2013

Selection System Prediction Of Safety: A Step Toward Zero Accidents In South African Mining

Rachel Aguilera-Vanderheyden
Minnesota State University - Mankato

SELECTION SYSTEM PREDICTION OF SAFETY: A STEP TOWARD ZERO

ACCIDENTS IN SOUTH AFRICAN MINING

BY

RACHEL AGUILERA-VANDERHEYDEN

A THESIS SUBMITTED IN

PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

IN

INDUSTRIAL/ORGANIZATIONAL PSYCHOLOGY

AT

MINNESOTA STATE UNIVERSITY, MANKATO

MAY 2013

ACKNOWLEDGEMENTS

I would like to thank all of the individuals who have supported me in various ways throughout the process of completing my thesis. A special thanks to my advisor, Dr. Daniel Sachau, who provided me with the opportunity to study mining injuries in South Africa, and who was an integral part of the development and editing of my thesis. I would also like to thank my committee members, Dr. Kristie Campana and Dr. Kathleen Dale, for their valuable feedback. A special thank you to my husband, Santiago, for his continued patience and encouragement. Thank you to my family and friends, who have taken interest in all of my ventures including my research, and have supported me in my journey. Finally, I would like to express my gratitude to JvR Consulting for providing the data for this study, without which this research would not have been possible.

Abstract

The research for the following paper titled, Selection System Prediction Of Safety: A Step Toward Zero Accidents In South African Mining and authored by Rachel Aguilera-Vanderheyden was conducted at Minnesota State University, Mankato located in Mankato, Minnesota. This study was a requirement of the Industrial/Organizational Psychology Master's Program and was conducted during the 2012-2013 academic school year.

Underground mining is a high-risk industry with a history of frequent accidents and deaths. The purpose of this study is to identify cognitive and psychomotor factors that may predict, and ultimately be used to prevent injuries. More specifically, I tested the extent to which the Raven's Progressive Matrices, a measure of cognitive ability, and the Vienna Test System, a measure of psychomotor ability, predicted injury – It was hypothesized that the Raven's scores would explain additional unique variance beyond the psychomotor scores alone. The results show that the Raven's scores were significantly predictive of Serious Injuries when analyzed in isolation, however, the scores did not explain unique variance when analyzed with other psychomotor variables. Models were established for predicting injuries across three injury levels (Dressing Case, Lost Time, and Serious Injury). Expected increases in accuracy of predicting were identified and translated into expected cost savings for the organization studied.

Table of Contents

CHAPTER

I. INTRODUCTION 1
South African Mining 2
Predicting Safety Compliance and Outcomes 3
Psychomotor Ability 4
Cognitive Ability 5
The Present Study 7
Hypotheses 7

II. METHOD 8
Participants 8
Measures 8
Injury data 8
Vienna Test System (VTS) 8
Raven's Standard Progressive Matrices 13
Paterson Job Grade 13
Absenteeism 14

III. RESULTS 15
Hypothesis #1 16
Hypothesis #2 20
Hypothesis #3 20

IV. DISCUSSION 21
Limitations 25
Future Research 25

V. REFERENCES 27

VI. APPENDIX A 30

CHAPTER I

INTRODUCTION

Worldwide, mining is a high-stakes industry in which people risk their lives every day. In 2010 alone, there were 70 mining fatalities in the U.S., a fatality rate of 25.4 per 100,000 full time employees (Centers for Disease Control and Prevention, 2012). Mining employs one percent of the global workforce, yet is disproportionately responsible for eight percent of fatal workplace accidents (International Labour Organization, 2010). Due to the nature of the work, injuries and deaths have historically been accepted as an inevitable consequence of mining (Cullen, Camm, Jenkins & Mallet, 2006).

The most frequent types of injuries and fatalities are those involving fall of ground (rock falls), transportation, machinery, gassings, slips, falls, collapse of materials, and rolling rocks (Department of Minerals and Energy, 2008; van Niekerk, 2012). These types of accidents and fatalities are typically the result of a failure to comply with safety policies and regulations (Jansen & Brent, 2005).

While injuries and deaths are tragedies, they are also very expensive. According to the U.S. Department of Labor, Mine Safety & Health Administration (n.d.), the cost of a mining injury without lost work time is approximately $7,000 USD. The cost of an injury with lost work time is $27,000 USD, and the cost of a mining fatality is nearly $1,000,000 USD. These estimates include not only the obvious worker compensation costs, but also the costs of training a replacement worker, repairing equipment, and investigating the incident. Accident costs have prompted many mining companies to increase their investment in safety (PWC, 2011).

A number of key factors pose a safety risk in mining including unpredictable natural events, engineering flaws, a weak culture of health and safety (lack of support and value of safety at one or multiple levels of the organization), and human error. Historically, safety researchers focused their efforts on improving engineering for a safer mining workplace. However, Paul & Maiti (2007) suggest these efforts that address engineering "followed the law of diminishing returns," and are no longer reducing accidents with their previous success (p.450). Consequently, researchers are turning their attention to safety culture and preventing error – the human side of the safety equation. This provides hope for accident prevention through selection and training of employees.

South African Mining

The South African mining industry employs about 500,000 South Africans and accounts for approximately 18% of the nation's GDP (Statistics South Africa, 2012; Chamber of Mines, 2012). Because of mining's central role in their economy, South Africans both reap the benefits and suffer the consequences of mining. South Africa's deep-level gold mines are among the most dangerous work environments in the world. Over the last century there have been between 69,000 and 100,000 deaths and more than one million injured (Department of Mineral Resources, 2009). South Africa holds approximately 40% of the world's available resources, with 1,600 mines, and a sizable proportion of the world's mining accidents (allAfrica, 2013). Compared to the 70 U.S. mining fatalities in 2010, South Africa had what they considered a successful year with only 127 fatalities in 2010 (Centers for Disease Control and Prevention, 2012; van Niekerk, 2012).

In an attempt to improve the safety of South African mines, the Mining Health and Safety Act 29 was instated in 1996. This Act requires employers to provide a safe work environment for their employees, to conduct investigations after accidents occur, and to promote a strong culture of health and safety in the mines (United States Department of Labor, Mine Safety & Health Administration: Synopsis of Mining Law, n.d.). This Act holds all parties responsible for ensuring a safe work environment and preventing future mining accidents.

