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THE CONCURRENT VALIDITY OF LEARNING POTENTIAL AND PSYCHOMOTOR ABILITY MEASURES FOR THE SELECTION OF HAUL TRUCK OPERATORS IN AN OPEN-PIT MINE

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ABSTRACT

The purpose of the study was to evaluate the concurrent validity of learning potential and psychomotor ability measures for the prediction of haul truck operator performance in an open-pit mine. Additional goals were to determine the nature of the relationship between learning potential and psychomotor abilities and to assess the relative contributions of these variables as predictors. The predictors were the TRAM 1 Learning Potential test and Vienna Test System subtests that were administered to 128 experienced haul truck operators. The job performance criteria used were spotting in time, corrected tons hauled and supervisor ranking. The concurrent validity of the learning potential and psychomotor ability measures was partially supported. An exploratory factor analysis provided relatively convincing evidence for a general cognitive ability factor (g) underlying performance on the learning potential and several psychomotor measures. The existence of a general psychomotor factor was not substantiated in the current study. Suggestions were made for improving design and criterion shortcomings.

OPSOMMING

Die doel van die ondersoek was om die saamvallende geldigheid van leerpotensiaal en psigomotoriese metings vir die voorspelling van die werkprestasie van sleepvragwabestuurders in 'n oopgroefmyn te beoordeel. Addisionele doelwitte was om die aard van die verwantskap tussen leerpotensiaal en psigomotoriese vermoëns te gepaal en om die relatiewe bydraes van hierdie veranderlikes as voorspellers te bepaal. Die voorspellers was die TRAM 1 Leerpotensiaaltoets en die Vienna Test System subtoetse wat toegepas is op 128 ervare sleepvragwabestuurders. Die werkprestasiekriteria was inteikentyd, gekorrigeerde tonmaat gesleep en toesighouerbeoordeling. Die saamvallende geldigheid van die leerpotensiaal en psigomotoriese metings is gedeeltelik ondersteun. 'n Ondersoekende faktorontleding het die bestaan van 'n algemene kognitiewe vermoëfaktor (g), wat onderliggend aan die leerpotensiaal en verskeie psigomotoriese metings is, redelik oortuigend gestaaf. 'n Algemene psigomotoriese faktor is nie in die huidige ondersoek gevind nie. Voorstelle is gemaak om die ontwerp- en kriteriumtekortkominge te verbeter.

There are two main reasons why time and effort should be invested in the pursuit of valid personnel selection procedures, namely to remain within the ambits of the law, referred to here as the legal incentive (Lopes, Roodt & Mauer, 2001; Mauer, 2000a, 2000b) and secondly, to maximise the probability of selecting the potentially most productive candidate(s), referred to in this paper as the economic incentive (Hunter & Hunter, 1984: Schmidt & Hunter, 1981).

The legal incentive involves industrial relations, ethical and cultural issues, and the social utility of fairness considerations (Lopes et al., 2001; Mauer, 2000a, 2000b; Wheeler, 1993). The economic incentive encompasses issues such as shortages of skills, the impact of globalisation as experienced in the South African economy and the need for increased competitiveness (Wheeler, 1993). These two incentives, however, provide a useful categorisation of the benefits for using scientific selection procedures in South African organisations.

The validity of psychological tests and other assessments used by organisations to make decisions affecting an individual's career status is a legal requirement as per the Employment Equity Act (55 of 1998). There is currently no other option for organisations than validating the tests and other assessments that are used to make career decisions about their employees or potential employees. Only in this way can there be scientific proof of compliance with the requirements set by the Employment Equity Act, thereby making selection decisions based on these measures legally defensible.

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Beyond the legal requirements, there are distinct economic gains to be made by using selection procedures that are valid. Accurate predictions of applicants' performance on the job and subsequent selection of the most able candidates, should translate into increases in the productivity and performance level of the organisation (Anastasi & Urbina, 1997; Hunter & Hunter, 1984; Schmidt & Hunter, 1981, 1998). This conception forms the foundation of studies concerning the utility of selection procedures.

Schmidt and Hunter (1998) concluded that, in contrast to random selection, the utility of selection measures is directly proportional to the validity thereof and that the potential economic gains to be derived by replacing less valid predictors of performance with measures that have higher validity, are quite large in financial terms. The higher the validity coefficient of a selection measure, the greater is the economic utility for the period that the selected candidates work for the organisation, and vice versa. It thus makes economic sense for organisations to investigate the validity of the various selection methods that may be used in their specific context. In the present study, the context was the need for a valid selection procedure for haul truck operators in an open-pit platinum mine.

Minerals are South Africa's major source of foreign exchange earnings and it is anticipated that "mining will dictate the pace of economic development for many years to come" (Chamber of Mines, 2002, p.1). South Africa holds 94% of the world's known Platinum Group Metals (PGM's), the only other major supplier being Russia (mostly from stockpiles). Since 1999 there have been significant increases in the demand for platinum, which is expected to be sustained in the short to medium term (Anglo American Platinum Corporation Limited, 2000).

Due to the overall shortfall in supply and the strong demand fundamentals for PGM's, there is growing competition between various platinum producers (both nationally and globally) to supply this shortfall at the largest profit margins possible. This means that productivity at existing operations has to be increased. It also implies that expansion projects (with the same focus on low cost and high productivity rates) have to be undertaken. These demands point to the need for valid selection procedures for existing operations and for expansion projects to ensure that employees are skilled and productive and can add value to the operations.

In an open-pit platinum mine, the haul truck operator plays a major role in the overall productivity of the mine. At the platinum mine in question, haul truck operators make up the largest contingent of operators (128 out of a total of 200) on the mine. Compared to other types of production equipment at the operation, the fleet of haul trucks is by far the largest investment in terms of capital outlay and running costs. A further consideration is that, relatively speaking, the safety risks regarding haul trucks are high, because they are mobile and capable of higher speeds than any of the other mobile production equipment in the pit.

The production process for haul truck operators consists of the following components: loading, transporting and tipping. Haul truck operators are responsible for transporting material (ore or waste) from the loading face to various tipping areas (crusher, stockpile or waste dumps) depending on the nature of the material to be tipped. They then tip the material into the crusher or onto a stockpile depending on the status of the crusher.

At the loading face, it is the responsibility of haul truck operators to manoeuvre and place the truck into a position where it is ideal for the face shovel or front end loader to load the material. This procedure is referred to as "spotting in". In the case of the shovel, the haul truck must be positioned so that the shovel has no need to over-swing or overextend the "arm" of the shovel. (Overextending the "arm" leads to losses in productivity, because the time taken to swing is longer and it also puts strain on the machine, resulting in potential damage to the shovel). In the case of the front end loader (which is on wheels), the ideal placement of the truck for loading has productivity and safety implications. If the haul truck operator does not place the haul truck optimally, the loader needs to reposition itself to tip with a full load in the bucket. This may result in the machine over-balancing with resultant injuries and property damage. As highlighted earlier, the material is then transported to the crusher, the waste dump or the ore dump (stockpile).

At the crusher the operators have to reverse the truck into the ideal position to tip. At waste and ore dumps they need to reverse towards a safety berm in order to tip over the side of the dump. A safety berm is a heap of rock/sand of 1.5 metres high on the edge of the dump. It has two main uses. Firstly, haul truck operators use it to "spot into" the dump in terms of location and direction, and secondly, it signals to haul truck operators when they have reversed too far, which may result in the truck falling down the side of a 30-40 metre dump resulting in injury or death and property damage. The process of manoeuvring and placing the truck in the ideal position to tip is also referred to as "spotting in". Therefore "spotting in" is required for the loading and the tipping components of the production process.

The technology on haul trucks is advanced. On-board computers are linked to a dispatch system that monitors performance and indicates where and when operators should load, dump, refuel and report for service. The operators interact with the dispatch system throughout the shift (by pressing various options on the communication touch screen in the haul truck) to indicate their current status so that the dispatch system can allocate trucks to the various loading points optimally.

