to recommend psychomotor testing as cost effective for selection purposes (Ackerman & Cianciolo, 2000).

The relationship between cognitive ability and psychomotor ability

A study was conducted to investigate the nexus of cognitive and psychomotor tests as might be used for personnel selection and assessment (Ree & Carretta, 1994). These domains are frequently seen as independent. A multiple aptitude cognate test battery and a psychomotor test battery were administered to 354 United States Air Force recruits. The average multiple correlation of the cognitive tests and each psychomotor score as a criterion was 0.34, corrected for range restriction (Caretta & Ree, 1995)).

The psychomotor performance and cognitive abilities of human beings vary from person to person and can be affected by certain factors. These abilities can also slow down due to aging. It has been reported that cognitive capacities in older age groups are lower as compared to younger age groups (Mather & Carstensen, 2005). Studies carried out to observe the effect of other factors such as occupation and education have shown that no significant relationship exists between these factors and cognitive abilities (Punekar & Kelkar, 2006).

Cognitive tests and psychomotor tests bear little superficial similarity (Carretta & Ree, 1997). Cognitive tests require answering questions on an answer sheet while psychomotor tests are usually computer-administered and use control sticks, the computer pointing device called the mouse, and foot pedals. The dissimilarity between cognitive and psychomotor tests has caused several researchers to consider them as unrelated to one another (Carretta & Ree, 1997).

Safety behavior

The Mining Industry Occupational Safety & Health Association (2011) has noted that in 2008, 171 South African mining fatalities occurred, in 2009, 168 South African mining fatalities occurred, in 2010, 128 South African Mining fatalities occurred and (so far) for January to August 2011, 76, South African Mining fatalities occurred.

Safety is a crucial consideration in the mining industry (Mines Health and Safety Act 29 of 1996), and arguably enjoys even more focus than productivity. It makes sense that the mining industry should be interested in identifying potential operators who display the least risk from a safety perspective. Despite its importance validity studies relating to safety criteria are rare. This may be due to the difficulty of obtaining safety criteria that are reliable (accidents are, generally speaking, relatively infrequent events and near-misses are seldom reliably reported) (Pelser, 2002).

Safety is “freedom from those conditions that can cause death, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment” (Reason, 1990, p. 29)

The need to improve safety performance is readily apparent given that industrial accidents result in significant harm to people, the environment and the economy (Bain, 1999). Two influential schools of thought that deal with the management of hazardous technology are Normal Accident Theory and High Reliability Theory (Sagan, 1993).

***Normal Accident Theory: Charles B Perrow (1925* -)**

Perrow (1984), an organizational theorist, is the originator of the National Accident Theory (NAT). His work began in 1979 when he was advising a presidential commission investigating the accident at Three Mile Island. Basically, Perrow identified system complexity as the primary accident cause and identified system complexity attributes. A system accident, as defined by Perrow (1984), involves the unintended interaction of multiple failures in a tightly coupled system that allows a cascading of failures. He concluded that these accident types were built-in or inevitable with complex, high technological systems. Perrow (1994, p. 212) stated these accidents were a normal occurrence because of complexity; hence, the theory was named Normal Accident Theory. This theory identifies that two important system characteristics - tight coupling and interactive complexity which make complex software driven systems especially prone to system accidents (Perrow, 1994). These interactions can be unexpected, unplanned, incomprehensible, and unperceivable to system designers or system users. Therefore, abnormal outcomes are more likely and human interventions are less likely to mitigate the abnormal outcomes (Sagan, 1993).

High Reliability Theory (Todd LaPorte)

The theory of High Reliability Organisations (La Porte, 1994) is based on the belief that accidents can be prevented through good organisational design and management. In contrast to Normal Accident Theory, which claims that it is impossible to prevent severe accidents in sufficiently complex systems, High Reliability Theory has a more optimistic approach and emphasises the good things that can be done instead.

Safety is the primary organisational objective for High Reliability Organisations (Greenfield, 1998). Redundancies, simulations, a strict organisational structure, decentralised decision-making, learning from mistakes, mindfulness, good training, and experienced personnel are seen as important requisites for being highly reliable organization (Rousseau, 1996).

Numerous studies of nuclear power plants, chemical plants and in air traffic control systems show that safety is not the primary objective (Sagan, 1993). Rather, it is effectiveness despite production pressures. Other studies show that organisations learn, but they learn the wrong things (Reason, 1990); they learn to cut corners, that disasters are rare, and that they are not likely to be vulnerable as a consequence of their own risky enterprise.

Mine Mechanisation

In the context of this research, mechanisation refers to any machine, process or activity that reduces the human effort required to break or move rock or material in a mine (Robbins, 2000).

Mine mechanisation, especially the mechanisation of underground hard rock mines provides a large potential for reduced costs and improved profitability (Willis & Ashworth, 2002). For many years, machines have been used to continuously excavate soft minerals in underground mines. In some cases, this includes the soft, or weak, rocks that surround the valuable mineral being extracted (Ataei, Khalokakaei & Hossieni, 2009). Coal is probably the most common example. Much of the mine development tunneling in underground coal mines is done in coal. If that is not practical, for example where tunnels must be driven in the over or underlying rock, the same type of machine can sometimes be used, especially where the rock is shale or soft sandstone (Robbins, 2000).

Mechanised Ability

Various writers (Fleishman & Hempel, 1954; Harrel 1977; McCormick & Tiffin 1975; Nunnally, 1970) have concluded that mechanical ability is a composite ability comprising various other sub-abilities. The particular sub-abilities included in a test of mechanical ability are dependent on the purpose for which the test is to be used, but most writers (Lawshe & Balma, 1966; Nunnally, 1970) agreed that the concept “mechanical ability” can be divided into two broad factors, namely the cognitive and the psychomotor or physical aspects. McCormick and Tiffin (1975) were of the opinion that mechanical ability testing is mainly concerned with the measurement of the cognitive aspects, although they accept that the physical aspects are also important for the successful completion of many mechanical tasks.

An analysis of the finding of many an investigation into mechanical ability reveals that the following factors are most frequently represented in mechanical ability tests (Botha, 2007):

- Intellectual abilities
- Spatial relations
- Perceptual ability
- Mechanical comprehension
- Motor dexterity

- Mechanical information (Knowledge)

Harell (1977) e.g. found by means of a factor analytic study that perceptual and spatial abilities, and manipulative skills are important. Anastasi (1961) discussed various tests of mechanical ability and the factors that they measure. Among these are perceptual abilities, mechanical reasoning, mechanical information, mechanical comprehension and arithmetic, which is important in trade training.

RESEARCH DESIGN

Research approach

This research was conducted within the field of personnel psychology encompassing the subdisciplines of psychometrics and organizational and personnel psychology. Industrial and Organisational Psychology is an applied field of psychology. It is described by Muchinsky, Kriek and Schreuder (1998) as the field concerned with behavior in the workplace. Different paradigm perspectives are used for the variables of this research. Learning potential is based on humanism (every organism has an inherent growth potential or self-actualising tendency) (Meyer, Moore & Viljoen, 1989) because it is regarded as changeable (De Beer, 2000). Psychomotor ability is based on positivism. Pure positivism assumes that only observable behaviour can be studied (Meyer, Moore & Viljoen, 1989). Safety behavior is also based on positivism. However, Mouton (1997) contended that positivism in the 20th century has relaxed its rigid empiricist criteria. According to him the quantitative methodological approach in twentieth century psychology can be regarded as positivist. Modern positivism differs from pure positivism in that modern positivism accepts that certain theoretical constructs need to be used.