Despite improvements in death and injury rates over the past 10 years, the fatality and injury rates are still unacceptably high (Department of Mineral Resources, 2011). There were 123 fatalities in South African mining in 2011 alone (Chamber of Mines of South Africa, 2012). The mining industry is no longer accepting the notion that accidents are inevitable, and has established a new goal of zero accidents (Cullen et al, 2006). South African President Jacob Zuma emphasized the "need to vigorously support and entrench a culture of zero harm in [the mining] industry" ("Mining Safety in South Africa," n.d.).

Predicting Safety Compliance & Outcomes

A lack of safety compliance is an antecedent of workplace accidents, which makes it of interest for the present study. Safety compliance may take the form of abiding by safety regulations, making use of the appropriate safety equipment, or following protocol to report accidents (Turner et al, 2012). Researchers have identified a variety of predictors of employee compliance with safety rules. For example, perceived social support of one's colleagues for work-related matters has a positive relationship with safety compliance (Turner et al, 2012). This was thought to be the case due to the team-based environment of the study. Striving to reach a goal as a team, there is more accountability and motivation to proceed in accordance with safety regulations. Organizational trust has also been found to help bridge the gap between the existing safety climate in an organization and an individual's motivation to engage in safe behaviors (Kath, Magley & Marmet, 2010). Additional factors that positively predict safety-related workplace behaviors include safety knowledge, safety motivation, the ability to predict dangerous outcomes, and an internal locus of control for influencing safety in the work environment (Christian, Bradley, Wallace & Burke, 2009; Snyder et al, 2011). It is clear that individual differences have a strong impact on employee safety compliance. The present study will add to the literature on individual differences predictive of workplace injury by focusing on psychomotor ability and cognitive ability.

Psychomotor Ability

Psychomotor ability is "the process of interaction between the perceptual systems (or five senses), the brain (where perceptual information is interpreted) and the body (where the individual reacts to such perceptual stimuli)" (JvR Histories, n.d.). Psychomotor ability has been studied for centuries, and has largely been tied to job performance as the outcome of interest. While job performance and safety outcomes are different metrics, they are not mutually exclusive. Especially in the high-risk work environment of mining, an employee must perform safely in order to perform well (Edmonds-Ward & Trendell, 1998). Because psychomotor ability is predictive of job performance, it is also likely related to safety outcomes (Hunter & Hunter, 1984). Vorster, Pires & Taylor (2011) found support for this notion, providing evidence for a connection between psychomotor abilities and accidents within a mining context. A number of psychomotor metrics were shown to have curvilinear relationships with accidents on the job. In a study by Karner (2000) the psychomotor "test results of the drivers who had committed alcohol-related offences were significantly worse than those of the norm population" (as cited in Schuhfried, n.d.). Salgado (1994) also found psychomotor ability to be a significant predictor of accidents with a validity coefficient of .33 (as cited in Anderson, 2001).

More specifically, psychomotor ability has been shown to be increasingly predictive of job performance as job complexity decreases (JvR Histories, n.d.; Pelser, 2009; Hunter & Hunter, 1984; Carretta & Ree, 2000). In other words, when job complexity is low, psychomotor ability will be much more highly related to job performance than when the job complexity is high. Psychomotor ability is a more relevant, better predictor of performance for simple frontline jobs than it is for higher-level managerial jobs. Due to the interrelatedness of safety compliance and job performance, one would expect to see a similar relationship between psychomotor ability and safety compliance.

Cognitive Ability

Cognitive ability has been described as:

> The ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings – 'catching on,' 'making sense' of things, or 'figuring out' what to do (Gottfredson, 1997).

Meehl (1993) notes that while frequently thought of as operating solely in educational or vocational contexts, cognitive ability is, in fact, an individual difference that penetrates all aspects of life (as cited in Lubinski, 2004). Cognitive ability has been a central topic of study in the social sciences over the past 100 years and it has been connected to many outcomes of interest. Cognitive ability is a predictor of numerous outcomes such as physical, economic, and psychological well-being, socio-economic status (Judge, Ilies & Dimotakis, 2010), positive affect (Chmiel et al, 2012), counterproductive work behaviors (e.g. absenteeism) (Dilchert, Ones, Davis & Rostow, 2007), and training success (Bertua, Anderson & Salgado, 2005). There is some research tying cognitive ability to workplace injury (Ferguson, McNally & Booth, 1984), however, the outcome most frequently and strongly associated with cognitive ability is job performance (Bertua et al, 2005; Carretta & Ree, 2000; Hunter & Hunter, 1984; JvR Histories, n.d.; Pelser, 2009).

The nature of the cognitive ability and job performance relationship is the inverse of that between psychomotor ability and job performance. The more complex a job, the better cognitive ability will predict job performance (Carretta & Ree, 2000). This relationship is also expected to be true with respect to predicting accidents. The higher the cognitive requirement for completing a task successfully, the higher the probability human error will occur (Ford & Wiggins, 2012). This is of critical importance, as human error is a direct component leading to occupational accidents and injuries, and is also involved in system and equipment failures (Reinach & Viale, 2006 as cited in Ford & Wiggins 2012; Reason, 2000). This suggests that possessing high cognitive ability in a more complex job is important and should minimize negative outcomes by successfully meeting the cognitive requirements. Translating this relationship from job performance to its subcomponent of safety compliance, we would expect that for highly complex jobs, cognitive ability would positively predict safety compliance, and ultimately, accidents.

The Present Study

The present study will address the validity of psychomotor ability, as measured by Vienna Test System scores, and cognitive ability, as measured by Raven's Progressive Matrices scores, as predictors of gold mining accidents in one South African company. Counterproductive Work Behaviors, as measured by absenteeism, will also be examined to further establish the link from predicting job performance to predicting safety. The goal of this study is to identify which individual differences are indicative of a miner likely to be part of a workplace accident. This information could be used for potential selection requirements, ultimately minimizing injuries and fatalities in the mine.

Hypotheses. It is hypothesized:

1. Raven's Progressive Matrices scores will explain unique variance toward the prediction of accidents, beyond that explained by the Vienna Test System scores of psychomotor ability alone.
2. As job complexity increases, as measured by Paterson job grade categorization, the predictive validity of the Raven's Progressive Matrices scores will increase, and the predictive validity of the Vienna Test System scores will decrease when assessing injuries as the outcome of interest.
3. Counterproductive Work Behaviors, as measured by absenteeism, will be positively correlated with accidents in the workplace when controlling for time off due to injury.