Consequently, training involves the actual operation of the truck, the mechanics of the dispatch system, and it also focuses on safe and efficient "spotting in" under various environmental conditions, safety policies and procedures. Training periods are thus typically long and relatively expensive.

Bearing in mind the high costs of haul trucks, the potential for accidents, and the high training costs, it is suggested that (as in the aviation industry) "even small improvements in identifying potential wash-outs could yield large cost avoidance savings" (Ree & Carretta, 1998, p. 82). Ree and Carretta's (1998) viewpoints highlight three possible criteria against which the effectiveness of selection procedures can be measured, namely productivity, safety, and length of time taken to complete the training programme. The only criterion that was used in this study, was productivity.

Unstructured interviews were traditionally used to select haul truck operators at the open-pit mine as has also been done internationally in other kinds of operations (Campion, Pursell & Brown, 1988; Robertson, Gratton & Rout, 1990), despite the fact that such interviews yield low criterion validities (Schmidt & Hunter, 1998). Earlier research already supported the validity of cognitive and psychomotor ability as predictors of training success and of job performance criteria for positions requiring the operation and maneuvering of mobile machinery (Bouwer, 1985; Carretta, 1989; Duke & Ree, 1996; Gutenberg, Arvey, Osburn, & Jeanneret, 1983; Hunter & Hunter, 1984; Jensen, 1982, 1986).

Research findings generally indicate encouraging to strong correlations for cognitive (org) and psychomotor abilities as predictors of job performance and training success in jobs requiring operating skills. In two meta-analyses of aviation studies by Hunter & Burke (1994) and Martinussen (1996) modest correlations for various measures of cognitive ability, ranging between 0,13 and 0,22, were found. These findings were questioned by Carretta and Ree (2000) as under-reported, due to possible statistical artifacts (such as range restrictions and unreliability). In contrast, a vast amount of research indicate strong correlations, ranging from 0,36 to 0,70, between cognitive abilities and job performance and training criteria (Carretta & Ree, 1996b, 1997, 2000; Hunter, 1986; Hunter & Hunter, 1984; Jensen, 1986; Schmidt & Hunter, 1998). Similar findings in earlier and more recent studies are reported for psychomotor abilities as predictors of job performance and training success (Duke & Ree, 1996; Mashburn as cited in Griffin & Koonce, 1996). In psychomotor assessments in which computer technology replaced many apparatus tests, strong correlations have also been reported (Cox, 1988; Fleishman, 1988; Griffin & Koonce, 1998; Ree & Carretta, 1998; Schoeman, 1995; Wheeler & Ree, 1997). A number of studies also refer to general cognitive ability or g as an additional predictor, thus pointing to the interaction between cognitive and psychomotor abilities in the prediction of job performance (Carretta, 1989, 1992; Carretta & Ree, 1994, 1997; Chaiken, Kyllone & Tirre, 2000; Duke & Ree, 1996; Hunter & Burke, 1994; Martinussen, 1996; Tirre & Raouf, 1998). Studies which indicate the influence of moderator variables, such as socioeconomic status (job status or occupational level) and age (Humphreys, 1984; Jensen, 1986; Kantor & Carretta, 1988) on the correlation between cognitive abilities and psychomotor abilities and job performance, are particularly relevant for South Africa.

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 et al., 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). Learning potential measures have not been validated against job performance criteria, as was the case in this study.

The psychomotor abilities utilised by haul truck operators at loading and tipping sites are very specific. It was therefore important to select appropriate job-related predictors that would capture candidates' psychomotor abilities to perform their jobs. For the present study it was decided to use the Vienna Test System which is a diagnostic instrument developed for the assessment of driving ability in Austria and that is now utilised world-wide for the same purpose (Schuhfried, 1996). It is made up of a battery of primarily psychomotor tests, but it also includes computerised versions of intelligence and personality tests. The system requires no prior driving experience to yield predictions of driving ability and therefore it is ideal for use in the selection of potential haul truck operators. Various validity studies had been conducted in Europe for the different sub-tests of the Vienna Test System (Bukasa, Wenninger & Brandstätter, as cited in Schuhfried, 2000a; Cale, as cited in Schufried, 2000a), but none have been carried out at an open-pit mine in South Africa.

Bearing in mind the significant role that haul truck operators play in the productivity of an open-pit platinum mine, combined with the legal incentive for the use of valid selection procedures in the South African context and the economic realities of the importance of productivity to the expanding platinum mining industry, the current study was an attempt to find valid predictors that may be used to select haul truck operators. In view of the research findings mentioned above, it was decided to investigate whether a cognitive measure of learning potential and psychomotor ability tests are valid predictors of the job performance of haul truck operators in an open-pit mine so that these predictors might in the future be used for the selection of operators.

Moderator variables often have an impact on the relationships between predictor and criterion variables in criterion validity studies. For the current study it was therefore also necessary to investigate the effect of potential moderators that have been found to operate in similar contexts in earlier research. The final aim of the study was to investigate the relationships between the predictors to determine whether general cognitive ability (g) underlies performance in all the predictors (cognitive and psychomotor predictors), or whether two underlying factors would be found, namely g and general psychomotor ability.

The hypotheses were stated as follows:

- Learning potential and psychomotor abilities are valid predictors of haul truck operator performance in an open-pit mine.
- Moderator variables (specifically age, years of education, and years of operating experience) influence the relationship between learning potential, psychomotor abilities and haul truck operator performance.
- Learning potential and psychomotor abilities are positively correlated.
- Two factors underlie learning potential and psychomotor abilities, namely a general cognitive ability (g) factor and a general psychomotor factor.

METHOD

Respondents

All of the haul truck operators at an open-pit mine (N = 128) were included in the sample for the present study. There were 125 males as against only three females and all of the respondents were Black. Their mean age was 41,56, their mean number of years of education was 8,23 and they had a mean of 15,13 years of operating experience.

Measuring instruments

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), the predictor variables and the criterion variables.

Moderator variables

It is common practice in applied psychological research to investigate whether biographical variables such as age, sex and education moderate the relationships between predictor and criterion variables (Cascio, 1998). Anastasi and Urbina (1997) stressed the need to include only those variables for which there is evidence of their moderating effects in multiple regression analyses. It was therefore decided to investigate age, education and experience as potential moderators in the predictor–criterion relationships, because the results of several earlier studies indicated that these variables may act as moderators in the present study.

For instance, Oehlschlagel and Moosbrugger (cited in Schuhfried, 1996) and Wagner (cited in Schuhfried, 1996) found that as age increases, performance in psychomotor tests decreases. With regard to educational level, Hunter and Hunter (1984), Martinussen (1996) and Schmidt and Hunter (1998) found that correlations of years of education with job performance and training outcomes were relatively small (in the 0,10 to 0,20 range). It was nevertheless decided to include years of education as a potential moderator of job performance, because it was not certain whether the mentioned validity coefficients were relevant to the South African context, where the quality of schooling in many schools had been of a questionable standard and access to the schooling system, for the greater part of the population, had been problematic. It was anticipated that the number of years of schooling that the candidates claimed to have completed, would give a very rough indication of their current literacy and numeracy levels. This might have affected the ease with which they acquired the knowledge and skills to perform the job, a relevant issue due to the considerable variation among the candidates in this study who reported education levels varying from illiterate to higher than Grade 12.

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 machinery such as cars, trucks and forklifts.

Predictor variables

Two measuring instruments were used to assess the predictor variables. The first was a cognitive test to measure the respondents' overall learning potential, namely the TRAM 1 Learning Potential Test Battery (Taylor, 1999). Secondly, several subtests of the Vienna Test System (Schuhfried, 1996, 2000a, 2000b, 2000c), namely the Cognitrone, Determination Unit, Two-hand Coordination and Zeit Bewegung Abschätzung (ZBA) sub-tests, were used to assess psychomotor ability.