An empirical study was conducted to determine the learning potential and psychomotor ability of mining operators as well as to compare the learning potential and psychomotor ability of the following sub-groups (based on the biographical variables): age, years of experience, educational level and gender. The work safety behavior of the individuals in the sample group was also measured and the relationship between the two measures of the independent variables (learning potential and psychomotor ability) and work safety behavior was determined. The population under consideration was mining operators working for the particular mining group and a convenience sample used in this study consisted of 200 mining operators working at a particular mine. The Learning Potential Computerised Adaptive Test (LPCAT) was used to measure the learning potential of the sample (de Beer, 2000a, 2000b, 2000c). The Vienna Test System (VTS) was used to measure the psychomotor ability of the sample VTS) (Schuhfried, 1996, 2000a, 2000b, 2000c). The biographical variables were received via biographical information cards of the employees, which needed to be completed before taking the test. Work safety behavior of the employees was measured by each line manager in the form of a scorecard.

This research study has been an empirical study aimed at quantitatively testing concurrent validity of learning potential and psychomotor ability. The relationship between mining operators' learning potential and psychomotor ability as well as work safety behavior was evaluated. The latter is considered indicative of their capability to operate a moving machine by the utilization of measuring instruments that are capable of measuring their learning potential and psychomotor ability and measuring safety behavior by means of their safety score cards. The safety score cards has three options to choose from, poor safety behaviour (a person will have a poor safety score, if the person has a bad safety record – accident or incident occurred), average safety behaviour (a person will have a average safety score if no accident occurred, but this person for example did not follow safety procedures), good safety behaviour (this person follows all safety procedure with no accidents or incidents).

De Vos, Delport, Fouche and Strydom (2002, p. 79), defined a quantitative method as "based on positivism, which takes scientific explanation to be nomothetic. Its main aims are to measure the social world objectively, to test hypotheses and to predict and explain human behaviour. A quantitative study may therefore be defined as an inquiry into social or human problems based on testing a theory composed of variables, measured with numbers and analysed with statistical procedures in order to determine whether the predictive generalization of the theory holds true".

A cross-sectional design was used to achieve the research aims. Cross-sectional designs are used to examine groups of subjects in various stages of development simultaneously (Burns & Grove, 1993). Information collected is used to describe the population at that moment. According to Shaughnessy and Zechmeister (1997), this design can also be used to assess interrelationships among variables within a population. According to Shaughnessy and Zechmeister (1997), this design is best suited to address the descriptive and predictive functions associated with the correlation design, whereby relationships between constructs are examined.

Data collection was done by using the above measures to obtain the mentioned test information as well as biographical data (age, years experience, educational level and gender) – the latter obtained from biographical data records. Safety behavior was measured by safety score cards which was completed by the sample group's line managers. The results will be reported in terms of learning potential, psychomotor ability test results and work safety behavior score of the various mining operator employees and the relationship between the variables.

The learning potential computerised adaptive test (LPCAT) and Vienna Test System (VTS) were administered after a letter of consent regarding participation was signed by employees from the mine. The tests were administered in small groups on the mine premises on suitable dates. All line managers completed a safety score card for each mining operator employee. The safety score card was handed in at the safety department.

Research method

The empirical study involved a quantitative investigation into the relationship between learning potential and psychomotor ability as independent variables and safety behavior as dependent variable.

Population and sample

A research population includes all members of the group under study. In this study the population was machine operators working for the mining group, while the convenience sample that was used consisted of 200 machine operators working at a specific mine. Of these, 190 were males, 5 were females and 5 were unknown. Most of the respondents were Black and experienced machine operators. All 200 machine operators from this mine participated in the study and they were assessed over a period of two months. The respondents were obliged to complete the work-related testing to determine on what level they are and what machines they are allowed to operate at the mine. Instructions for both tests were given in English and Sepedi, because most of the respondents were Sepedi speaking.

All 200 operators in the sample group were from the same area in the Limpopo Province. All the demographics (race, age, years education and work experience) are set out in different tables below. In table 1 below one can see that most sample was black. Since the white group was very small, the focus was more on the black group.

Table 1

Participants' race

Race	Frequency	Percent
Black	195	97.5
White	0	0.0
Unknown	5	2.5
Total	200	100.0

Secondly, the gender of the sample were analysed. In table 2 below one can see that 95% of the sample were males and only 2,5% were females, the other 2,5% were unknown.

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Table 2

Participants' gender

Gender	Frequency	Percent
Female	5	2.5
Male	190	95.0
Unknown	5	2.5

Total	200	100.0

It is noticable from the sample that most of the operators were males (table 2).

Thirdly, age of the sample group was analysed. Table 3 shows that the minimum age was 21 and the maximum age was 60, with an average age of 34.57 in the sample.

Table 3

Participants' age

N	Minimum	Maximum	Mean
200	21	60	34.57

Fourthly, the sample group was analysed by means of their years experience in the company. The average years experience was 9.90 years with a minimum of 1 year experience a maximum of 26 years experience. Table 4 shows the years work experiene.

Table 4

Participants' work experience

N	Minimum	Maximum	Mean
200	1	26	9.90

Fifthly, years education starting at grade 1 was anlalysed for the sample. A minimum of 6 years education (grade 6) was reported and a maximum of 13 years (Grade 12 plus one year). An average years of education was 9.99 years. Table 5 shows the years education.

Table 5

Participants' education

N	Minimum	Maximum	Mean
195	6	13	9.99

Respondents had a minimum of 6 years and a maximum of 13 years' education, with an average of 9.99 years. It was noted that with an average of 9.99 years education, it meant that most respondents had at least grade 10, which is equal to NQF level 1 – 3.

Some of the data for some of the respondents were not available. The number of valid cases is reported in table 6. Missing data occurred mostly for the criterion measures, but there appeared to be no logical reason why the missing data would result in a biased sample.

Descriptive statistics for the predictor variables and dependent variables are presented in table 6 and 7. Usually the mean is the best measure for describing a set of data with a single value.

Three categories of variables had to be assessed for the study. These included the moderator variables (age, number of years of education and number of years of operating experience) and the predictor variables as well as dependent variables.

Moderator variables

Biographical data have been described as “permitting the respondent to describe himself in terms of demographic, experiential or attitudinal variables presumed or demonstrated to be related to personality structure, personal adjustment or success in social, educational or occupational pursuits” (Owens, cited in Drakeley, 1989).

Whilst cognitive ability tests are generally accepted to provide the best indication of future performance in terms of predictive validity, biographical data can be equally effective (Hunter & Hunter, 1984).