CHAPTER II

METHOD

Participants

Data was collected from 337 miners across 7 mines of a large South African gold mining company. The sample was largely male (97.6%), and ranged the five occupations of Loco Operator (55.2%), Scraper Winch Operator (32.9%), Loader Operator (7.4%), New Era Loco Operator (2.4%), and Single Drum Winch Operator (2.1%).

Measures

Data collected includes injury data ranging three levels of severity (dressing case, lost time, and serious injury), Vienna Test System scores on six subtests (2HAND, DT, ZBA, LVT, RT, and COG subtests), Raven's Progressive Matrices scores, Paterson job grades (job complexity) per occupation, as well as absenteeism data.

Injury data. Injuries were labeled as one of three categories, each with varying degrees of severity. Dressing Case is the first category, consisting of injuries that need attention, medical or otherwise, but are treated in-house and do not result in any days off due to injury. The next category is a Lost Time Injury in which a worker is unable to work the day after an injury, up to a couple shifts after the injury. Finally, Serious Injuries are categorized as severe due to production time lost, possible equipment or infrastructure damage, financial cost for medical treatment or payment to families of injured workers, or possible loss of life.

Vienna Test System (VTS). VTS scores of psychomotor ability were collected from the following six subtests:

1. The Two-Hand Coordination (2HAND) test assesses "Testing of visuomotor coordination (eye-hand and hand-hand coordination)" (Schuhfried, n.d.). The test-taker is to guide a dot through a maze with both straight and curved track components, given a joystick for each hand that only propels the dot up and down or left to right (Figure 1). This test is scored on both time taken to complete the maze, as well as amount of time spent outside of the maze lines (in error).

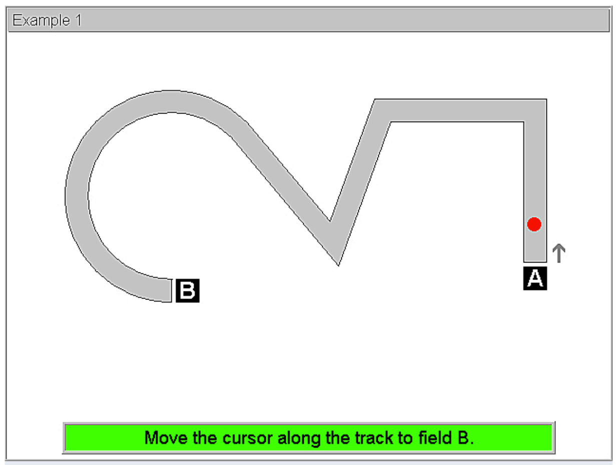

Figure 1. Example of the Two-Hand Coordination (2HAND) Subtest (Schuhfried, n.d.)

2. The Determination Test (DT) assesses an individual's "reactive stress tolerance and the associated ability to react" (Schuhfried, n.d.). The test-taker receives visual and audio stimuli, and is to accurately respond to these prompts with the appropriate reaction (Figure 2). The DT consists of three phases: practice, stress, and recovery. The individual gets comfortable with the test during the practice phase, is stressed during the second phase through increased speed of prompts, and is then given a third phase that is again a slowed pace of prompting to demonstrate ability to recover from stress. Individuals are scored on reaction time as well as correct, incorrect, delayed, and omitted number of reactions.

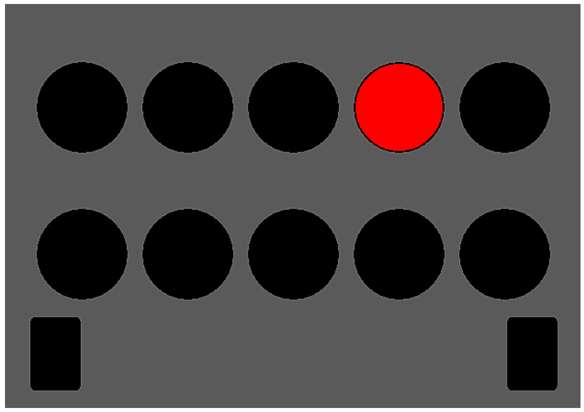

Figure 2. Example of the Determination Test (DT) Subtest (Schuhfried, n.d.)

3. The Time Movement/Anticipation test (ZBA) assesses “an individual’s ability to imagine the effect of a movement and correctly estimate the movement of objects in space” (Schuhfried, n.d.). As the individual watches a ball move across the computer screen, the ball suddenly disappears and they are to indicate when and at what position the ball would have crossed a line (Figure 3). Data is recorded on the time and position accuracy.

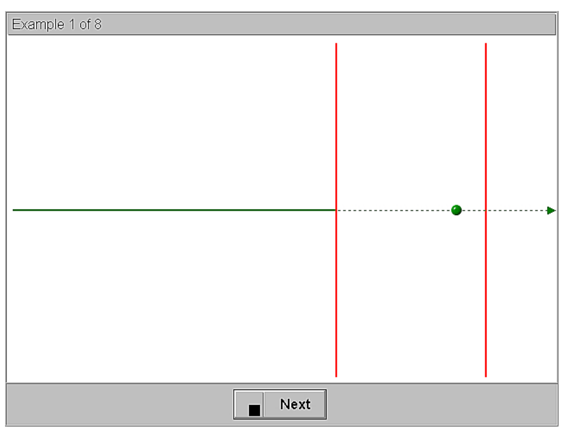

Figure 3. Example of the Time/Movement Anticipation Test (ZBA) Subtest (Schuhfried, n.d.)

4. The Visual Pursuit Test (LVT) assesses “visual orientation ability and skill in gaining an overview” (Schuhfried, n.d.). Test-takers are presented with an image of many intertwined lines creating a maze. When told which line to follow through the maze on one end, individuals must identify where the line comes out on the other end of the maze (Figure 4). Data is collected on accuracy, speed, and the number of mazes completed.