TRAM 1 Learning Potential Test Battery

General cognitive ability, or g, has consistently been found to be a valid indicator of job performance when compared with other potential predictors (Gutenberg, et al.,1983; Hartigan & Wigdor, 1989; Hunter, 1986; Hunter & Hunter, 1984; Jensen, 1986; Levine, Spector, Menon, Narayanan & Cannon-Bowers, 1996; Schmidt & Hunter, 1981, 1998; Schmidt et al., 1988; Schmidt & Hunter, 1998). Furthermore, culture-fairness in the assessment of cognitive potential is a particularly important issue in the

South African context (Taylor, 1994). The TRAM 1 Learning Potential Test Battery (Taylor, 1999) was therefore selected as a predictor in this study.

The TRAM 1 is a learning potential assessment instrument for candidates who fall in the illiterate and semi-literate ranges or who have not had formal schooling up to Grade 10 (Taylor, 1999). It was included in this study as a culture-fair measure of learning potential, which should also give an indication of fluid intelligence (gf) and general cognitive ability or g (Taylor, 1994).

The test requires candidates to translate symbols into other symbols, using a dictionary. The symbols are pictorial or quasi-geometric. The symbols are translated using some underlying rule (such as opposites – sun/moon; or the symbols being used together – such as teacup/teapot). In Phase A1 candidates first complete the translation process by themselves. Thereafter they are given a lesson to explain the underlying rules, followed by the completion of Phase A2. Then they are given another test book and another dictionary to assess the transfer of skills. The final step is the completion of a memory test (Taylor, 1999).

Scores are provided on the following dimensions: Automatisation, Transfer, Memory and Understanding, Speed and Accuracy. Composite scores of respondents' overall performance are also generated (Taylor, 1999). Only the overall assessment rating was used as a predictor in this study. Taylor (1999) reported reliability coefficients ranging from 0,62 to 0,95 for the various dimensions. In terms of validity, he found that composite scores on the TRAM 1 correlated significantly (r = 0,59) with academic performance in an ABET course and also with academic performance (r = 0,51) in N1 studies (NQF level 2, or grade 10).

Vienna Test System

In the past decade the Vienna Battery has been used relatively widely in South Africa. De Jager and Van der Walt (1993) reported on the reliability and validity of the stress tolerance test for operators of moving equipment at a diamond mine. Local predictive validity studies of the Vienna Test System for predicting the job performance of truck drivers (De Jager, 1997) and of operators of moving equipment in a coal mine (De Jager & Van der Walt (1997) have also been performed.

The subtests of the Vienna Test System that were used as predictors, are discussed below.

- *Cognitrone*: This subtest of the Vienna Test System assesses candidates' ability to concentrate and to adjust their work tempo to different stimuli patterns. It was included because of its logical conceptual link with haul truck operator performance. Haul truck operators are required to demonstrate sustained concentration throughout the shift, taking into consideration the demands which the continually changing operating environment places on them.

  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).

  In the subtest, candidates are required to indicate as fast and as accurate as possible whether any of four figures presented on a computer screen is similar to the figure in the test question. The test yields various options in terms of differentiated results. In this study "sum correct reactions" was utilised. It gives an indication of performance quality and, to some extent, also provides data on processing speed (Schuhfried, 2000a).

  Schuhfried (2000a) reported a split-half reliability of 0,95 for the subtest. In criterion-related validity studies significant correlations between test results and safety criteria, such as accident frequency and driver errors were obtained (Bukasa, Wenninger & Brandstätter as cited in Schuhfried, 2000a; Cale as cited in Schuhfried, 2000a). However, no criterion-related studies with the Cognitrone as the predictor, and operator or driver performance as the criterion, could be found. A correlation of 0,48 with the Determination Unit subtest was reported (Wagner as cited in Schuhfried, 2000a). This substantial correlation may have been due to both tests tapping similar needs for sustained concentration, efficient information processing and quick reaction time. Negative correlations with age were reported in two studies (Oehlschlagel & Moosbrugger, Wagner as cited in Schuhfried, 2000a).
- *Determination Unit*: This subtest assesses candidates' reaction speed, reactive stress tolerance and ability to demonstrate sustained multiple-choice reactions to rapidly changing stimuli (Schuhfried, 1996). Like the Cognitrone, this test was included because of its conceptual links with haul truck operator performance requirements. Its focus is on the operators' appropriate and fast responses in rapidly changing environments that may involve stress. This is particularly relevant in the mining environment where the operators of moving machinery need to cooperate closely, with very little margin for error, to achieve production objectives.

  The Determination Unit requires the discrimination of colours and acoustic signals, memorisation of the relevant characteristics of stimulus configurations and response buttons, and also memorisation and application of assignment rules. Individuals have to react to differently coloured visual stimuli as well as acoustic stimuli that require either finger or foot responses. The test starts off slowly, gains speed to a very fast response requirement (approximating high stress situations, such as accident or near-accident situations) and then slows down marginally (approximating the period just after the accident/near-accident). Bearing in mind that the reactions required are not simple, a certain amount of overlap between general cognitive ability (g) and performance in this test should be expected (Jensen, 1993). The score used in this research was "overall results correct", which reflected the total number of appropriate timely and delayed responses for the entire test.

  Schuhfried (1996) reported an internal consistency reliability of 0,99 for the Determination Unit. In various criterion-related validity studies significant correlations between results on the Determination Unit and driving performance criteria were obtained, for instance in a study with driving behaviour during a test drive as well as results of a driving test as the criteria (Klebelsberg & Kallina; Karner & Neuwirth as cited in Schuhfried, 1996). In another example driving safety criteria, frequency of accidents and driver errors, were used (Cale; Wenninger & Brandstätter as cited in Schuhfried, 1996).
- *Two-hand Coordination Speed and Accuracy*: This subtest assesses hand-eye and hand-hand coordination. It was included as a predictor in this study because of the two-hand coordination requirements of haul truck operating activities.

  Candidates are required to move a cursor on a given track with the aid of two joysticks, one that can move forward and backward and one that can move right and left. Candidates must therefore use both hands in a coordinated way to move the cursor along the track within acceptable accuracy limits. The track consists of three sections varying in the demands made on the left and right hands. The scores yielded are "total mean duration" (the speed dimension) and "total percentage error duration" (the accuracy dimension).

  Internal consistency reliabilities of the measures varied from 0,85 to 0,97 (Schuhfried, 2000c). No criterion-related validity studies were found.

- *Zeit Bewegung Abschätzung (ZBA)*: This subtest of the Vienna Test System assesses candidates' ability to correctly estimate and anticipate motion and distance pertaining to moving objects. It was included in this study because of its perceived relevance to "spotting in" activities. If haul truck operators can estimate both distance and direction, it will arguably be easier for them to "spot into" the loading equipment correctly and quickly on their first attempt.

  In the test a slow-moving dot moves across the screen. At a stage it disappears and candidates are required to indicate both where and when it will hit a line. The test is very similar to the LAMP tests developed in World War II, in which an aeroplane appeared on the left side of the screen, travelled across the screen and then disappeared behind a cloud. Candidates were required to estimate when the aeroplane would reappear on the right hand side of the cloud (Ree & Carretta, 1998).

  For the present study only linear progressions were included. Sine wave progressions were omitted, because they relate to operating activities more complex than the operating activities required for the operation of haul trucks. The scores used were "median of deviation time during a linear progression" (time estimation), which was measured in seconds, and "median of direction deviation during a linear progression" (motion estimation), which was measured in pixels.

  Schuhfried (2000b) reported internal consistency reliabilities of 0,92 for the ZBA time estimation measure and 0.69 for the ZBA motion estimation measure. No validity studies on the current version of the subtest could be found, nor have studies on the relative effects of age or any other potential moderator variable been reported.

