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Investigating the use of Psychomotor Abilities Tests as Predictors of Training Performance in the Canadian Forces Technical and Mechanical Occupations

Thesis, submitted in partial fulfillment of the Requirement for the Degree of Master of Science in Applied Psychology (Industrial/Organizational)

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ABSTRACT

The present study examined the predictive validity of three psychomotor ability measures, manual dexterity, finger dexterity, and motor coordination, on two criteria, training success/failure, and training performance. The incremental validity of three psychomotor ability measures beyond measures of g, were examined in a military sample of Canadian Forces Personnel being trained in technical and mechanical occupations.

Trainees engaged in Qualification Level 3 training (n = 340) completed the three psychomotor ability scales of the General Aptitude Test Battery; archival data were collected from a cognitive measure: the Canadian Forces' General Classification Test Form 3 Revised (n = 332). Training performance criteria were based on knowledge tests and instructor evaluations of student performance on occupation-related performance objectives. Criterion data were letter grades (n = 209), percentage grades (n = 254), and pass/fail indications (n = 301), taken from course evaluation reports.

Analyses were conducted separately for the Technical (n = 98) and Mechanical (n = 242) occupation groups, and for both groups combined (n = 340). For the combined group, cognitive ability was significantly related to letter grades and the pass / fail criterion. Manual dexterity was also related to both letter grades and success / failure criteria, and motor coordination was related to success / failure. For the Mechanical group, significant relationships were found between letter grade performance and cognitive ability, and between letter grade performance and manual dexterity. In the Technical group there was a significant relationship between manual dexterity and letter grades.

After controlling for gender and language, the cognitive measure predicted training performance in the combined group and in the separate Mechanical group. Manual dexterity added significant incremental validity to cognitive ability in the combined and in the mechanical-only group; however, validity beyond g was not improved by finger dexterity or motor coordination. For the technical family, letter grade performance was predicted by manual dexterity. Success / failure in training was predicted by cognitive ability only for the combined group; however, for the mechanical group alone, success / failure was predicted by cognitive ability, manual dexterity, and finger dexterity.

The results of this study suggest that cognitive ability is a valid predictor of Qualification Level 3 performance for mechanical occupations in the CF. The results also indicate that manual dexterity tests improve validity beyond g in predicting performance for mechanical occupations, and to a lesser extent for technical occupations. Future research should investigate whether tests of psychomotor ability can discriminate between mechanical and other occupations of the Canadian Forces.

Investigating the use of Psychomotor Abilities Tests as Predictors of Training Performance in the Canadian Forces' Technical and Mechanical Occupations

Introduction

Two important issues in Industrial and Organizational (I/O) psychology are the selection and classification of personnel into suitable jobs. General mental ability (GMA, or g) predicts performance across a broad spectrum of jobs (e.g., Gottfredson, 1986; Hunter, 1983; Hunter & Hunter, 1984; Schmidt & Hunter, 1998). Non-cognitive abilities (e.g., psychomotor and perceptual ability), may add significant predictive validity to measures of g (e.g., Lubinski & Dawis, 1992; Schmidt & Ones, & Hunter 1992; Schmidt & Hunter, 1998; Wise, McHenry, & Campbell, 1990).

Project A, an extensive seven-year research program whose purpose was to improve the selection and classification of entry-level occupations of the United States (US) Army (Campbell, 1990), discovered that different components of job performance showed different patterns of relationships with potential predictor measures. Different mixes of skills, interests, temperament, and background may be needed to obtain the optimal prediction of technical proficiency across jobs (Wise, McHenry, & Campbell, 1990). Across nine different occupations, GMA was the best predictor of Core Technical Proficiency and of General Soldiering Proficiency. Adding spatial and psychomotor tests to GMA improved prediction of performance in those two occupation categories.

The Canadian Forces embarked on a similar long-term research plan in 1991 to improve selection and classification of entry-level Non-Commissioned Members (NCMs). The research plan (Halliwell & Spinner, 1991) started with clustering of 66 entry-level NCM occupations into five job families (Military, Operator, Administrative, Technical, and Mechanical), grouped according to common ability requirements (Catano & Ibel, 1995). The next stage involved validity analyses of modified selection and screening measures for those five families. Final stages included implementation of a modified cognitive test and identification of other suitable measures. The Canadian Forces Aptitude Test (CFAT) was developed as part of this process. The CFAT is a psychometrically sound measure of cognitive ability and aptitudes (MacLennan, 1997, Woycheshin, 1999). Catano (1995) pointed out that the CFAT would not measure the full range of abilities associated with all CF occupations. He suggested that the selection/classification process could be improved for some job families by incorporating non-cognitive ability measures, including measures of psychomotor ability.