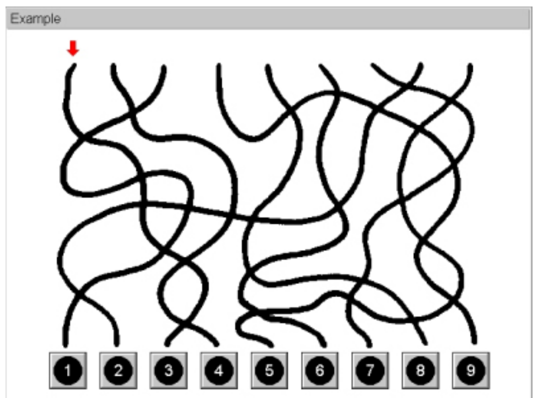

Figure 4. Example of the Visual Pursuit Test (LVT) Subtest (Schuhfried, n.d.)

5. The Reaction Test (RT) assesses “reaction time and motor time” (Schuhfried, n.d.). Test-takers are to keep their finger on a button and only remove it to press a second button when presented with a specific combination of audio and visual stimuli (Figure 5). Data is collected on accuracy, completeness and speed of responses.

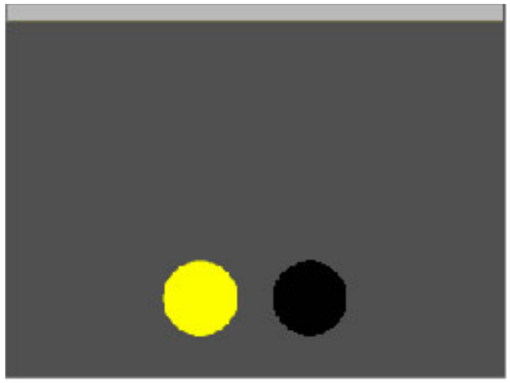

Figure 5. Example of the Reaction Test (RT) Subtest (Schuhfried, n.d.)

6. The Cognitrone test (COG) assesses "attention and concentration through comparison of figures with regard to their congruence" (Schuhfried, n.d.). Individuals are presented with four constant figures and one figure below that changes after each response (Figure 6). The test-taker must indicate if the figure below matches any of the four constant figures, maintaining attention through a monotonous task. The test is scored on accuracy and reaction time of responses.

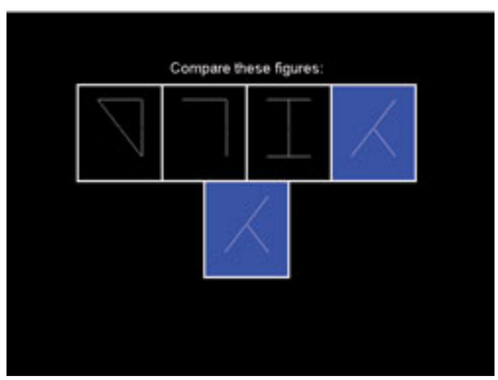

Figure 6. Example of the Cognitrone Test (COG) Subtest (Schuhfried, n.d.)

Raven's Standard Progressive Matrices. The Raven's Standard Progressive Matrices measure of cognitive ability is of special interest for the present study due to its language-free format, which greatly minimizes language and cultural biases in assessment (Pearson, n.d.). Within the context of South African mining, Raven's Standard Progressive Matrices is the most obvious choice for cognitive ability selection tests due to the country's extremely diverse population with respect to both language and culture. South African miners may speak any of the 11 official languages, numerous indigenous languages, and/or Fanagalo – a pidgin language created in the gold mines.

Raven's Progressive Matrices data were obtained from miners at the time of application for their current position. This measure of cognitive ability presents the test-taker with a large image that has a piece missing. The test-taker must identify which of the 6 options presented is the match for the missing piece of the large image (Figure 7). Tests are scored on accuracy of responses for all items. Raw scores on this measure were used for analyses.

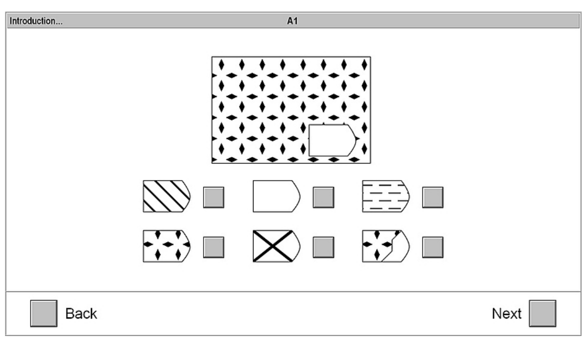

Figure 7. Raven's Standard Progressive Matrices Example Item (Schuhfried, n.d.)

Paterson job grade. The Paterson job grade classification data were collected for each of the occupations present in the sample. Using this system, jobs are ranked according to their decision-making requirements. Ranks in the present sample ranged from A4D to B6N, including a total of 7 levels. This classification was used as a measure of job complexity for the present study.

Absenteeism. Absenteeism data was collected for a 200-day span, from July 2012 to January 2013. For the purposes of the present study, the category of Absent Without Permission was used for analyses, as it is most representative of counterproductive work behavior.

CHAPTER III

RESULTS

Data was collected from multiple sources within the mining organization, and combined in order to conduct comparative analyses. Total injuries per individual ranged from 0 to 6, and were categorized according to level of severity as a Dressing Case, a Lost Time Injury, or a Serious Injury. However, due to restriction of range of injuries (employees with zero or one injury made up 91.4% of dressing cases, 95.3% for Lost Time injuries, and 96.7% for Serious Injuries), these variables were dichotomized for analyses across each of the levels of severity. The dichotomized variables resulted in 21.1% of all employees having zero injuries, 46.3% with dressing cases, 43.9% with lost time injuries, and 25.2% with serious injuries (Note: the total of all injury and non-injury percentages does not equal 100%, as individuals could have multiple types of injuries).

The complete list of psychomotor and cognitive variables assessed in the following analyses can be found in Appendix A.

The Determination Test (DT) subtest consisted of 3 phases (practice, stress, recovery) in which seven variables were measured during each phase. These variables were averaged across phases to create an overall metric for the DT, in order to minimize the issue of shared variance, as there was a high correlation of variables across phases.

Logistic regression was the statistical analysis chosen for this study because the predicted dependent variables were dichotomized (yes = 1, no = 0 for three injuries levels), and the predictor variables were not all normally distributed (See appendix A).