Criterion variables

In an attempt to balance the shortcomings of objective (Cascio, 1998; Deary, 2001) and subjective criteria (Anastasi & Urbina, 1997; Cascio, 1998; Guion, 1987; Thorndike, Cunningham, Thorndike & Hagen, 1991), both objective and subjective criterion measures were used in the study. No attempt was made to determine the reliability of the various criteria, due to difficulties in obtaining the data required to determine such reliabilities.

Two objective criterion variables, namely spotting time into loading equipment and tons per work hour corrected for kilometres hauled and gradient, were assessed. The subjective criterion variable measured was supervisor ranking.

Scheepers (1973) pointed out that an acceptable driving criterion could only be achieved by registering the movements of the vehicle on a continuous basis in much the same way as a flight recorder registers the movements of an aircraft in flight. At the open-pit mine in question, every truck was constantly monitored by a Geographical Positioning System (GPS) and the computerised dispatch centre had continuous data on every truck/operator combination in terms of location, tons loaded, status (such as service/breakdown) and other variables relevant to the monitoring of the performance of every truck/operator combination. This data was used to compile the objective criterion data.

Spotting time into loading equipment

This criterion variable was included, because it involves the two most complex operating skills required from haul truck operators. Firstly, the ability to manoeuvre and place the truck in an optimal position for the shovel or front end loader to be able to load, without having to swing further than necessary or to overextend the "arm" of the shovel, is referred to as "spotting in". The second skill involves reversing into the ideal position to tip into the crusher or to "spot into" the safety berm in order to tip at the waste or ore dumps. It was argued that the more difficult operators found these two skills, the longer it would take them to load or tip, and thus the less productive they would be.

The dispatch system provided data on these variables per truck/operator combination on a continuous basis. "Spotting in" was calculated by determining the time between the "full action of the previous truck" and the "first bucket action of the new truck". This criterion was calculated in "overtrucked" situations, that is, when there was at least one truck waiting to be loaded.

Spotting time into the dumping or tipping sites was omitted as a criterion, because the measuring equipment at the various tipping/dumping sites lacked accuracy. Therefore, only time taken to "spot in" under the bucket was used as the spotting time criterion measure. To remove the effect of the different loading equipment (shovel versus front end loaders), only "spotting in" times for the shovel were included. Spotting time was averaged over a three-month period.

Tons per work hour corrected for kilometres hauled and gradient

The operators drove different routes to the various pieces of loading equipment and places of loading material or loading areas, and therefore they did not travel the same distance to transport their loads (ore or waste). The routes that they travelled also differed substantially in terms of road gradients. It was thus not possible to use tons hauled per hour as an indicator of productivity. Some correction was required for kilometres hauled and gradient of the road.

The following calculation was performed to correct the data extracted from the computerised dispatch system:

The tons hauled were divided by the hours worked (WH). WH referred to haul truck operating time, excluding time spent in the queue waiting for loading equipment availability (WH = operating time – queue time). WH was then divided by the kilometres travelled yielding a "tons corrected for distance hauled" (TCDH) measure. Road gradient was incorporated by multiplying the linear distance travelled by a correction factor calculated by the dispatch system from the road network data that is captured on the system to yield an "effective flat haul rate" (EFH). Finally, TCDH was corrected to a "tons per work hour corrected for kilometres hauled and gradient" (TPKH) by multiplying TCDH with EFH (TPKH = TCDH * EFH). This variable, TPKH, was used as the second criterion and the results were also averaged over a three-month period.

Supervisor ranking

Supervisor rankings were included as an additional criterion variable. The rankings were obtained in a relatively rudimentary fashion with the aim of corroborating the findings of the objective criteria. The supervisors of every shift were asked to rank the operators on their shifts, using the paired comparisons method (Cascio, 1998). The supervisors were instructed to decide which operator in every pair of operators they would select if the loading conditions were particularly difficult (due to congestion in the loading area or wet road conditions) with number 1 being the best operator, number 2 the second best operator and so forth.

No attempt was made to compare operators between shifts, because of the unreliability that could potentially be caused by different supervisors not being familiar with the performance of all the operators on all the shifts. Care was taken to ensure that this criterion was not contaminated by supervisors having access to either predictor or objective criterion scores.

Procedure

The respondents were assessed in groups with the TRAM 1, depending on their availability. They were also requested to complete the various subtests of the Vienna Test System that were used as predictors in the present study. The criterion measures were obtained during the same time period that the assessments were done. The Spotting Time and Corrected Tons Hauled variables were obtained from the computerised dispatch system in operation at the mine and averaged per operator over a period of three months. The Supervisor Ranking variable for the operators was obtained from their supervisors.

Due to various practical considerations, some of the data were not available for a number of members of the sample. The numbers of valid cases are reported in Table 1. 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.

RESULTS

The first step in the analysis of the data entailed examining the distributions of the variables. The descriptive statistics for the moderator, predictor and criterion variables are given in Table 1. These include means, standard deviations, and indices of skewness and kurtosis. Rather than reporting the conventional skewness and kurtosis statistics computed by the SPSS package, these statistics were converted to z values as suggested by Field (2000) to increase the interpretability of the obtained values. As a rule of thumb, absolute values of z that are larger than 2, are considered indicative of deviation from normality.

Furthermore, the so-called Kolmogorov-Smirnov test of the normality of a distribution was performed and the results are also reported in Table 1. If the p value of this test statistic is smaller than 0,05, the distribution deviates in some way from normality. When this is the case, the skewness and kurtosis values, or a histogram of the distribution, may give more information about the shape of the distribution (Field, 2000).

TABLE 1
DESCRIPTIVE STATISTICS FOR THE MODERATOR, PREDICTOR AND CRITERION VARIABLES

	N	Min	Max	M	SD	Skew-ness z	Kurto sis z	Kolm-Sm*	p
Age	128	25,00	60,00	41,56	8,12	0,95	1,16	0,07	0,200
Years of education	127	0,00	13,00	8,23	2,79	-2,39	0,70	0,10	0,023
Years of operating experience	118	1,00	35,00	15,13	8,07	1,41	0,92	0,07	0,200
TRAM 1 Learning potential	121	31,96	86,72	62,64	11,97	0,08	1,48	0,12	0,004
Cognitrone	127	83,00	696,00	426,63	117,04	-2,01	0,34	0,09	0,093
Determin-ation unit	127	167,00	519,00	411,96	72,16	-3,90	1,17	0,08	0,200
Two-hand coordination speed	127	23,47	123,63	62,33	22,59	2,70	0,89	0,09	0,200
Two-hand coordination accuracy	127	0,00	8,78	1,07	1,51	12,61	4,51	0,25	0,000
ZBA time estimation	127	0,19	4,01	1,10	0,80	7,47	2,41	0,18	0,000
ZBA motion estimation	127	5,00	155,00	28,13	20,15	14,14	5,78	0,20	0,000
Spotting time in seconds	110	62,00	108,00	79,07	7,58	3,76	1,73	0,10	0,036
Corrected tons hauled	94	2042,11	2922,39	2469,94	161,78	0,91	1,31	0,07	0,200
Supervisor rankings	110	1,00	30,00	14,74	8,21	0,10	1,61	0,09	0,200

Kolmogorov-Smirnov test statistic for the normality of a distribution

In the case of Two-hand Coordination Accuracy, ZBA Time Estimation and ZBA Motion Estimation the skewness was severe and positive (see Table 1). Because low scores indicated good performance on these subtests, the positive skewness indicated that most of the respondents performed well on these subtests. This may also mean that the test did not allow for an adequate degree of variability amongst candidates. As expected, all the variables that were skewed or leptokurtic, also deviated from normality (see the Kolmogorov-Smirnov test statistics in Table 1). In addition, the distribution of the TRAM 1 deviated significantly from normality, despite demonstrating no significant skewness or kurtosis. Examination of the histogram of the TRAM 1 distribution revealed a bipolar tendency in the scores.