It is common practice in applied psychological research to investigate the effects of biographical variables such as age, gender and education in terms of possibly moderating the relationship between the predictor and criterion variables (Cascio, 1991). Anastasi (1988) stressed the need to include only those variables for which there is evidence of moderating effects. In this study, age, education and experience were investigated as potential moderators in the predictor-criterion relationships. Studies by Martinussen (1996), Schmidt and Hunter (1998), Schmidt, Hunter, Outerbridge and Goff (1988) and Shinar (1978) hinted that experience may be a moderating variable in a validity study such as this one. Years of operating experience was therefore also included as a potential moderator variable. It was defined as experience in operating any mobile machine such as cars, trucks and forklifts (Bergh, Pelser & Visser, 2005).

Predictor variables

Predictors were selected according to the Society for Industrial Psychology’s (1992) guidelines for the selection of predictors, namely

- Predictors should be reliable and valid.
- Predictors should be chosen on the basis that there is a logical, empirical or theoretical reason for them to be included.

- Predictors should be selected based on scientific knowledge rather than experience.
- Predictors should be as objective as possible.

Two measuring instruments were used to assess the predictor variables. The first was the Learning Potential Computerised Adaptive Test (LPCAT) (De Beer, 2000a, 2000b, 2000c), this test is a cognitive test, used to measure the respondents overall learning potential. Secondly, the Vienna Test System (VTS) (Schuhfried, 1996, 2000a, 2000b, 2000c) were used to assess the psychomotor ability of the respondents. Four subtests of the VTS were used to assess the respondents, namely: Cognitrone, Determination Unit, Two-hand Coordination and Zeit Bewegung Abschatzung (ZBA).

LPCAT (Learning potential computerised adaptive test)

The LPCAT is specifically aimed at measuring learning potential by making use of non-verbal figural items only, focusing on learning potential in the non-verbal environment and using Item Response Theory (IRT) methods to improve the psychometric features of the test (De Beer, 2006). In addition, it is very suitable for screening if used together with other measures (De Beer, 2000). The LPCAT makes use of a dynamic test-train-retest format and is based on Vygotsky's concept and theory of the zone of proximal development referring to the difference performance with and without help. By means of computerised adaptive test techniques (based on IRT), test items are selected according to the appropriate level of difficulty to match the estimated ability level of the specific individual during the process of administering the test (De Beer, 2004).

The LPCAT's internal consistency reliability indices range between 0.925 and 0.987 (De Beer, 2002). The computerised format of the test contributes towards reliability and validity (Murphy, 2002), because of the accuracy in measurement. The use of standardized training and universal figural items contributes to the face validity of the LPCAT. In the standardization of the LPCAT, the correlation between the LPCAT and other cognitive tests was investigated to ensure construct validity. For a group of 92 first-year science and technology students, the LPCAT post-test score had a higher correlation with the General Scholastic Aptitude Test (GSAT) than the pretest score. The overall results showed that the two tests measured similar constructs, indicating construct validity (De Beer, 2000a).

The results from the LPCAT were presented as standard scores making use of T-scores. The norm comparison group is approximately Grade 10, which means that a T-score of fifty would be compared to a Grade 10 level of such reasoning performance. T-scores have a mean of fifty and a standard deviation of ten resulting in a range between twenty and eighty (De Beer, 2000).

Vienna Test System (VTS)

The Vienna Test System (VTS) is a computerised psychological assessment that consists of various personality, intelligence, and special ability assessments (Schuhfried, 1996). The VTS was developed by the

SCHUHFRIED Company in the early 1980s and has years of research backing the test system (Schuhfried, 1996). The company was founded in 1947 in Austria and the VTS is now available in 65 countries, on all 5 continents (Schuhfried, 1996).

The VTS assessment tools selected for operators relate directly to the critical tasks required of operators. These include monotonous concentration, estimation of speed and distances, multi tasking in times of emergencies, two hand co-ordination, etc. To cancel the habitual effect of training and experience that has an effect on operators' performance, the VTS assesses the same underlying abilities required by the operator for safe equipment operating but without these influences.

The four psychomotor tests which were used:

Cognitrone: This subtest of the Vienna Test System assesses candidates ability to concentrate and to adjust their work tempo to different stimuli patterns. The test is based on Reulecke's concentration theory, which postulates that concentration is made up of three variables, namely energy (concentration consumes energy), function (different actions require different levels of concentration) and precision (the quality of task completion). Individuals involved in tasks requiring concentration must continually regulate the energy, function and precision of their actions. This can be exhausting and cannot be maintained on a continuous basis (Reulecke, as cited in Schuhfried, 2000a).

The test has a split-half reliability of 0,95 (Schuhfried, 2000a). Criterion-related validity studies found significant correlations between test results and safety criteria, such as accident frequency and driver errors (Bukasa, Wenninger & Brandstätter as cited in Schuhfried, 2000a; Cale as cited in Schuhfried, 2000a). However, no criterion-related studies are available with the Cognitrone as predictor and operator or driver performance as criterion. A correlation of 0,48 was reported with the Determination unit subtest of the Vienna Test System, discussed in the following sub-section (Wagner as cited in Schuhfried, 2000a). This could be due to both tests tapping similar needs for sustained concentration, efficient information processing and quick reaction time. Negative impacts for age were reported in two studies (Oehlschlagel & Moosbrugger& Wagner as cited in Schuhfried, 2000a).

Determination Unit: The measure used in this research is the "overall results correct" result, which reflects the total number of appropriate timely and delayed responses for the entire test (encompassing the slow, medium ad fast phases of the test). This measure will be referred to in this study as "Determination unit efficiency" (Schuhfried, 2000a).

The Determination Unit demonstrates internal consistency of 0,99 (Schuhfried, 1996). Various criterion related validity studies found significant correlations between test results on the Determination unit and driving performance criteria. Correlations have been reported for the Determination Unit results with driving behavior during a test drive as well as results of a driving test (Klebelsberg & Kallina; Karner & Neuwirth as cited in Schuhfried, 2000a). Encouraging correlations between test results on the Determination unit and driving safety criteria have also been reported in terms of frequency of accidents and driver errors (Cale; Wenninger & Brandstatter as cited in Schuhfried, 2000b).

Two-hand Coordination Speed and Accuracy: The results yielded are “total mean duration” (speed dimension) and “total percentage error duration” (accuracy dimension). These variables are referred to as “Two-hand coordination speed” and “Two-hand coordination accuracy”, respectively in this study.

Internal consistency (Cronbach’s Alpha) of the standardised variables lies between 0,847 and 0,968 (Schuhfried, 2000c). No criterion-related validity studies could be located in the literature review.

Zeit Bewegung Abschatzung (ZBA): For the purpose of this study only linear progressions were included. Wave progressions were omitted, since they relate to operating activities more complex than the operating activities required for the operation of moving machinery (Schuhfried, 2000b).

Internal consistency was reported as 0,92 for the ZBA time estimation measure and 0,69 for the ZBA motion estimation measure (Schuhfried, 2000b). Validity studies on the previous version of this test (the Distance Estimation Test) indicate that drivers who overestimate distance (i.e. who stop too late) are more problematic than drivers who underestimate distance (Schuhfried, 2000b). This relates to the prediction of safety criteria. No validity studies relating the test to operator or driver performance criteria were reported for the previous version of the test. There are no validity studies available on the current version of the test (ie, the ZBA). No studies on the relative effects of age or any other potential moderator variable have been reported.
The results from the VTS was presented as percentiles.