Hypothesis #1

To test the first hypothesis, forward (likelihood ratio) logistic regression was used to compare the predictive validity of the Raven's Progressive Matrices raw scores to the six subtests of the Vienna Test System Psychomotor Ability assessment when predicting injuries. The forward (LR) type of regression was chosen due to the lack of literature to provide strong evidence suggesting certain psychomotor variables over others. A logistic regression was conducted separately on Raven's scores and each of the six subtest blocks of variables for each of the three levels of injuries. From each logistic regression, any significant predictors were identified and compiled into a preliminary model. Table 1 shows the significant variables from each logistic regression predicting Dressing Case injuries, Lost Time injuries, and Serious Injuries. Three variables were found significant predictors of Dressing Case injuries, seven of Lost Time injuries, and seven of Serious injuries for each respective preliminary model.

Table 1. *Preliminary Predictive Model Identified by Logistic Regression – Significant Variables Predicting Injuries at Dressing Case (n=156), Lost Time (n=148), and Serious Injury (n=85) Levels*

Predicting Dressing Case Injuries

Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^{β} (odds ratio)
DT (Averaged Variables)						
On Time Reactions[a]	-.007	.002	11.404	1	.001	.993
ZBA						
Median Deviation Time[b]	.309	.134	5.325	1	.021	1.362
LVT						
Overall Score[c]	-.041	.015	7.280	1	.007	.959

a. Cox & Snell R^2=.035; Nagelkerke R^2=.047
b. Cox & Snell R^2=.016; Nagelkerke R^2=.022
c. Cox & Snell R^2=.038; Nagelkerke R^2=.051

Predicting Lost Time Injuries

Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^{β} (odds ratio)
2HAND						
Overall Mean Duration[a]	.010	.005	4.503	1	.034	1.010
DT (Averaged Variables)						
Correct Reactions[b]	-.011	.003	12.304	1	.000	.989
ZBA						
Median Deviation Time[c]	.290	.137	4.477	1	.034	1.337
Median Direction Deviation[c]	.020	.007	8.349	1	.004	1.020
LVT						
Overall Score[d]	-.041	.015	7.218	1	.007	.960
RT						
Mean Motor Time[e]	.003	.002	4.158	1	.041	1.003
COG						
% of Incorrect Reactions[f]	.051	.020	6.643	1	.010	1.052

a. Cox & Snell R^2=.016; Nagelkerke R^2=.022
b. Cox & Snell R^2=.038; Nagelkerke R^2=.051
c. Cox & Snell R^2=.051; Nagelkerke R^2=.068
d. Cox & Snell R^2=.038; Nagelkerke R^2=.051
e. Cox & Snell R^2=.016; Nagelkerke R^2=.022
f. Cox & Snell R^2=.033; Nagelkerke R^2=.044

Predicting Serious Injuries

Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^{β} (odds ratio)
Ravens Raw Score[a]	-.025	.010	5.843	1	.016	.975
2HAND						
Overall % Error Duration[b]	.063	.024	6.885	1	.009	1.066
DT (Averaged Variables)						
Correct Reactions[c]	-.014	.004	14.167	1	.000	.987
ZBA						
Median Deviation Time[d]	.291	.149	3.872	1	.050	1.338
Median Direction Deviation[d]	.015	.006	6.602	1	.010	1.015
LVT						
Overall Score[e]	-.062	.017	13.010	1	.000	.940
COG						
% of Incorrect Reactions[f]	.037	.016	5.697	1	.017	1.038

a. Cox & Snell R^2=.017; Nagelkerke R^2=.026
b. Cox & Snell R^2=.024; Nagelkerke R^2=.037
c. Cox & Snell R^2=.044; Nagelkerke R^2=.065
d. Cox & Snell R^2=.037; Nagelkerke R^2=.054
e. Cox & Snell R^2=.065; Nagelkerke R^2=.102
f. Cox & Snell R^2=.022; Nagelkerke R^2=.032

Due to the significance derived from separate logistic regressions when creating the preliminary model, it was necessary to identify multicollinearity among variables within each of the three preliminary models (See predictor correlations in Table 2). This was accomplished, and the final model established, by including all predictive factors within their respective injury level models into forward (LR) logistic regressions. The corresponding final models can be found in Table 3.

Table 2. *Correlations of predictors in preliminary models*

	1	2	3	4	5	6	7	8	9	10
1. Ravens	1.00									
2. 2HAND - Overall % Error Duration	-.172**	1.00								
3. 2HAND – Overall Mean Duration	-.034	.247**	1.00							
4. DT - Correct Reactions	.293**	-.351**	-.273**	1.00						
5. DT – On Time Reactions	.252**	-.333**	-.319**	.916**	1.00					
6. ZBA - Median Deviation Time	-.136*	.232**	.423**	-.233**	-.254**	1.00				
7. ZBA - Median Direction Deviation	-.061	.037	.200**	-.123*	-.130*	.134*	1.00			
8. LVT - Overall Score	.157*	-.268**	-.318**	.329**	.341**	-.264**	-.038	1.00		
9. RT – Mean Motor Time	-.143*	.007	-.039	-.256**	-.229**	-.030	.261**	-.066	1.00	
10. COG - % of Incorrect Reactions	-.243**	.329**	.054	-.256**	-.190**	.234**	.043	-.082	.001	1.00

* $p<.05$, ** $p<.01$

Table 3. *Final Composite Models of Significant Variables Predicting Injury at Dressing Case, Lost Time, and Serious Injury Levels*

Predicting Dressing Case Injuries

Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^{β} (odds ratio)
DT (Averaged Variables)						
On Time Reactions[a]	-.007	.003	7.600	1	.006	.993

a. Cox & Snell R^2=.035; Nagelkerke R^2=.047

Predicting Lost Time Injuries

Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^{β} (odds ratio)
ZBA						
Median Direction Deviation[a]	.026	.008	11.041	1	.001	1.026

a. Cox & Snell R^2=.061; Nagelkerke R^2=.083

Predicting Serious Injuries

Predictor	β	*SE* β	Wald's χ^2	*df*	*p*	e^{β} (odds ratio)
ZBA						
Median Direction Deviation[a]	.023	.007	10.979	1	.001	1.023
COG						
% of Incorrect Reactions[a]	.077	.034	4.962	1	.026	1.080

a. Cox & Snell R^2=.079; Nagelkerke R^2=.125

The Dressing Case final model increased predictive accuracy from 57.6% to 63.1%. The Lost Time final model increased predictive accuracy from 61.7% to 66.1%, and the Serious Injury final model increased predictive accuracy from 80.3% to 81.9%.