To test the hypothesis that learning potential and psychomotor abilities can predict haul truck operator performance, the second step in the data analysis consisted of computing the product moment correlation coefficients between the predictors and the criteria, and also the correlations among the criteria. These correlations are reported in Table 2.

TABLE 2
CORRELATIONS OF THE MODERATORS AND PREDICTORS WITH THE CRITERIA, AND INTERCORRELATIONS OF THE CRITERIA

		Spotting time	Corrected tons hauled	Supervisor rankings
Age	Pearson r	-0,02	-0,13	0,01
	Sig. (2-tailed)	0,847	0,218	0,961
	N	110	94	110
Years of education	Pearson r	-0,02	0,19	-0,06
	Sig. (2-tailed)	0,875	0,075	0,527
	N	110	94	109
Years of operating experience	Pearson r	-0,07	-0,06	0,04
	Sig. (2-tailed)	0,497	0,611	0,720
	N	102	89	104
TRAM 1 Learning potential	Pearson r	-0.13	0.14	-0.24**
	Sig. (1-tailed)	0,092	0,089	0,007
	N	104	90	104
Cognitrone	Pearson r	-0,20*	-0,02	-0,15
	Sig. (1-tailed)	0,018	0,427	0,064
	N	110	94	110
Determination unit	Pearson r	-0,08	-0,07	-0,03
	Sig. (1-tailed)	0,212	0,256	,383
	N	110	94	110
Two-hand coordination speed	Pearson r	0,13	-0,04	0,05
	Sig. (1-tailed)	0,096	0,367	0,304
	N	110	94	110
Two-hand coordination accuracy	Pearson r	-0,04	0,02	-0.05
	Sig. (1-tailed)	0,325	0,422	0,295
	N	110	94	110
ZBA time estimation	Pearson r	0,02	0,09	0,12
	Sig. (1-tailed)	0,418	0,193	0,099
	N	110	94	110
ZBA motion estimation	Pearson r	0,03	0,00	0,03
	Sig. (1-tailed)	0,385	0,499	0,382
	N	110	94	110
Spotting time	Pearson r	1,00		
	Sig. (2-tailed)	-		
	N	110		
Corrected tons hauled	Pearson r	-0,03	1,00	
	Sig. (2-tailed)	0,793	–	
	N	94	94	
Supervisor rankings	Pearson r	0,41**	-0,02	1,00
	Sig. (2-tailed)	0,000	0,883	–
	N	99	85	110

** Correlation is significant at the 0,01 level
* Correlation is significant at the 0,05 level
N smaller than 128 is the result of incomplete pair-wise data

The intercorrelations among the job performance criteria were examined first (see Table 2). There was a significant and strong positive correlation ($r = 0{,}41$, $p < 0{,}001$) between Spotting time (an objective criterion) and Supervisor rankings (the subjective criterion). This correlation may be regarded as an indication that these two criteria measured the same dimension relatively reliably, thereby providing evidence for the construct validity of these job performance criteria. This result is noteworthy, because it occurred despite the trend for correlations between objective criterion measures and subjective criterion ratings to be low (Cascio, 1998). A certain degree of overlap between these two criteria had been anticipated due to the brief that the supervisors were given when asked to rank their candidates by using the paired comparisons method. They were asked to indicate which operator in every pair of operators they, the supervisors, would select if the loading conditions were particularly difficult (such as congestion in the loading area, or wet road conditions). The supervisor ranking criterion was therefore expected to measure, at least to some degree, the same dimension as the spotting time criterion.

The reliability and validity of the Corrected tons hauled criterion, however, was not supported. An explanation for the low correlations between this criterion and the other criteria was that the road network data on the dispatch system was not entirely updated at the time of the study, and that the flat haul rate correction factor that was implemented using this road network data as foundation, was thus not totally correct. This criterion was possibly not reliable enough to be used, because low reliabilities of criterion measures place a ceiling on the validity coefficients that are attainable. This may lead to a Type 2 error, namely in this case, missing a significant validity coefficient that was present (Carretta & Ree, 2000; Cascio, 1998; Schmidt, Hunter & Urry, 1976). It was not possible to determine the exact extent of this unreliability and the consequential effect size on the validity of the criterion.

The spotting times of each operator into the various pieces of loading equipment was readily observable, more so than the tons hauled per operator, which was inclined to get lost in the realities of different operators driving different haul distances and road gradients, and production being reported per day per shift rather than per shift per operator. It therefore made sense that Spotting time was a better objective criterion than Corrected tons hauled.

The correlations of the predictors with the criteria are also presented in Table 2. One-tailed significance tests were performed on these correlations, because the correlations were expected to be in a specific direction. For the Spotting time criterion only one statistically significant correlation was found, namely a negative correlation ($r = -0{,}20$, $p = 0{,}018$) with Cognitrone efficiency. The negative correlation provided partial support for the hypothesis that psychomotor measures can predict job performance of haul truck operators.

TABLE 3
CORRELATIONS OF THE MODERATORS WITH THE PREDICTORS AND INTERCORRELATIONS OF THE PREDICTORS

		TRAM 1 Learning potential	Cognitrone	Determination unit	Two-hand coordination speed	Two-hand coordination accuracy	ZBA time estimation	ZBA motion estimation
Age	Pearson r	-0,34**	-0,16	-0,34**	0,03	0,29**	-0,03	0,12
	Sig. (2-tailed)	0,000	0,072	0,000	0,782	0,001	0,782	0,171
	N	121	127	127	127	127	127	127
Years of education	Pearson r	0,39**	0,09	0,33**	-0,12	-0,03	-0,07	-0,01
	Sig. (2-tailed)	0,000	0,314	0,000	0,174	0,746	0,452	0,879
	N	120	126	126	126	126	126	126
Years of operating experience	Pearson r	-0,28**	0,00	-0,28**	-0,19*	0,31**	-0,03	0,13
	Sig. (2-tailed)	0,002	0,986	0,002	0,043	0,001	0,735	0,159
	N	117	117	117	117	117	117	117
TRAM 1 Learning potential	Pearson r	1,00						
	Sig. (2-tailed)							
	N	121						
Cognitrone	Pearson r	0,29**	1,00					
	Sig. (2-tailed)	0,002						
	N	120	127					
Determination unit	Pearson r	0,43**	0,29**	1,00				
	Sig. (2-tailed)	0,000	0,001					
	N	120	127	127				
Two-hand coordination speed	Pearson r	-0,10	-0,17	0,04	1,00			
	Sig. (2-tailed)	0,298	0,062	0,669				
	N	120	127	127	127			
Two-hand coordination accuracy	Pearson r	-0,24**	-0,09	-0,30**	-0,23**	1.00		
	Sig. (2-tailed)	0,009	0,301	0,001	0,010			
	N	120	127	127	127	127		
ZBA time estimation	Pearson r	-0,08	-0,11	-0,17*	0,00	-0,10	1,00	
	Sig. (2-tailed)	0,412	0,239	0,050	0,996	0,277		
	N	120	127	127	127	127	127	
ZBA motion estimation	Pearson r	-0,15	-0,08	-0,14	-0,01	0,15	0,08	1,00
	Sig. (2-tailed)	0,099	0,403	0,114	0,910	0,092	0,374	
	N	120	127	127	127	127	127	127

** Correlation is significant at the 0,01 level
* Correlation is significant at the 0,05 level
N smaller than 128 is the result of incomplete pair-wise data

Similarly, a single statistically significant correlation was obtained for the Supervisor ranking criterion, namely a negative correlation (r = -0,24, p = 0,007) with Learning potential. A low score on the Supervisor ranking criterion indicated good performance of the haul truck operator (the number 1 candidate was the best performer on every shift), and therefore this correlation meant that candidates who performed well on the learning potential measure, tended to be ranked as good operators by their supervisors. This correlation provided evidence in support of the hypothesis that learning potential can predict job performance of haul truck operators.

No significant correlations were found between the predictors and the Corrected tons hauled criterion. This result may be due to the problems relating to this criterion referred to earlier.