Dependent variables

Human factors is an important field whose reason for existence is the various types of errors that people make in performing their tasks (Sagan, 1993).

The work in a mine is challenging and those working in physical environments (i.e. processing plants and underground) naturally require some degree of physical fitness and strength (Singer, 2002; Wynn, 2001). Furthermore, employees work with explosives, test geological formations, operate load-haul-dump machines, scraper winches, heavy-duty machines and maintain mining machinery in conventional mines. The equipment and techniques used are varied and complex, with many areas requiring significant safety and skills training (Calitz, 2004).

With more than one hundred miners killed every year in the South African mining industry, this industry has proven to have the highest rates of fatal occupational injuries (McGwin, Valent, Taylor, Howard, Davis, Brissie, Rue, 2002).

Safety records of the sample group were used. In normal circumstances the supervisor of the operator will record any unsafe behaviour of the operator. These recordings will go to the safety department where it will be entered onto a spreadsheet. For the purpose of this study, the spreadsheet was used as safety records for the sample group. The data entered onto the spreadsheet are given in the following way:

Green – good behaviour – score 3
Orange – average behaviour – score 2
Red – poor behaviour – score 1

The brief was to determine whether operators, with good learning potential and high psychomotor performance will be more likely to act in a good safety behaviour way. This relationship, will at the same time imply that those with low scores on learning potential and psychomotor ability are more likely to show poor safety behavior.

No attempt was made to compare operators amongst shifts because of the unreliability that could potentially be caused by different supervisors not being familiar with the performance of all the operators.

Procedure

The Learning Potential Computerised Adaptive Test as well as the Vienna test system's four subtests were administered to the sample group over a time period of two months, and the respondents attended the sessions according to a specific roster. Moderator variables were obtained during these sessions. The safety score (dependent variable) for the operators was obtained from the safety department.

Due to various practical considerations, some of the data for a number of members of the sample were not available. The numbers of valid cases are reported in table 6 below .

Results

Descriptive statistics in respect of the predictor variables and dependent variables are presented respectively in table 6 and table 7. Usually the mean is the best measure for describing a set of data with a single value.

The aim of descriptive statistics is only to describe or analyse data, and not to draw conculsions or make inferences about the larger group (Foxcroft & Roodt, 2006; Spiegel, 1988). In table 6, below, the research results are described in terms of mean, minimum and maximum values and standard deviation.

Table 6

Descriptive statistics across the predictor variables

Descriptive statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std deviation**
Cognitrone efficiency - sum correct percentage	198	8	95	47.92	17.903
Determination unit efficiency - Overall correct results	198	8	95	52.19	18.356
2-hand speed - Seconds per run percentage	198	3	92	43.01	20.486
2-hand quality - correct total percentage	198	4	92	42.54	20.070
ZBA time estimation accuracy - deviation in seconds percentage	198	2	95	42.49	20.820
ZBA time estimation accuracy - deviation in pixels percentage	198	5	95	41.43	19.817
Pre test	196	21	60	43.51	7.896
Post Test	196	26	63	43.85	7.758
Valid N (listwise)	194				

From table 6 it is clear that the cognitrone efficiency shows the smallest standard deviation with the ZBA as the larger standard deviation. A minimum on the VTS was below 10 with all subtests in line with one another. Regarding the maximum score, all four subtests were in line with one another, with a maximum score above 90.The mean of the predictor variable scores was also in line with one another, all the scores averaged between 41.43 and 52.19. As previously mentioned that the focus was on the black group, because of the very small white group. Schoeman (1995) stated that race influences the learning potential of employees.

Table 7 presents the safety results in terms of frequency, percent, valid percent and cumulative percent. A 1 represents a poor safety score, 2 represents an average safety score and a 3 represents a good safety score.

Table 7

Safety score (ranked by supervisor: 3=Good; 2=Average; 1=Poor)

		Frequency	Percent	Valid percent	Cumulative percent
Valid	1	13	6.5	6.5	6.5
	2	163	81.5	81.5	88.0
	3	24	12.0	12.0	100.0
	Total	200	100.0	100.0	

The safety score indicated in table 7 is relatively representative of what is expected at the mine. If there were a bigger group with a safety score of 1, more accidents and unsafe work behaviour might occur. Most of the sample group fell into the average group, which is very positive at a mine.

Correlations

The aim of correlation is to describe the strength and direction of the linear relationshop that exists between two measured vairables (Christensen, 1997; Cooper & Schindler, 2001).

The Pearson Moment correlation coefficient (Hays, 1963) was calculated to determine the degree of relationship amongst the predictor and criterion variables. The statistical significance of all the correlations was determined for different levels of significance.

Correlations can vary in magnitude from -1 to 1, with -1 indicating a perfect negative linear relationship, (as one variable inreases, the other decreases) 1 indicating a perfect positive linear relationship (as one variable increases, the other decreases and the inverse) and 0 indicating no linear relation between two variables (Huysamen, 1987). As statistical significance of this value is largely influences by sample size, Jacob Cohen suggested that effect sizes should be interpreted based on the magnitude of the correlations – a correlation of 0.5 is interpreted as large effect size, 0.3 is interpreted as moderate effect size, and 0.1 is interpreted as small effect size (Cohen, 1988). The usual intepretation of this statement is that anything close to or greater than 0.5 is considered large effect size, values close to 0.3 is considered as moderate effect size and values close to 0.1 show small effect, and values smaller than 0.1 are considered of insubstantial effect.

In table 8 below, the results show that there are statistically significant relationships between the predictor variables. At the 1% level of significance (significance < 0.01) it practically shows a medium (0,3 – 0,5) effect size. A positive correlation of medium effect can be seen between the predictive variables. This implies that if a person did well in the learning potential test, then the same person tends to do well in the psychomotor ability test.

Table 8

Correlations between predictor variables

	Correlations	Pre	Post
Cognitrone efficiency - sum correct percentage	Pearson Correlation	.375**	.406**
	Sig. (2-tailed)	.000	.000
	N	194	194
Determination unit efficiency - Overall correct results	Pearson Correlation	.434**	.459**
	Sig. (2-tailed)	.000	.000
	N	194	194
2-hand speed - Seconds per run percentage	Pearson Correlation	.388**	.422**
	Sig. (2-tailed)	.000	.000
	N	194	194
2-hand quality - correct total percentage	Pearson Correlation	.375**	.400**
	Sig. (2-tailed)	.000	.000
	N	194	194
ZBA time estimation accuracy - deviation in seconds percentage	Pearson Correlation	.390**	.439**
	Sig. (2-tailed)	.000	.000
	N	194	194
ZBA time estimation accuracy - deviation in pixels percentage	Pearson Correlation	.414**	.459**
	Sig. (2-tailed)	.000	.000
	N	194	194

**. Correlation is significant at the 0.01 level (2-tailed).

From table 8 it is clear that there is statistical significance between the predictor variables. .

Table 9 depicts the correlations between the predictor variables and the demographic data measured on an interval scale. Statistically significant relationships are also shown. A significant correlation exists if $p<0.05$.