Although the Raven's Progressive Matrices raw scores were predictive of Serious Injuries at the preliminary model phase, they did not prove to explain any unique variance beyond that assessed by the Vienna Test System psychomotor subtests, and were therefore removed in the final model through the forward (LR) logistic regression. The first hypothesis was not supported.

Hypothesis #2

The second hypothesis comparing the differing predictive abilities of the Ravens and VTS measures on injuries across job complexity levels was unable to be conducted due to only 23 individuals in the "high job complexity" group. 93.2% of the present sample was categorized as an A4D level.

Hypothesis #3

To test the third hypothesis, a point-biserial correlation was conducted between the "Absent Without Permission" variable and:

- Dressing Case Injuries (r = -.064; *p* = *n.s.*)
- Lost Time Injuries (r = .048; *p* = *n.s.*)
- Serious Injuries (r = -.030; *p* = *n.s.*)
- Total Injuries(r = -.020; *p* = *n.s.*)

There was no relationship found between absenteeism and injuries.

CHAPTER IV

DISCUSSION

Through logistic regression analyses, specific psychomotor assessment metrics were identified as being predictive of injuries at the Dressing Case, Lost Time, and Serious Injury levels. The particular tests of interest for the final predictive model included components of the Determination Test (Dressing Case), the Time/Movement Anticipation Test (Lost Time & Serious Injury), and the Cognitrone Test (Serious Injury). While it was expected that the Raven's Progressive Matrices scores would provide unique predictive validity for injuries beyond that which the Vienna Test System could provide on its own, this was not supported. What was found was that the Raven's scores did prove to be significantly related to injuries. However, due to the overlap in variance explained through other psychomotor factors, the Raven's was not statistically significant when added to the final model.

The most likely reason for the present findings is that the psychomotor subtests already assess sufficient components of cognitive ability, rendering the addition of a separate cognitive ability measure redundant. According to Carretta & Ree (2000), there is a modest relationship between cognitive ability and psychomotor ability. While cognitive ability does seem to be important for predicting Serious Injuries, the variable from the Cognitrone Test (percentage of incorrect reactions) in the final model for Serious Injuries was significantly correlated with Raven's scores (r = -.234, p<.001), which may explain why it was not predictive in the final model with the Cognitrone variable.

Despite the fact that the first hypothesis was not supported, the findings of this study are still able to provide insight for the mining company with regard to their selection process. While job performance data separate from injuries was unavailable for analysis, it is uncertain which components of the psychomotor assessment successfully predict job performance. Therefore, it is not suggested to eliminate all subtests that were not found significant in this study, but rather to focus on the outlined variables in this paper in order to also consider safety outcomes during the selection process. To demonstrate the likely decrease of injuries in the workplace by upholding certain cut scores on the significant measures, the predictors of the three final models are shown in the expectancy tables below (see Tables 3-6).

Table 3. *Expectancy Table: The Impact of Various DT On Time Reactions Cutoff Scores on Dressing Case Injuries*

	Bottom Quartile	Second Quartile	Third Quartile	Top Quartile
No Injury	32	46	48	54
Yes Injury	51	36	36	29

Note: Success rate of predictor with cut score including top quartile: 54/83 (65.1%)
Success rate of predictor with cut score including top 2 quartiles: 102/167 (61.1%)
Success rate of predictor with cut score including top 3 quartiles: 148/249 (59.4%)

The success rate of the current selection system with regard to successfully predicting Dressing Case injuries is 181/337, or 53.7%. If the organization has the ability to be more selective in their hiring processes, they could expect to see that success rate increase to 65.1% by only selecting the top quartile of applicants based on their averaged score on the Determination Test number of On Time Reactions (Table 3). In other words, for every 100 people hired, the mine would decrease their number of Dressing Case injuries by about 11. Knowing the cost of a Dressing Case injury to be about $7,000 USD, this decrease would save the company about $77,000 USD for every 100 individuals hired

(United States Department of Labor, Mine Safety & Health Administration: Costs of Accidents, n.d.).

Table 4. *Expectancy Table: The Impact of Various ZBA Median Direction Deviation Cutoff Scores on Lost Time Injuries*

	Bottom Quartile	Second Quartile	Third Quartile	Top Quartile
No Injury	36	47	47	55
Yes Injury	47	41	31	28

Note: Success rate of predictor with cut score including top quartile: 55/83 (66.3%)
Success rate of predictor with cut score including top 2 quartiles: 102/161 (63.4%)
Success rate of predictor with cut score including top 3 quartiles: 149/249 (59.8%)

The success rate of the current selection system for predicting Lost Time injuries is 189/337, or 56.1%. By only selecting only the top quartile of applicants based on their scores on the Time/Movement Anticipation Test (ZBA) Median Direction Deviation measure, the organization could expect to see the success rate for predicting Lost Time injuries increase to 66.3% (Table 4). The change in success rate implies that for every 100 people hired by selecting only the top quartile applicants, there would be a decrease of over 10 Lost Time injuries. Knowing the average cost of a Lost Time injury to be about $27,000 USD, this new selection standard could save the organization $270,000 USD per 100 hires (United States Department of Labor, Mine Safety & Health Administration: Costs of Accidents, n.d.).

Table 5. *Expectancy Table: The Impact of Various ZBA Median Direction Deviation Cutoff Scores on Serious Injuries*

	Bottom Quartile	Second Quartile	Third Quartile	Top Quartile
No Injury	58	66	60	63
Yes Injury	25	22	18	20

Note: Success rate of predictor with cut score including top quartile: 63/83 (75.9%)
Success rate of predictor with cut score including top 2 quartiles: 123/161 (76.4%)
Success rate of predictor with cut score including top 3 quartiles: 189/249 (75.9%)

Table 6. *Expectancy Table: The Impact of Various COG % of Incorrect Reactions Cutoff Scores on Serious Injuries*

	Bottom Quartile	Second Quartile	Third Quartile	Top Quartile
No Injury	54	65	63	67
Yes Injury	29	19	19	16

Note: Success rate of predictor with cut score including top quartile: 67/83 (80.7%)
Success rate of predictor with cut score including top 2 quartiles: 130/165 (78.8%)
Success rate of predictor with cut score including top 3 quartiles: 195/249 (78.3%)