In the third step of the data analysis, the correlations of the anticipated moderators with the rest of the variables were examined. The purpose of these analyses was to determine whether age, years of education, and years of operating experience are moderator variables that influence the relationship between learning potential, psychomotor abilities and haul truck operator performance. Statistically significant correlations at the 0,01 level were obtained between the three potential moderator variables. There was a strong negative correlation between age and years of education (r = -0,50, p < 0,001). Similarly, there was a negative correlation between years of education and years of operating experience (r = -0,35, p < 0,001). As may be expected, the correlation between age and years of operating experience was strong and positive (r = 0,66, p < 0,001).

In Table 2 the correlations between the anticipated moderators and the criteria are reported. None of these correlations were statistically significant, which implies that evidence for the hypothesised influence of the possible moderator variables was not found in this part of the results. The correlations of the moderator variables with the predictor variables were studied next (see Table 3). There were several statistically significant correlations between the moderator variables and some of the predictors. It was therefore feasible that the moderators influenced the predictor-criterion relationship via their relationships with the predictors. Only in the cases of Cognitrone efficiency, ZBA time estimation or ZBA motion estimation were no significant correlations obtained between the proposed moderators and the predictors.

More particularly, the TRAM 1 Learning potential measure correlated statistically significantly with all the potential moderators. This variable correlated negatively with age (r = -0,34, p < 0,001), positively with years of education (r = 0,39, p < 0,001) and negatively with years of operating experience (r = -0,28, p = 0,002). The first two correlations were to be expected, but the reason for the negative correlation between years of operating experience and the TRAM 1 should be sought in the strong positive correlation between age and years of operating experience.

Similarly, the Determination unit efficiency measure also correlated statistically significantly with all the potential moderators. It correlated negatively with age (r = -0,34, p< 0,001), positively with years of education (r = 0,33, p < 0,001) and negatively with years of operating experience (r = -0,28, p < 0,002) The near-identical correlations of the TRAM 1 and the Determination unit measure with the moderators was at least to some degree due to the significant overlap in terms of the dimension assessed by these predictors (see Table 3, r = 0,43).

There were also statistically significant positive correlations of Two-hand coordination accuracy with age (r = 0,29, p = 0,001) and with years of operating experience (r = 0,31, p = 0,001). In other words, the older the operators were and the more years' experience they had as operators, the more likely they were to make errors on the Two-hand coordination test.

Two-hand coordination speed and years of operating experience correlated statistically significantly at the 0.05 level (r = -0,19, p = 0,043). This negative correlation means that candidates with more experience, were likely to perform weaker on the measure than those with less years of experience. In the present study the negative correlation between age and performance on the Cognitrone as reported by Oehlschlagel and Moosbrugger, and Wagner (as cited in Schuhfried, 2000a), was not replicated.

The next step in the assessment of the role of the anticipated moderators involved the statistical control of the effects of these variables. In Table 4 the partial correlations of the predictors with the criteria, controlling for age, years of education and years of operating experience, are presented.

Table 4
Partial correlations of the predictors with the criteria

		Spotting time	Corrected tons hauled	Supervisor rankings
TRAM 1 Learning potential	Pearson r	-0,18	0,05	-0,26*
	Sig. (1-tailed)	0,057	0,324	0,012
	N	76	76	76
Cognitrone	Pearson r	-0.21*	-0.04	-0.18
	Sig. (1-tailed)	0,032	0,355	0,061
	N	76	76	76
Determination unit	Pearson r	-0.08	-0.11	0.03
	Sig. (1-tailed)	0,233	0,164	0,407
	N	76	76	76
Two-hand coordination speed	Pearson r	0,03	-0,04	0,01
	Sig. (1-tailed)	0,398	0,375	0,465
	N	76	76	76
Two-hand coordination accuracy	Pearson r	-0,03	0,12	-0,04
	Sig. (1-tailed)	0,400	0,154	0,354
	N	76	76	76
ZBA time estimation	Pearson r	-0,10	0,11	0,03
	Sig. (1-tailed)	0,194	0,162	0,385
	N	76	76	76
ZBA motion estimation	Pearson r	0,07	0,02	0,01
	Sig. (1-tailed)	0,284	0,436	0,474
	N	76	76	76

* Correlation is significant at the 0,05 level

From Table 4 it is clear that the effects of the correlations of the moderator variables with one another and with the various predictors were negligible, because the moderator variables did not affect the predictor-criterion relationships significantly. The partial correlations reflected in Table 4 are only marginally higher for the two significant correlations (r = -0,21 and r = -0,26) than those reflected in Table 2 (r = -0,20 and r = -0,24) for which the moderator variables were not taken into account. However, in the case of the correlation between the TRAM 1 and Spotting time, the moderators did appear to have a minor effect, because the partial correlation was close to being statistically significant (r = -0.18, p = 0.057). This relationship shows promise for further research using learning potential as predictor.

In the fourth and final step of the data analysis, the intercorrelations between the predictors were studied. The purpose of these analyses was to test the hypotheses that learning potential and psychomotor abilities are positively correlated and that two factors underlie the predictors used in the present study, namely a general cognitive ability (g) factor and a general psychomotor factor. The intercorrelations between the predictors are presented in Table 3.

The TRAM 1 Learning potential correlated statistically significantly with three of the predictors intended to assess psychomotor ability, namely Cognitrone efficiency, Determination unit efficiency, and Two-hand coordination accuracy. All of these correlations were in the expected direction, implying that high learning potential scores tended to be associated with good performance on the psychomotor tests, and vice versa. Learning potential was correlated positively with Cognitrone efficiency (r = 0,29, p = 0,002) and Determination Unit efficiency (r = 0,43, p < 0,001), and negatively with Two-hand coordination accuracy (r = -0,24, p = 0,009) that reflected the percentage of error time. The hypothesis that learning potential and psychomotor abilities are correlated, was therefore supported.

With respect to statistically significant correlations between the psychomotor predictors, the Determination unit correlated positively with the Cognitrone (r = 0,29, p = 0,001), and negatively with Two-hand coordination accuracy (r = -0,30, p = 0.001) and ZBA time estimation accuracy (r = -0,17, p = 0,05). There was also a statistically significant negative correlation between Two-hand coordination speed and Two-hand coordination accuracy (r = -0,23, p = 0,01). All of these correlations were in the expected direction. The positive correlation between Cognitrone efficiency and Determination unit efficiency obtained in this study supported Wagner's (as cited in Schuhfried, 2000a) findings of a correlation of 0.48 between the Determination unit and the Cognitrone.

An exploratory factor analysis was subsequently carried out on the intercorrelations of the TRAM 1 and the Vienna Test System subtests used in this study to explore the relationships between the predictors in greater detail. As a first step, the correlation matrix was tested for sampling adequacy and the null hypothesis of an identity matrix was also tested. The Kaiser-Meyer-Olkin measure of sampling adequacy was equal to 0,63 and Bartlett's test of sphericity was statistically highly significant [÷2 (21) = 73,68, p < 0,001]. These results were acceptable and it was thus decided to proceed with the factor analysis.

The principal axis method of factor analysis was performed on the data, but the results did not yield an unambiguous solution with respect to the appropriate number of factors to be extracted. Various strategies are available to assist the researcher in deciding on how many factors to extract and two of these were implemented in this study. The first strategy used was the Kaiser-Guttman criterion, which specifies that the number of factors to extract is determined by the number of factors with eigen values larger than unity (Stevens, 1992). The second strategy used was the so-called "scree" test (Cattell, 1979).

The eigen values of the various factors (which indicated the relative importance of the factors in terms of the overall variability in the data accounted for by each factor) were plotted against the number of factors that could be extracted. Two observations were made from the plot, namely, there were three factors with eigen values larger than unity and the line appeared more or less straight from Factor 2 onwards. The Kaiser-Guttman criterion therefore indicated that three factors should be extracted, whereas the "scree" started at Factor 2, indicating that only one factor should be extracted. To complicate matters further, the existence of two factors were hypothesised, namely g and psychomotor ability. It was therefore decided to extract single-factor, two-factor and three-factor solutions in anticipation that the most appropriate solution would be suggested by the pattern of results.