Table 9

Correlations between predictor variables and demographic

Correlations				
		Age	Education	Experience
Cognitrone efficiency - sum correct percentage	Pearson Correlation	.187**	.212**	-.194**
	Sig. (2-tailed)	.000	.003	.006
	N	198	194	198
Determination unit efficiency - Overall correct results	Pearson Correlation	-.269**	.323**	-.274**
	Sig. (2-tailed)	.000	.000	.000
	N	198	194	198

2-hand speed - Seconds per run percentage	Pearson Correlation	-.330**	.376**	-.301**
	Sig. (2-tailed)	.000	.000	.000
	N	198	194	198
2-hand quality - correct total percentage	Pearson Correlation	-.292**	.351**	-.303**
	Sig. (2-tailed)	.000	.000	.000
	N	198	194	198
ZBA time estimation accuracy - deviation in seconds percentage	Pearson Correlation	-.335**	.378**	-.349**
	Sig. (2-tailed)	.000	.000	.000
	N	198	194	198
ZBA time estimation accuracy - deviation in pixels percentage	Pearson Correlation	-.345**	.404**	-.344**
	Sig. (2-tailed)	.000	.000	.000
	N	198	194	198
Pre-test	Pearson Correlation	-.235**	.220**	-.225**
	Sig. (2-tailed)	.000	.000	.000
	N	196	195	196
Post-test	Pearson Correlation	-.312**	.287**	-.282**
	Sig. (2-tailed)	.000	.000	.000
	N	196	195	196

**. Correlation is significant at the 0.01 level (2-tailed).

From table 9 it is clear that age had a statistically significant negative relationship with the predictor variables, except cognitrone, which had a statistically significant positive relationship. This meant that as the age of the respondents increased, their test scores were likely to decrease.

The same effect could almost be seen with work experience. Work experience also showed a statistically significant negative relationship with the predictor variables. With an employee who gains more work experience, the employee obviously gets older. This means that as the work experience of the employees increased, it seemed likely that their tests scores would decrease.

Table 9 shows a significant positive relationship between years of education and the predictor variables. This meant that the more years' education, the more the respondents' test scores were likely to increase.

In the light of the main aims of the study, the question arose whether there were any statistically significant differences between the LPCAT, the VTS and the safety score of the respondents. Table 10 presents the group statistics.

Table 10

Group statistics – predictor variables and dependent variable

Safety score (ranked by supervisor: 3=good; 2=average; 1=poor)								
Safety Score	**1**		**2**		**3**		**Total**	
	Mean	**Std dev**	**Mean**	**Std dev**	**Mean**	**Std dev**	**Mean**	**Std dev**
Cognitrone efficiency - sum correct percentage	**30.17**	13.803	**48.70**	16.226	**52.13**	24.101	47.96	17.743
Determination unit Efficiency - Overall correct results	**32.50**	16.178	**53.23**	17.397	**56.35**	19.080	52.31	18.199
2 Hand Speed - Seconds per run percentage	**17.75**	12.001	**43.65**	18.995	**50.48**	23.463	42.86	20.322
2 Hand Quality - correct total percentage	**24.00**	17.315	**42.80**	19.353	**49.70**	21.036	42.45	20.041
ZBA time estimation accuracy - deviation in seconds percentage	**22.08**	18.362	**42.84**	19.544	**50.87**	23.984	42.51	20.781
ZBA time estimation accuracy - deviation in pixels percentage	**21.33**	19.910	**41.74**	18.408	**48.96**	22.260	41.33	19.708
Pre test (LPCAT)	**38.42**	8.618	**43.84**	7.379	**45.22**	8.949	43.66	7.744
Post Test (LPCAT)	**38.25**	7.829	**44.21**	7.218	**45.57**	9.248	44.01	7.634

From table 10 it is clear that the poor safety performers were also the ones who scored the lowest on both the VTS and the learning potential computerised test. Moreover, the average safety performers all had average scores while the good safety performers all obtained higher scores than the other two groups on both VTS and the LPCAT.

Analysis of variance (ANOVA)

The purpose of using ANOVA is to deduce to what extent the differences between two (or more) groups occur by chance, which is done by comparing the groups' variances with each other (Christensen, 1997; Foxcroft & Roodt, 2006; Kerlinger & Lee, 2000; Spiegel, 1988). Both parametric and non-parametric ANOVA were done to compare the mean scores reflected above, because of the big size difference in the groups based on safety performance scores.

Table 11

ANOVA results of predictor variables

ANOVA			
		F	Sig.
Cognitrone efficiency - sum correct percentage	Between groups	9.285	.000
	Within groups		
	Total		
Determination unit efficiency - Overall correct results	Between groups	10.876	.000
	Within groups		
	Total		
2-hand speed - Seconds per run percentage	Between groups	13.561	.000
	Within groups		
	Total		
2-hand quality - correct total percentage	Between groups	8.353	.000
	Within groups		
	Total		
ZBA time estimation accuracy - deviation in seconds percentage	Between groups	10.121	.000
	Within groups		
	Total		
ZBA time estimation accuracy - deviation in pixels percentage	Between groups	10.450	.000
	Within groups		
	Total		
Pre-test (LPCAT)	Between groups	3.123	.046
	Within groups		
	Total		
Post-test (LPCAT)	Between groups	3.835	.023
	Within groups		
	Total		

Table 11 indicates that the resulting F-values for both the pre- and post-test scores were statistically significant at a $p<0.05$ level. This was an indication that the mean differences between the predictor variables did not occur by chance and can therefore be used to predict future relationships.

Furthermore, the resulting F-values for the cognitrone efficiency, determination unit efficiency, 2-hand speed and quality as well as the ZBA time estimation accuracy were statistically significant at a $p<0.01$ level, therefore these differences could not be attributed to chance.

Table 12

Parametric ANOVA

Test of homogeneity of variances				
	Levene Statistic	**df1**	**df2**	**Sig.**
Cognitrone efficiency - sum correct percentage	5.716	2	195	.004
Determination unit efficiency - Overall correct results	.170	2	195	.844
2-hand speed - Seconds per run percentage	4.203	2	195	.016
2-hand quality - correct total percentage	.555	2	195	.575
ZBA time estimation accuracy - deviation in seconds percentage	1.181	2	195	.309
ZBA time estimation accuracy - deviation in pixels percentage	.413	2	195	.663
Pre-test	.951	2	193	.388
Post-test	.799	2	193	.451

One of the assumptions of the one-way ANOVA is that the variances of the groups compared are similar. Table 12 shows that the significance value is greater than 0.05 ($p>0.05$) for all the predictor variables except the cognitrone efficiency and 2-hand speed; in other words, the assumption of homogeneity of variance is met for all predictor variables except for cognitrone efficiency and 2-hand speed.

Since table 12 revealed that variances for all variables were not similar, the Robust test of equality was done (see table 13). The Robust test of equality was applicable to use because the data consisted of independent observation clusters where the measurements in each cluster may be dependent (Iachine, Petersen & Kyvik, 2004).