The success rate of the current selection system for predicting Serious Injuries is 252/337, or 74.8%. This is better than the success rate for the two previous classes of injury, but there remains room for improvement. While the predictor variable from the Time Movement/Anticipation Test (ZBA), Median Direction Deviation, does provide some statistical improvement to the success rate of selection on Serious Injuries, it appears that the bulk of practical improvement is derived from the Cognitrone test (COG) variable, Percentage of Incorrect Reactions (Tables 5 & 6). By selecting only the top quartile of applicants based on their score on the Cognitrone Percentage of Incorrect Reactions, the success rate for Serious Injuries would be expected to increase to 80.7%. Therefore, for every 100 individuals hired, Serious Injuries would decrease by about 6. With the average cost of a Serious Injury nearing $1,000,000 USD, this means that for every 100 applicants hired under this selection standard, the company could expect to save nearly $6,000,000 USD (United States Department of Labor, Mine Safety & Health Administration: Costs of Accidents, n.d.).

Overall, if applying this top quartile standard across the significant variables in each of the three final models, the organization is looking at a savings of $6,347,000 USD and about 27 fewer injuries per 100 individuals hired.

Limitations

A limitation of the present study was related to the lack of variance in Paterson job grades necessary for conducting analyses on the second hypothesis. While a central part of the study was intended to assess predictive ability differences based on job complexity, this was not possible with the present sample of employee data.

With respect to the unsupported third hypothesis, it is important to consider the context of when the absenteeism data was collected. This data came from the 200-day span between July 2012 and January 2013. During this time, there were a number of major strikes in the South African mining industry. While absences due to strikes were categorized under a separate variable, the strikes greatly minimized the opportunity for personal absences without permission of an already short timespan. By decreasing the days of opportunity for regular absences, this may have hidden any potential relationships with injuries. It would be ideal for future studies to obtain data for a longer span of time to lessen any impact of absence due to mine or country-wide strikes.

Future Research

It would be of great benefit for researchers to establish different injury prediction models based on job level complexity to more accurately identify the core traits associated with the employees' differing tasks. Also, due to the limited number of studies using psychomotor scores to predict mining injuries, research should be conducted to replicate the findings of the present study. While individual differences and human error are but one piece of the injury puzzle, any improvement that can be made to increase the safety of the mining environment is greatly needed. Each small improvement means fewer injured workers, fewer fatalities, and a more effective and safer workforce. Due to the great importance of these safety outcomes, in both employee safety/health/life as well as monetary, this field merits more research.

CHAPTER V

REFERENCES

allAfrica. (2013, February 05). Retrieved from South Africa: Govt 'Committed to Future of SA Mining': http://allafrica.com/stories/201302051073.html

Anderson, N. (2001). Handbook of industrial, work & organizational psychology. London: Sage. Available from http://www.sage-ereference.com.ezproxy.mnsu.edu/hdbk_orgpsych1/.

Bertua, C., Anderson, N., & Salgado, J. (2005). The predictive validity of cognitive ability tests: A UK meta-analysis. *Journal of Occupational and Organizational Psychology , 78*, 387-409.

Carretta, T., & Ree, M. (2000). Validity and Utility of Alternative Predictors of Job Performance. *Ability and Personnel Selection , 8* (4), 227-236.

Centers for Disease Control and Prevention. (2012, September 18). *Statistics: All Mining*. Retrieved 2013, from Office of Mine Safety and Health Research: http://www.cdc.gov/niosh/mining/statistics/allmining.html

Chamber of Mines. (2012). *Facts & Figures 2012.* Retrieved from http://www.bullion.org.za/documents/F_F_2012_Final_Web.pdf

Chamber of Mines of South Africa. (2012). *Facts and Figures*. Retrieved February 1, 2013, from Chamber of Mines: http://www.bullion.org.za/content/?pid=71&pagename=Facts+and+Figures

Chmiel, M., Brunner, M., Keller, U., Schalke, D., Wrulich, M., & Martin, R. (2012). Does childhood general cognitive ability at age 12 predict subjective well-being at age 52? *Journal of Research in Personality* , 627-631.

Christian, M., Bradley, J., Wallace, J., & Burke, M. (2009). Workplace Safety: A Meta-Analysis of the Roles of Person and Situation Factors. *Journal of Applied Psychology , 94* (5), 1103-1127.

Cullen, E., Camm, T., Jenkins, M., & Mallet, L. (2006). *Getting to Zero: The Human Side of Mining.* National Institute for Occupational Safety and Health.

Department of Mineral Resources. (2011). *About Mine Health & Safety*. Retrieved February 1, 2013, from Department of Mineral Resources: http://www.dmr.gov.za/mine-health-a-safety.html

Department of Mineral Resources. (2009). *Cooperative Governance*. Retrieved February 01, 2013, from Department of Mineral Resources: http://www.ndmc.gov.za/Hazards/Natural/OtherDisasters/MineDisasters.aspx

Department of Minerals and Energy. (2008). *Mine Health and Safety Inspectorate Annual Report 2007-2008.*

Dilchert, S., Ones, D., Davis, R., & Rostow, C. (2007). Cognitive Ability Predicts Objectively Measured Counterproductive Work Behaviors. *Journal of Applied Psychology , 92* (3), 616-627.

Edmonds-Ward, L., & Trendell, B. (1998). Merit based selection and performance assessment for mineworkers. *Coal Operators' Conference.* University of Wollongong: Research Online.

Ferguson, J., McNally, M., & Booth, R. (1984). Individual characteristics as predictors of accidental injuries in naval personnel. *Accident Analysis and Prevention , 16* (1), 55-62.

Ford, M., & Wiggins, B. (2012). Occupational-Level Interactions Between Physical Hazards and Cognitive Ability and Skill Requirements in Predicting Injury Incidence Rates. *Journal of Occupational Health Psychology* , 1-11.

Gottfredson, L. (1997). Mainstream Science on Intelligence: An Editorial With 52 Signatories, History, and Bibliography . *Intelligence* , 13-23.

Hunter, J. & Hunter, R. (1984). Validity and Utility of Alternative Predictors of Job Performance. *Psychological Bulletin , 96* (1), 72-98.