For the two-factor and three-factor solutions the factor axes were rotated using the direct oblimin method of oblique rotation. The delta parameter was set at zero (the default setting of the SPSS programme) to ensure that the correlations allowed between the factors were not large. The factor pattern matrices containing the factor loadings (standardised regression coefficients in the case of the two- and three-factor solutions) of these three solutions are reported in Table 5. The single-factor solution is reported in the second column, the two-factor solution in the third and fourth columns, and the three-factor solution in the fifth to seventh columns. Factor loadings that are equal to or larger than 0,30 are indicated in bold type.

TABLE 5
PRINCIPAL AXIS FACTOR SOLUTIONS OF THE CORRELATIONS BETWEEN THE PREDICTORS

	Single factor	Factor 1	Factor 2	Factor 1	Factor 2	Factor 3
TRAM 1 Learning potential	0,61	0,66	0,01	0,64	0,15	0,00
Cognitrone	0,38	0,47	0,16	0,42	0,22	-0,06
Determination unit	0,72	0,63	-0,24	0,67	-0,10	-0,04
Two-hand coordination speed	0,03	-0,13	-0,51	-0,03	-0,66	-0,07
Two-hand coordination accuracy	-0,41	-0,32	0,52	-0,48	0,33	-0,30
ZBA time estimation	-0,11	-0,12	-0,06	-0,08	0,07	0,54
ZBA motion estimation	-0,24	-0,22	0,10	-0,23	0,05	0,04

Factor loadings larger than 0,30 are indicated in bold

DISCUSSION

The primary goals of the study were to investigate whether a learning potential test and psychomotor ability tests were valid predictors of the job performance of haul truck operators, to determine the impact of potential moderator variables on the relationships between the predictor and criterion variables, and to establish whether performance in the predictors could be ascribed to two underlying factors, namely g and general psychomotor ability.

The distributions of the variables were examined in view of the negative effects that some properties of variables may have in a validation study. For instance, if there is restriction of range or if the shapes of the predictor and criterion variables are dissimilar (such as one being positively skewed and the other being negatively skewed), the range of the correlations possible in a set of data is affected (Hays, 1994). Predictably, the three Vienna subtests that exhibited the severest degrees of skewness, were also severely leptokurtic and deviated from normality. These observations may be a reflection of the presence of range restriction which is a typical obstacle in concurrent validity studies. Since all the respondents were experienced operators, the scores on the above-mentioned variables grouped together at the end of the scale that reflected good performance. The bipolar distribution of the TRAM 1 may possibly be explained by the nature of a learning potential measure, where "catching on" (Jensen, 1986) and automatisation (Sternberg, 1984) or "improvement with practice" (Jensen, 1986) play a significant role. The two peaks of the distribution may very well reflect the results of the candidates who "caught on" to the learning tasks and automatised or improved with practice, and those who did not.

In the present study, the variables that were expected to act as moderators did not notably affect the predictor-criterion relationships. Furthermore, the hypothesis that learning potential and psychomotor ability measures would predict the criteria used in the present study, was only partially verified. This result contrasted with Bouwer's (1984) findings of no significant correlations between psychomotor measures and job performance for heavy duty truck drivers in a South African study. Two statistically significant correlations were obtained, namely between the TRAM 1 and the Supervisor ranking criterion and between Cognitrone efficiency and the Spotting time criterion.

It was expected that earlier findings by Carretta (1989), Carretta and Ree (1994, 1997), Gibb and Dolgin (1989), Hunter and Hunter (1984), McHenry, Hough, Toquam, Hanson, & Ashworth (1990) and Ree and Carretta (1994) of psychomotor abilities providing significant, albeit small, incremental validity beyond general cognitive ability (or learning potential), would be replicated in the present study. Initially stepwise multiple regression analyses were planned for regressing each of the three job performance variables on the predictor and potential moderator variables to ascertain the extent to which each of the predictors explained the various criteria. This plan was abandoned, because there were too few significant correlations or partial correlations (controlling for the moderator variables) between the predictor and job performance variables.

The haul truck operator position should be classified as a low complexity job requiring only very basic cognitive skills. This fact may explain the lack of high correlations between learning potential and performance. It has generally been found that general cognitive ability or g tends to correlate better with job performance in more complex jobs (Levine et al., 1996; Gutenberg et al., 1983; Hunter, 1986; Jensen, 1986). Nonetheless, various studies have indicated that the validity of cognitive ability varies across jobs, but that it never approaches zero (Hartigan & Wigdor, 1989; Hunter, 1986; Hunter & Hunter, 1984; Schmidt & Hunter, 1981; Schmidt et al., 1988).

The hypothesis that learning potential and psychomotor abilities are correlated, was supported in the current study. This finding also corroborated earlier findings indicating that general cognitive ability, g, and psychomotor ability are positively correlated (Carretta & Ree, 1997, 2000; Chaiken, et al., 2000; Hunter & Hunter, 1984; McHenry, et al., 1990; Rabbit, Banerji & Szymanski, 1989; Ree & Carretta, 1994; Tirre & Raouf, 1998). Moreover, this result contained new information, because the measure of general cognitive ability used in this study was a learning potential measure.

The shared variance between the TRAM 1 and three of the psychomotor measures was possibly due to a common factor of cognitive ability or g. It appeared that these four measures formed a cluster of substantial intercorrelations. Similarly, the intercorrelations between the psychomotor predictors could point to the presence of a higher order psychomotor factor as found in earlier studies (Carretta & Ree, 1997; Chaiken et al., 2000; Ree & Carretta, 1994; Vernon, as cited in Walsh & Betz, 1990). To test the research hypothesis that the combined use of the TRAM 1 and the Vienna Test System measures applied in this study would yield a general cognitive ability or g factor and a general psychomotor factor, a factor analysis was indicated.

The most striking feature of the factor matrices presented in Table 5 is that the same four measures loaded highly on the first factor for all three of the solutions. The magnitudes of the loadings on the first factor also corresponded rather closely between the three solutions. The four predictors in question were the TRAM 1 and the three psychomotor variables that correlated significantly with the learning potential measure (see Table 3). These subtests of the Vienna Test System were Cognitrone efficiency, Determination Unit efficiency and Two-hand coordination accuracy.

Furthermore, the remaining factors of the two-factor and three-factor solutions could not be interpreted unambiguously, because only two substantial factor loadings were obtained per factor. This means that these factors were not adequately determined (Harman, 1976; Huysamen, 1989) and had to be disregarded. When there are less than three variables loading on a factor, there is probably not enough evidence to make valid interpretations about the factor in question. A cautious interpretation of the data of the current study therefore shows that the factor analytic findings did not constitute sufficient evidence for the existence of a general psychomotor factor. The hypothesis relating to a general psychomotor factor was thus not substantiated. The single-factor solution that was indicated by the Cattell "scree test" therefore appeared to be the most acceptable explanation of the variability in the predictor variables.

The hypothesis that general cognitive ability, g, underlies performance on the TRAM 1 learning potential measure and psychomotor measures, was accepted, because a single factor that had high loadings on the cognitive and some psychomotor measures proved to be the only viable solution. This finding also corresponded with earlier research showing that cognitive tests and psychomotor tests are inclined to load on general cognitive ability or g (Carretta & Ree, 1997; Chaiken et al., 2000; Hunter & Hunter, 1984; McHenry et al., 1990; Rabbit et al., 1989; Ree & Carretta, 1994; Tirre & Raouf, 1998). The high loading of the Determination unit efficiency variable on the postulated g factor, could possibly be ascribed to the fact that the responses required for this test were complex (Jensen, 1993).