Table 13

Robust test of equality of means					
		Statistic[a]	df1	df2	Sig.
Cognitrone efficiency - sum correct percentage	Welch	11.879	2	24.698	.000
	Brown-Forsythe	7.476	2	39.607	.002
Determination Unit Efficiency - Overall correct results	Welch	11.192	2	24.929	.000
	Brown-Forsythe	10.578	2	39.473	.000
2-hand speed - Seconds per run percentage	Welch	30.125	2	28.020	.000
	Brown-Forsythe	15.359	2	40.527	.000
2-hand quality - correct total percentage	Welch	9.910	2	25.500	.001
	Brown-Forsythe	8.808	2	42.100	.001
ZBA time estimation accuracy - deviation in seconds percentage	Welch	10.638	2	24.818	.000
	Brown-Forsythe	9.252	2	41.086	.000
ZBA time estimation accuracy - deviation in pixels percentage	Welch	9.119	2	24.310	.001
	Brown-Forsythe	8.891	2	38.506	.001
Pre-test	Welch	2.464	2	22.224	.108
	Brown-Forsythe	2.529	2	33.900	.095
Post-test	Welch	3.403	2	22.319	.051
	Brown-Forsythe	3.142	2	36.361	.055

a. Asymptotically F distributed.

The robust test was done where a significance difference ($p<0.05$) between the variances was seen. Table 13 reveals that there was a significant difference on all the tests between the safety score except for the pre- and post-test of the LPCAT.

Non-parametric ANOVA

Non-parametric ANOVA was used because of the small difference between possible safety score (1, 2 or 3) in the safety behaviour group 1 and 3 and to test the differences in these groups. The non-parametric comparison revealed the same results as above (see table 14).

In testing the null hypothesis, two types of errors can be made: rejecting the null hypothesis when it should be accepted (type-1 error) and accepting the null hypothesis when it should be rejected (type-2 error). According to Spiegel (1988), the only way to reduce both types of error is to increase the sample size.

Table 14

Non-parametric ANOVA

Hypothesis test summary

	Null hypothesis	Test	Sig.	Decision
1	The distribution of cognitrone efficiency – sum correct percentage is the same across categories of safety score ranked by supervisor 3=good; 2=average; 1=poor.	Independent samples Kruskal-Wallis test	.001	Reject the null hypothesis
2	The distribution of determination unit efficiency – sum correct percentage is the same across categories of safety score (ranked by supervisor 3=good; 2=average; 1=poor).	Independent samples Kruskal-Wallis test	.000	Reject the null hypothesis
3	The distribution of 2-hand speed seconds per run percentage is the same across categories of safety score (ranked by supervisor 3=good; 2=average; 1=poor).	Independent samples Kruskal-Wallis Test	.000	Reject the null hypothesis
4	The distribution of 2-hand quality correct total percentage is the same across categories of safety score (ranked by supervisor 3=good; 2=average; 1=poor).	Independent samples Kruskal-Wallis test	.001	Reject the null hypothesis
5	The distribution of ZBA time estimation accuracy – deviation in second percentage is the same across categories of safety score (ranked by supervisor 3=good; 2=average; 1=poor).	Independent samples Kruskal-Wallis test	.000	Reject the null hypothesis
6	The distribution of ZBA time estimation accuracy – deviation in pixel percentage is the same across categories of safety score (ranked by supervisor 3=good; 2=average; 1=poor).	Independent samples Kruskal-Wallis test	.000	Reject the null hypothesis
7	The distribution of the pre-test is the same across categories of safety score (ranked by supervisor 3=good; 2=average; 1=poor).	Independent samples Kruskal-Wallis test	.106	Retain the null hypothesis
8	The distribution of the post-test is the same across categories of safety score (ranked by supervisor 3=good; 2=average; 1=poor).	Independent samples Kruskal-Wallis test	.050	Retain the null hypothesis

Asymptotic significances are displayed. The significance level is .05.

Table 15 illustrates the pair wise comparison of predictor variables and dependent variables.

Table 15

Pair wise comparison of predictor variables and dependent variable

Sample	Test stats	Std error	Std test stats	Sig.	Adj sig.
1-2	-62.161	16.511	-3.765	**.000**	**.001**
1-3	-66.264	19.721	-3.360	**.001**	**.002**
2-3	-4.104	12.530	-.327	.743	1.000

Each row tests the null hypothesis that the sample 1 and sample 2 distribution are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05.

The post hoc test pairwise comparison of the safety groups revealed throughout that there were significant differences between groups 1 and 2 as well as between groups 1 and 3, but not between groups 2 and 3.
In testing a hypothesis, the maximum probability with which the researcher is prepared to risk a type-1 error is referred to as the level of significance (Spiegel, 1988).

Discriminant analysis

Discriminant analysis is used to determine which continuous variables discriminate between two or more naturally occurring groups (Poulsen & French, 2008). A discriminant analysis was carried out to determine which combination of independent variables could be used to classify the respondents' safety scores into groups who obtained poor versus average versus high safety scores. The resulting discriminant function separates the members of the groups maximally. The assumption of discriminant analysis is that the independent variables are continuous but that the dependent variable is categorical (Kerlinger & Lee, 2000).

Table 16 illustrates the classification table obtained form the discriminant analysis combination of a good, average, and poor safety score.

Table 16

Discriminant analysis – Classification results of the safety score

Classification results[a]

		Safety score - ranked by supervisor 3=good; 2=average; 1=poor	Predicted group membership			
			1	**2**	**3**	**Total**
Original	Count	1	1	11	0	12
		2	2	157	0	159
		3	1	22	0	23
	%	1	8.3	**91.7**	.0	100.0
		2	1.3	**98.7**	.0	100.0
		3	4.3	**95.7**	.0	100.0

a. 81.4% of original grouped cases correctly classified.

From table 16 it is evident that 81.4% of the total group were correctly classified. Furthermore, 98.7% of the average performers were correctly classified and none of the high performers was correctly classified. It would appear that the model works better to classify average safety performance. The relative size of the subgroups is related to this finding. A common technique used to test the classification results of a discriminant analysis is to compare it with a random distribution where every case is simply classified as belonging to the largest group; in this case, the average group. Using this method, 97.14% of cases would be correctly classified, as opposed to the 81.4% of cases correctly classified by the model. It would appear that the model does not add any predictive value.

DISCUSSION

The aim of the study was to validate learning potential and psychomotor performance for identifying safe working behaviour of machine operators in a platinum mine using safety behaviour as criterion measure. The results indicate that the test battery is indeed valid for predicting which candidates would be the higher scorers of safety behaviour and who would be lower scorers of safety behaviour after completing the LPCAT and the psychomotor ability test. Moderator variables showed an overall mean of 34.57 for the respondents' age; 9.99 overall mean for years' education, and 9.90 overall mean for work experience.

The data were analysed using correlations (to ascertain the direction and strength of the relationship between the variables) and regression (to explore the predictability of the independent variable).

Descriptive statistics show that most of the respondents scored average on the LPCAT, psychomotor ability and safety behaviour. They had an average mean of 41.43 to 52.19 across the LPCAT, psychomotor ability and safety behaviour. The average scores showed a good distribution in terms of safety behaviour for the respondents, which is a very good indicator for the safety behaviour at the mine.