The purpose of the present study is to investigate whether the use of psychomotor ability tests improve the current Canadian Forces selection/classification process. This study examines the increase in validity that occurs when psychomotor ability tests are used in addition to a cognitive predictor, the CFAT. Specifically, the present study investigates the extent to which psychomotor abilities, measured by the psychomotor ability sub-scales of the General Aptitude Test Battery (GATB), predict training performance/success in the Technical and Mechanical occupations of the Canadian Forces.

General Ability Theory

The discussion of abilities refers to general capacities of persons such as verbal ability, mathematical ability, and spatial visualization, related to the performance of human tasks. Measures of several of these capacities are often combined to produce a measure of general mental ability, also referred to as general cognitive ability, cognitive ability, GMA or g.

Cognitive Abilitv as a Predictor of Performance

General cognitive ability is a well-established, valid predictor of training and work performance. Ghiselli, (1973) found that cognitive ability was a better predictor of work and training performance than other occupational aptitude tests including personality, psychomotor and perceptual abilities, across 20 different jobs. Hunter and Hunter (1984) conducted a meta-analysis of 515 validation studies by the United States Employment Services (USES), finding that cognitive ability was the best predictor of training and work performance across different jobs and job families. Hunter (1986) also found cognitive ability to be a better predictor of training success than other measures, in a large sample study involving four job families in the United States military. Schmidt and Hunter (1998) concluded that general mental ability was the most central determining variable in job performance.

Validity generalization studies have examined the predictive validity of cognitive measures across numerous civilian and military occupations. Generally researchers found mean validities in the range of .44 to .51 for work performance (Hunter & Hunter, 1984; Ree, Earles, & Teachout, 1994; Schmidt & Hunter, 1998;) and .33 to .62 for training performance (Hunter, 1986; Hunter & Hunter, 1984; Olea, & Ree, 1994; Ree, & Earles, 1991; Schmidt & Hunter, 1998).

Cognitive Measures used by the Canadian Forces

Cognitive ability tests are used in the Canadian Forces (CF) for selection and classification of entry-level NCM and Officer occupations. All applicants must complete a test of general cognitive ability and achieve a pre-established minimum score to be considered eligible for entry into the CF. Top-down selection is based on the test scores as well as other indicators such as educational background, a semi-structured interview, security and reference checks. Scores on cognitive ability also help to determine suitability of applicants for different entry-level NCM occupations.

General Classification Test, Form 3 Revised (GC 3-R). The GC3-R is a measure of general cognitive ability that was used for screening and selection of Canadian Forces (CF) Non-Commissioned Members (NCMs) between 1991 and 1996 (Ibel, 1993). The GC3-R is a 75-item paper and pencil test of general cognitive ability available in French and in English. The test is a 30-minute timed test with items not completed scored as incorrect.

Research on an earlier 80-item version of the GC3 found it to be a valid predictor of NCM Qualification Level 3 (QL3) training (Angus & Halliwell, 1987). Legras and Staples (1983) found a strong correlation ($r = .75$) between the GC3 and the Wechsler Adult Intelligence Scale – Revised (WAIS-R), suggesting it is valid measure of general cognitive ability. A psychometric analysis of the GC3 resulted in removal of five items from the French and English versions (Angus & Halliwell, 1987). Angus and Halliwell (1987) reported reliabilities of .87 for the English version and .84 for the French version of the revised GC3 (GC3-R). Spinner (1991) found alpha coefficients of .86 for Anglophone Males, .84 for Anglophone Females, .83 for Francophone males, and .79 for

Francophone Females. Woycheshin (1999) validated the GC3-R on training performance for the Technical, Mechanical and Operator job families and found coefficients ranging from .15 to .53. These data suggest that the GC3-R is a reliable and valid measure of general cognitive ability.

Canadian Forces Classification Battery (CFCB). The CFCB is an aptitude battery that was used in conjunction with the GC-3 (and GC3-R) from 1981 until 1996. It is comprised of seven subtests; Word Knowledge (WK), Arithmetic Knowledge (AK), Automotive Information (AI), Electronic Information (EI), Scientific Knowledge (SK), Pattern Analysis (PN), and Mechanical Comprehension (MC). Scores are calculated by counting the number of correctly answered items. Equivalent versions are available in French and English with separate norms for Anglophone and for Francophone NCM applicants. Spinner (1991) conducted psychometric analyses of the CFCB and GC3 tests and found that the CFCB and GC3 had a great deal of overlap in the constructs they measured. He suggested removing the GC3 as well as the technical scales of the CFCB. The proposed replacement measure would include three scales; Problem Solving, derived from the CFCB AK items and GC3 numerical and problem solving items; General Knowledge, derived from CFCB WK, SK and GC3 vocabulary items; and Pattern Analysis, derived from CFCB PN, and MC items. An additional Technical Knowledge scale was proposed for males only derived from CFCB AI and EI items. These scales were all found to psychometrically sound except for the Technical Knowledge scale, which was biased against females. The currently used Canadian Forces Aptitude Test (CFAT) evolved from Spinner's (1991) work.