International Labour Organization. (2010, September 03). *Mining: A hazardous work*. Retrieved February 07, 2013, from International Labour Organization: http://www.ilo.org/safework/areasofwork/hazardous-work/WCMS_124598/lang--en/index.htm

Jansen, J., & Brent, A. (2005). Reducing accidents in the mining industry — an integrated approach. *The Journal of The South African Institute of Mining and Metallurgy , 105*, 719-726.

Judge, T., Ilies, R., & Dimotakis, N. (2010). Are Health and Happiness the Product of Wisdom? The Relationship of General Mental Ability to Educational and Occupational Attainment, Health, and Well-Being. *Journal of Applied Psychology* .

JvR Histories. (n.d.). *A Brief History of the Psychomotor Assessment Domain*. Retrieved 2013, from The Histories Project: http://www.histories.jvrafrica.co/a-brief-history-of-the-psychomotor-assessment-domain/

Kath, L., Magley, V., & Marmet, M. (2010). The role of organizational trust in safety climate's influence on organizational outcomes. *Accident Analysis and Prevention , 42*, 1488-1497.

Lubinski, D. (2004). Introduction to the Special Section on Cognitive Abilities: 100 Years After Spearman's (1904) "'General Intelligence,' Objectively Determined and Measured". *Journal of Personality and Social Psychology , 86* (1), 96-111.

"Mining Safety in South Africa". (n.d.). Retrieved 2013, from Mining Safety: http://www.miningsafety.co.za/dynamiccontent/61/Mining-Safety-in-South-Africa

Paul, P., & Maiti, J. (2007). The role of behavioral factors on safety management in underground mines. *Safety Science* , 449-471.

Pearson. (n.d.). *Raven's Progressive Matrices*. Retrieved 2012, from Assessment and Information: http://www.pearsonassessments.com/haiweb/Cultures/en-US/Site/ProductsAndServices/

Pelser, M. (2009). *Psychomotor Ability And Its Relation To Intelligence As Predictor Of Performance.* Retrieved February 2, 2013, from http://uir.unisa.ac.za/bitstream/handle/10500/1522/07Chapter4.pdf;jsessionid=AFC7A121B402DA9C384864D3CA72A2CE?sequence=1

PWC. (2011). *SA Mine: Review of trends in the South African mining industry.* www.pwc.co.za.

Reason, J. (2000). Human error: models and management. *Western Journal of Medicine , 172* (6), 393-396.

Schuhfried. (n.d.). *Overview of all the dimensions in the Vienna Test System HR*. Retrieved 2012, from http://www.schuhfried.com/vienna-test-system-vts-alt2012/vienna-test-system-hr/dimensions

Snyder, L., Krauss, A., Chen, P., Finlinson, S., & Huang, Y. (2011). Safety performance: The mediating role of safety control. *Work , 40*, 99-111.

Statistics South Africa. (2012). *Latest Key Indicators*. Retrieved February 1, 2013, from Statistics South Africa: http://www.statssa.gov.za/keyindicators/keyindicators.asp

Turner, N., Stride, C., Carter, A., McCaughey, D., & Carroll, A. (2012). Job Demands–Control–Support model and employee safety performance. *Accident Analysis and Prevention , 45*, 811-817.

United States Department of Labor, Mine Safety & Health Administration. (n.d.). *A Synopsis of Mining Law for South Africa*. Retrieved 2013, from http://www.msha.gov/minelink/compend/safrica.htm

United States Department of Labor, Mine Safety & Health Administration. (n.d.). *Costs of Accidents*. Retrieved 2012, from http://www.msha.gov/s&hinfo/costgenerator/costgenerator.htm

van Niekerk, L. (2012, October 01). *Mineral Resources*. Retrieved 2013, from South African Government Information: http://www.info.gov.za/aboutsa/minerals.htm

Vorster, P., Pires, J., & Taylor, N. (2011). How to Effectively Select Candidates and Interpret Assessment Data for Safety in Leading Mines. *SAIMM, AMMSA and SACMA* .

CHAPTER VI

APPENDIX A

Vienna Test Systems Subtests	Variables Measured	*M*	*SD*
Two-Hand Coordination Test (2HND)	▪ Overall Mean Duration	30.29	26.69
	▪ Overall Mean Error Duration	1.76	3.21
	▪ Overall Percent Error Duration	4.64	5.42
	▪ Score of Coordination Difficulty	2.35	.98
Determination Test (DT)	Scores averaged across 3 phases for analyses:		
	▪ Median Reaction Time	.88	.20
	▪ Correct Reactions	127.13	36.52
	▪ On Time Reactions	84.60	52.41
	▪ Delayed Reactions	42.53	23.94
	▪ Incorrect Reactions	26.01	32.83
	▪ Overall Reactions	153.14	40.44
	▪ Omitted Reactions	40.94	31.49
Time/Movement Anticipation Test (ZBA)	▪ Median Deviation Time	1.28	.83
	▪ Median Direction Deviation	27.64	21.39
Visual Pursuit Test (LVT)	▪ Number of Correct Items	37.43	4.15
	▪ Median Time for Correct Answers	4.51	2.13
	▪ Median Time for Incorrect Answers	5.00	3.05
	▪ Working Time	198.25	97.75
	▪ Number of Pictures Viewed	40.56	1.57
	▪ Overall Score	28.83	10.16
Reaction Test (RT)	▪ Correct Reactions	15.89	1.02
	▪ No Reaction	.10	.96
	▪ Incomplete Reactions	.01	.11
	▪ Incorrect Reactions	.79	2.40
	▪ Mean Reaction Time	520.05	121.36
	▪ Mean Motor Time	272.87	77.42
	▪ Measure of the Dispersion Reaction Time	75.42	29.59
	▪ Measure of the Dispersion Motor Time	33.97	14.30
Cognitrone Test (COG)	▪ Sum of Correct Reactions	352.87	139.10
	▪ Sum of Hits	110.08	42.97
	▪ Sum of Correct Rejections	242.80	97.30
	▪ Mean Time of Correct Reactions	1.23	.70
	▪ Sum of Incorrect Reactions	10.01	26.42
	▪ Mean Time of Incorrect Reactions	1.23	1.03
	▪ Sum of Correct and Incorrect	362.89	140.90
	Reactions	2.97	7.56
	▪ Percentage of Incorrect Reactions		
Ravens Standard Progressive Matrices			
	▪ Ravens raw scores	31.45	12.24