Many positive correlations of medium effect were found between the predictor variables (LPCAT and psychomotor ability) and moderator variables (age, educational level and work experience).
A statistically significant negative ($p<0.05$) relationship exists between the predictor variables and age, which means that as the age of the respondents increased, it seemed likely that their test scores would decrease. Work experience showed a statistically significant negative ($p<0.05$) relationship with the predictor variables. As individuals gain more work experience, they get older. This means that as the respondents' work experience increased their tests scores seemed likely to decrease. A significant positive relationship exists between the predictor variables and years of education, which means that with increased education, it then seemed likely that their test scores would also increase.

The respondents' safety behaviour scores revealed that most of them scored average, and only a small group scored poor and good, respectively. This is a positive aspect for the mine, because if more of the respondents had a poor score then more accidents were likely to occur.

Because of the big difference in group size, a parametric and non-parametric ANOVA were done. The parametric ANOVA showed that all tests showed a significant difference ($p<0.05$) except for the LPCAT which did not show a significant difference. Pairwise comparisons were done and indicated clearly that a significant difference exists between safety group 1 and 2 and safety group 1 and 3. No significant differences were reported between safety group 2 and 3.

The study found that of the two predictor variables, the VTS statistically significantly predicted safe working behaviour.

LIMITATIONS AND RECOMMENDATIONS

When further studies are planned, the results of the present study may be used to plan which additional safety behaviour results must be taken into consideration to obtain a broader safety behaviour profile of an employee.

An important limitation of the current study was the attenuation of item statistics and test reliability because of the homogeneity of the sample group in their levels of safety performance.
Group homogeneity can result in items with ceiling effects or with highly skewed score distributions. These items would be unable to discriminate between groups as effectively as other items could (Scott, Fayers, Aaronson, Bottomley, De Graeff, Groenvold, Gundy, Koller, Petersen, & Sprangers, 2010).

The simultaneous assessment of a large number of employees at the same time requires good facilities and and a number of test administrators. It would preferable be to test smaller groups to ensure that all the employees understand the test instructions for each test.

During the initial testing phase, the four sub-tests of the VTS (COG, DT, ZBA, 2HAND) and the LPCAT were administered with short breaks between each test. It would preferable be to spread this testing phase over two sessions to prevent the sample from becoming bored and tired.

A very important limitation of this study was the big differences in the size of the sub-groups based on the safety performance which made the comparison between the safety score and the predictor variables difficult. Overall, one can conclude that the study would have benefited from including a sample group that was more heterogeneous in safety performance.

The predictive bias of the test should be explored. Biographical questions that elicit responses in home languages and mother tongues might be included because many people want to claim English as their home language when it is not, or they want to claim that they do have a higher education than what they actually have.

It is recommended that a broader safety behaviour profile must be obtained of each employee and not only a single safety score consisting of poor, average and good. This will enhance the quality of the criterion.

Further research into a reliable safety instrument can be utilized to measure and obtain a reliable safety score which can then be compared to learning potential and psychomotor ability.

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CHAPTER 4
FINDINGS, LIMITATIONS AND RECOMMENDATIONS

4.1 INTRODUCTION

In this chapter the study is concluded, the findings and limitations are discussed and recommendations are made.

The aim of the study was to determine whether learning potential and psychomotor performance can predict safe working behaviour of machine operators in a platinum mine. Accordingly, the study wished to determine the learning potential and psychomotor ability of mining machine operators as well as compare the following sub-groups (based on the biographical variables): age, years' experience, educational level and gender. The respondents' work safety behaviour was measured and the relationship between the two measures of the independent variables (learning potential and psychomotor ability) and work safety behaviour determined.

4.2 HYPOTHESES

In order to achieve the aim, the researcher formulated the following hypotheses:

1. Learning potential and psychomotor results are statistically significant (valid) predictors of safe working behaviour.
2. Learning potential is a statistically significant (valid) predictor of safety behaviour of operators in a mechanised platinum mine.
3. Psychomotor ability is a statistically significant (valid) predictor of safety behaviour of operators in a mechanised platinum mine.
4. There is a statistically significant correlation between learning potential and psychomotor ability scores.

4.3 FINDINGS ON HYPOTHESES 1 AND 4

Hypotheses 1 and 4 state that learning potential and psychomotor results are statistically significant (valid) predictors of safe working behaviour and that there is a statistically significant correlation between learning potential and psychomotor ability scores. The correlations between the predictor variables; correlations between predictor variables and demographics; the descriptive statistics across the predictor variables, and ANOVA results of predictor variables are relevant to these hypotheses.

4.3.1 Correlations between the predictor variables

There was a significant and strong positive correlation (r = 0.375 – 0.459) between the VTS and the LPCAT (pre-test and post-test). This may, to a certain degree, be indicative of the reliability and validity of these predictor variables. A positive correlation of medium effect was found between the predictive variables. This implies that people who do well in the learning potential test, tend to do well in the psychomotor ability test.

4.3.2 Correlations between predictor variables and demographics

There was a statistically significant negative relationship between age and years' experience and the predictor variables. This means that as the respondents' age increased, their test scores decreased and if their work experience increased, their test scores decreased. A significant positive relationship exists between years of education and the predictor variables. This means that the more years' education the respondents had, the more their tests scores increased.

4.3.3 Descriptive statistics across the predictor variables

The aim of descriptive statistics is to describe or analyse data, and not to draw conclusions or make inferences about the larger group (Foxcroft & Roodt, 2006; Spiegel, 1988). The cognitrone efficiency showed the smallest standard deviation with the 2-hand as the larger standard deviation (see chapter 3, table 6). The results showed a good distribution of scores. A minimum on the VTS was all below 10 with all subtests in line with one another. The same was noticed with the maximum score, all four subtests were in line with one another, with a maximum score above 90. The mean of the predictor variable scores was also in line with one another; all the scores averaged between 41.43 and 52.19.

4.3.4 ANOVA results of predictor variables

The F-values for both the pre- and post-test scores for groups compared based on safety performance were statistically significant at a $p<0.05$ level. This was an indication that the mean differences between the predictor variables did not occur by chance and could therefore be used to predict future relationships. The F-values for the cognitrone efficiency, determination unit efficiency, 2-hand speed and quality, as well as the ZBA time estimation accuracy were statistically significant at a $p<0.01$ level. These differences could therefore not be attributed to chance.

4.4 FINDINGS ON HYPOTHESES 2 AND 3

Hypotheses 2 and 3 state that learning potential and psychomotor ability are statistically significant (valid) predictors of safety behaviour of operators in a mechanised platinum mine. The following aspects are relevant to these hypotheses: group statistics – predictive variables and dependent variable; non-parametric ANOVA – hypothesis test summary and pairwise comparison of the predictor variables and dependent variable

4.4.1 Group statistics – predictive variables and dependent variable

From table 3 in chapter 3 it is clear that the poor safety performers are also those who scored the lowest on both the vienna test battery and the learning potential computerised adaptive test. It can also be seen that the average safety performers, all had average scores on both the VTS and theLPCAT. The trend continues with the good safety performers, all the good safety performers scored well on both the vienna test battery and the learning potential computerised adaptive test.

4.4.2 Non-parametric ANOVA – hypothesis test summary

Non-parametric ANOVA was used due to the small difference between possible safety score (1, 2 or 3) in the safety behaviour group 1 and 3, and to test the differences in these groups. The non-parametric comparison (in table 14, chapter 3) showed the same results as above.