The fact that some of the psychomotor measures loaded on the general cognitive factor (g) rather than on the postulated psychomotor factor, may constitute evidence that reaction time is a measure of general cognitive ability as postulated by the information processing school of thought on intelligence (Jensen, 1982, 1993; Vernon as cited in Jensen, 1986). The research of Jensen (1982, 1986, 1993), Kranzler and Jensen (1991), Kyllonen and Christal (1990), and Miller and Vernon (1992) that indicated that the correlation between cognitive and psychomotor abilities might be due to cognitive abilities such as information processing speed, working memory capacity, and reaction time that typically also underlie good performance in many psychomotor tests, also found some indirect support in the results of the present study.

Another explanation for the finding that the psychomotor measures loaded on g, may be the view that the measurement of g is unavoidable in all measures of ability, because a degree of reasoning is unavoidable when responding to test material, regardless of whether the test requires a psychomotor response, specialized knowledge or verbal skills (Carretta & Ree, 1996a, 1996b). According to Jensen (1980), most tests would be reduced to practical uselessness once g has been partialled out.

In future research it should nevertheless be kept in mind that two-factor or three-factor solutions may be viable theoretically, because there is ample evidence for solutions including a general psychomotor factor (Carretta & Ree, 1997; Chaiken et al., 2000; Ree & Carretta, 1994; Vernon as cited in Walsh & Betz, 1990). When further studies are planned, the results of the present study may be used to plan which additional psychomotor tests should be included in an exploratory factor analysis. For instance, in the two-factor and three-factor solutions Factor 2 consisted of the two Two-hand coordination tests which, compared to the other psychomotor tests, made stringent demands on fine motor coordination. The respondents were required to move a cursor on a given track with the aid of two joysticks, one which can move forward and backward only, and one that can move right and left only. Hence candidates had to use both hands in a coordinated way to move the cursor through the track within acceptable accuracy limits. The track consisted of three sections varying in the demands made on the left and right hands. These results suggested that the Two-hand coordination tests defined a general psychomotor factor. Similarly, the combination of the Two-hand coordination accuracy and the ZBA time estimation variables in Factor 3 may indicate the presence of a psychomotor precision factor, because both measures required precision accuracy. The ZBA time estimation variable involved the accurate prediction of the speed at which an object was moving and deviations were measured in milliseconds, whereas the Two-hand coordination accuracy variable involved the assessment of the accuracy of small, precise movements. The possibility of the existence of such psychomotor factors may be worthy of investigation in future studies.

In conclusion, evidence for the concurrent validity of the cognitive measure, learning potential, for predicting the job performance of haul truck operators, was obtained for one of the criteria, namely supervisor ranking. This result corresponded with findings of other researchers that cognitive measures can predict job performance and training criteria (Gutenberg et al., 1983; Hartigan & Wigdor, 1989; Hunter, 1986; Hunter & Hunter, 1984; Jensen, 1986; Levine et al., 1996; Schmidt & Hunter, 1981, 1998; Schmidt et al., 1988). In this study limited evidence was found for the concurrent validity of psychomotor ability in a low level entry job requiring operating skills as was found by other researchers (Carretta, 1989, 1992; Carretta & Ree, 1994; Duke & Ree, 1996; Hartigan & Wigdor, 1989; Hunter & Burke, 1994; Hunter & Hunter, 1984; Levine et al., 1996; Martinussen, 1996; Schoeman, 1995; Wheeler & Ree, 1997). Only Cognitrone efficiency correlated significantly with one of the criteria, namely spotting time.

A possible reason for the paucity of significant predictors in this study is range restriction in the predictors for which no correction was made. This was a concurrent validity study and all the subjects were experienced operators. It can therefore be argued that limited variability in the performance on the psychomotor measures was to be anticipated. The severe kurtosis present in some of the psychomotor predictors, notably in the ZBA motion estimation accuracy, ZBA time estimation accuracy and Two-hand coordination accuracy measures, supported the notion of the operation of range restriction in this study. A cross-validation using a predictive design is recommended, because this would minimise the range restriction which is typical of concurrent designs. Range restriction was expected to be active in the current study, particularly due to the levels of experience of the candidates which influenced their scores on the predictors and hence confounding the relations between predictors and criteria. The presence of range restriction might have led to the validity estimates reported being much lower than they were in reality (Anastasi & Urbina, 1997; Cascio, 1998).

An important limitation of this study was that no attempt was made to control for the motivational aspects of operator performance, a typical limitation of concurrent validity designs (Anastasi & Urbina, 1997; Cascio, 1998). For the objective criteria, Spotting time and Corrected tons hauled, operator performance was assessed over a three-month period based on performance records captured on a routinely basis by the computerised dispatch system. The operators were therefore not aware of their performance being assessed. It is thus conceivable that the predictor variables related to driving ability, whereas the criterion variables related to driving behaviour. Driving behaviour could have been affected by a myriad of motivational factors that may have impacted on the correlations found in the study (Cascio, 1998, Deary, 2001), thereby depressing the validity coefficients obtained. It is recommended that all participants in future studies be informed that there will be systematic monitoring of their operating performance over a three-month period. Although this will not remove all motivational effects, it may have the effect of limiting their impact.

The criterion problem which plagues most validity studies, was also a relevant factor in the current study. Because the road network data and the consequent correction factor that was built in to correct for road gradient (the "effective flat haul rate") were suspect, criterion unreliability was suspected for the criterion, Corrected tons hauled. There was insufficient data available to attempt to estimate its effect and hence correction for attenuation of the validity coefficients could also not be attempted. Professional technical auditing of the computerised dispatch system should be undertaken before any further cross-validation studies are attempted to ensure that the objective criteria are reliable. Furthermore, the subjective criterion, namely Supervisor ranking, was obtained in a relatively rudimentary fashion using the paired comparisons ranking method (Cascio, 1998), the focus being on attempting to corroborate the findings of the objective criteria. Although the strong correlation between performance on the Spotting time criterion and the Supervisor ranking criterion appeared to indicate good reliability and validity of the Supervisor ranking criterion, it is advisable that a more robust performance measure such as a behaviourally anchored rating scale be used (Cascio, 1998; Latham & Saari, 1984) to improve the psychometric properties of the criterion and also to provide a better understanding of the performance levels of the various operators.

There are three criteria against which the effectiveness of selection procedures may be measured, namely productivity, safety and length of time taken to complete a training programme. Due to the limited scope of this study, productivity was the only criterion used. No attempt was made to link the predictors to safety or training criteria, both of which hold promise for further research.

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).

It can also be argued that the Vienna Test System subtests relate better to safety than to productivity measures. For instance, the Cognitrone yields data in terms of the candidates' ability to concentrate and to adjust their work tempo to different stimuli patterns (Schuhfried, 2000a). The Determination unit focuses on operators' capacity to make appropriate and fast responses in rapidly changing environments that may involve stress Schuhfried, 1996). The test starts off slowly, gains speed to a very fast response requirement (approximating high stress situations, e.g. 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 on candidates' hand-eye and hand-hand coordination, which is conceptually related to safety because of small movements that need to be made during the spotting in process in tight loading conditions (Schuhfried, 2000c). The Distance estimation time and motion measures attempt to identify those 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 (Schuhfried, 2000b). It is clear that the Vienna Test System subtests have a strong conceptual link to safety and therefore it is recommended that the safety variables pertinent to haul truck operator performance should be measured using a simulator. Scores on the predictor variables can then be correlated with the safety variables, such as the number of times during the simulation exercise that the operator stopped too late, underestimated the speed of approaching vehicles, or displayed risk behaviour (such as driving too fast or overtaking on an incline).

Bearing in mind the limitations of the present study that were pointed out above, and the fact that only partial evidence for the concurrent validity of the TRAM 1 Learning potential measure and the Vienna Test System in predicting job performance of haul truck operators was found, it is recommended that further research be conducted to correct these limitations. In particular, attention should be paid to using safety variables as job performance criteria.

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