In testing the null hypothesis, two types of errors can be made: rejecting the null hypothesis when it should be accepted (type-1 error) and accepting the null hypothesis when it should be rejected (type-2 error). According to Spiegel (1988), the only way to reduce both types of error is to increase the sample size.

4.4.3 Pairwise comparison of the predictor and dependent variables

The post hoc test pairwise comparison of the safety groups showed significant differences between groups 1 and 2 as well as between 1 and 3 throughout, but not between group 2 and 3. In testing a hypothesis, the maximum probability with which the researcher is prepared to risk a type-1 error is referred to as the level of significance (Spiegel, 1988).

4.5 FINDINGS ON HYPOTHESIS 1

Hypothesis 1 states that learning potential and psychomotor results are statistically significant (valid) predictors of safe working behaviour. The following aspects are relevant to this hypothesis: test of homogeneity of variances and the Robust test of equality of means.

4.5.1 Test of homogeneity of variances

One of the assumptions of the one-way ANOVA is that the variances of the groups compared are similar. A significance value which are greater than 0.05 ($p>0.05$) for all the predictor variables except the cognitrone efficiency and 2 Hand Speed were found. In other words the assumption of homogeneity of variance is met for all predictor variables except for cognitrone efficiency and 2Hand speed. Because there were no similar variances for all variables, the Robust test of equality was done.

4.5.2 Robust tests of equality of means

The robust test was done where a significant difference ($p<0.05$) between the variances was found. A significant difference was seen on all the tests between the safety score except for the pre- and post-test of the LPCAT.

4.6 LITERATURE REVIEW

The literature review examined definitions of learning potential and how it is measured. Dynamic assessment and what it brings about was explained. Haywood (1997, p.16) identifies three major groups of dynamic assessment approaches: “restructuring the test situation”, “learning within the test”, and “metacognitive intervention, teaching generalisable cognitive operations”. Vygotsky’s socio-cultural theory and his zone of proximal development (ZPD) were explained. The LPCAT, used in this study, follows the dynamic assessment philosophy of test-train-retest.

Regarding psychomotor ability and how it is measured, the researcher found limited literature available on the topic. One of the pre-requisites for an operator is passing the VTS assessment before being allowed to operate any moving machine. Measures of psychomotor coordination or hand-eye coordination as it is sometimes called are commonly included in selection batteriesbecause they have an obvious relation to the task and the results of validation research support their inclusion in selection batteries (Hilton & Dolgin, 1991). This study found that the VTS is a good selection method used in selecting operators.

In regard to the theoretical relationship between learning potential and psychomotor with specific reference to the mining environment, the literature revealed that the factors influencing either learning potential or psychomotor ability, or in some instances both, vary from person to person (see chapter 2). Both the LPCAT and VTS tests were computer administered. Cognitive tests require answering questions on an answer sheet while psychomotor tests are usually computer-administered and use control sticks, the computer mouse, and foot pedals. The literature review indicated that many researchers consider cognitive and psychomotor tests unrelated to one another because of their dissimilarity.

In respect of what is meant by safety behaviour and how it is measured, the literature reviewed emphasised the importance of safety. It can be argued that the VTS subtests relate better conceptually to safety than to productivity measures:

- The Cognitrone yields data in terms of candidates' ability to concentrate and to adjust their work tempo to different stimuli patterns. Hence, all the VTS subtests have a strong conceptual link to safety.
- The determination unit specifically focuses on operators' capacity to make appropriate and fast responses in rapidly changing environments that may involve stress. The test starts off slowly, gains speed to a very fast response requirement (approximating high stress situations like accident or near-accident situations) and then slows down marginally (approximating the period just after the accident/near-accident).
- The two-hand coordination subtest focuses specifically on operators' hand-eye and hand-hand coordination, which is conceptually related to safety in terms of small movements that need to be made during the spotting in process in tight loading conditions.
- The distance estimation time and motion measures, for example, attempt to identify candidates who are least likely to underestimate distance and hence stop too late or cut in front of moving machinery when it is not safe to do so.

Argyris and Schön (1978) provided specific guidance for overcoming defences and improving performance. When applied to safety, theory of action explains why individuals and companies who are honestly committed to operating in a safe manner nevertheless produce sub-optimal results and are unable to learn how to improve.

4.7 LIMITATIONS

The study was restricted to one operation in the research organisation, which is only one of the many business units of a large mining house. In addition, the population was limited to 200 respondents. The findings of this study can, therefore, not be generalised to all mines and mining companies in the country.

The language of the test administration could have been a restricting factor. All testing took place in English (which is the official language) placing most of the respondents at a disadvantage, because they were Sepedi speaking. Although no comprehension is involved in the tests, the test administrator gave the instructions to the respondents in English. While the findings of the study were limited by the dependent variable utilized, a definite relationship was identified between learning potential and psychomotor ability.

The attenuation of item statistics and test reliability because of the homogeneity of the population in their levels of safety performance could result in items with ceiling effects or with highly skewed score distributions.

These items would be unable to discriminate between groups as effectively as other items could (Scott, et al, 2010).

During the initial testing phase, the four sub-tests of the VTS (COG, DT, ZBA, 2-HAND) and the LPCAT were administered with short breaks between each test. It would preferable be to spread the testing phase over two sessions to prevent the respondents becoming bored and tired.

A very important limitation of this study was the big differences in the size of the sub-groups based on the safety performance, which made the comparison between the safety score and the predictor variables difficult. The study would have benefited from a group of respondents who were more heterogeneous in safety performance. The fact that a single score was used to reflect safety performance is a limitation that should be addressed in future research.

Rural communities place restrictions on measurements that are influenced by educational level, and the respondents all came from a rural community.

Limited research is available on mechanised ability, and this is an important factor for the current trend in mining, nationally and internationally.

4.8 RECOMMENDATIONS

Based on the findings the researcher makes the following recommendations for practice and further research.

4.8.1 Practice

In an effort to limit the effects of an average safety behaviour score, whether in a concurrent or predictive design, it is recommended that all employees be informed that there will be systematic monitoring of each individual's safe working behaviour over a twelve-month period, with quarterly intervals. This should provide a robust measure of the criterion variable of safety behaviour.
It is recommended that a broader safety behaviour profile should be obtained of each employee and not only a single safety score consisting of a poor, average and good. This will enhance the quality of the criterion measure.
Focusing on the safety criterion, the mining industry should identify potential operators, who display the least risk from a safety perspective.
There is a need for more literature on mechanised ability.

4.8.2 Further research

Further research should be conducted on the following topics:

- Additional safety behaviour results that should be taken into consideration to obtain a broader safety behaviour profile of employees
- Development of a reliable safety instrument to measure and obtain a reliable safety score which can then be compared to learning potential and psychomotor ability
- Dynamic assessment and measurement of safety behaviour in the mining industry
- The reliability and validity of the dependent variable
- The development of a better, broader safety score card to ensure more detailed, quantifiable, reliable and valid rankings from the line managers per operator.

4.9 CHAPTER SUMMARY

This chapter briefly discussed the findings and limitations of the study and made recommendations for practice and further research.

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