Canadian Forces Aptitude Test (CFAT). The CFAT is a standardized test of general cognitive ability that is currently used to select and classify personnel for the Canadian Forces (CF). The 60-item, paper and pencil test measures Problem Solving (PS - 30 items), Spatial Ability (SA - 15 items), and Verbal Skills (VS - 15 items); all three scales combine into the CFAT full-scale score. The CFAT is a speeded test arranged in ascending order of difficulty. Items not completed are scored as incorrect.

Specific Aptitude Theory

Supporters of the specific aptitude hypothesis purport that g may not be enough. Hull (1928) was among the first to hypothesize that general mental ability was not a sufficient predictor of performance for all occupations. GMA is usually measured by summing scores of several specific ability tests, for example combining scores of a vocabulary test, an arithmetic test, and a technical aptitude test (Hunter, 1986). Hull (1928) theorized that instead of summing scores and using only a measure of GMA to predict performance, multiple regression procedures should be used to combine test scores with different weights for different jobs to improve predictive validity. This was, and still is an appealing idea because of its potential for counseling, selection and classifying applicants into one of several occupations or occupation families. If different employee aptitudes were required for success in different jobs, and if those aptitudes could be identified in employees, then good person-job matches could be achieved. In other words, Hull's hypothesis would be true if different jobs used different cognitive aptitudes and if those aptitudes could be accurately measured (Hunter, 1986).

Several studies support the existence of three distinct ability domains: cognitive, psychomotor and perceptual (Hammond, 1984; Hunter, 1983; Watts and Everitt, 1980).

These three domains have become the typical grouping in discussions of specific aptitudes (e.g., Fleishman & Quaintance, 1984; Gottfredson, 1986; Lubinski & Dawis, 1992; Sackett, 1990). All three major content domains (cognitive, perceptual, & psychomotor) are valid predictors of performance (Lubinski & Dawis, 1992).

The suggestion that other measures add little incremental validity to using GMA alone (c.f., Olea & Ree, 1994) may be a misunderstood conclusion. Hunter and Hunter (1984) stated that this misunderstanding might be the result of a failure in the literature to distinguish between what is being measured (content) and how it is being measured (method). For example, a typical study may examine the incremental validity of a cognitive test, an interview and reference checks, when in fact all of these "methods" may be measuring the same "content" (e.g., ability, or experience), and therefore will naturally be highly correlated. Some researchers contend that the incremental validity of specific aptitudes could be demonstrated more clearly if other domains beside general cognitive ability, such as perceptual or psychomotor ability were measured (Schmidt, Ones, & Hunter 1992).

Psychomotor Abilities

Research in the field of psychomotor ability has been conducted almost exclusively by Edwin A. Fleishman and his colleagues over the last 50 years (see for example Fleishman, 1953, 1954, 1956, 1972, 1975, 1982, 1988; Fleishman & Hempel, 1956; Fleishman & Quaintance, 1984; Fleishman & Mumford, 1988, 1991; Fleishman & Reilly, 1992; Hempel & Fleishman , 1955). The culmination of Fleishman's work on human abilities can be found in the Handbook of Human Abilities (Fleishman & Reilly, 1992). Fleishman and Reilly (1992) list 52 human abilities grouped into four domains;

cognitive, psychomotor, physical, and sensory-perceptual. Fleishman (1953) defined psychomotor ability tasks roughly as those that combine physical (motor) activities with responses to some simple or complex stimulus situation. Fleishman's primary interest was with the motor activity required of persons to complete tasks. After several years of research with apparatus and other paper and pencil psychomotor ability tests, Fleishman (1956) found that the construct sometimes called general psychomotor ability is actually comprised of several unitary abilities. Research conducted up to 1956 identified 11 relatively independent factors in psychomotor skill. These factors have been reviewed and refined to become the ten psychomotor abilities now listed in the Handbook of Human Abilities (Fleishman & Reilly, 1992). The psychomotor abilities listed include control precision, multilimb coordination, response orientation, rate control, reaction time, arm-hand steadiness, manual dexterity, finger dexterity, wrist-finger speed, and speed-of-limb movement (see Appendix A for complete descriptions).

Psychomotor Abilities as Predictors of Performance. Validity generalization studies have shown that psychomotor ability, in particular, adds significant validity to cognitive based selection systems (Alderton, Wolfe, and Larson, 1997; Caretta, 1990; Hunter, 1981, 1983; Hunter & Hunter, 1984; McHenry, Hough, Toquam, Hanson, & Ashworth, 1990; Ree & Carretta, 1994; Wise, McHenry, & Campbell, 1990; Wolfe, 1997). In these studies, the validity of psychomotor ability as a predictor ranged from .17 to .44, decreasing with increases in job complexity while the validity of cognitive ability predictions ranged from .27 to .61, increasing with job complexity. Except for the "sales clerk" occupation (R = .28), multiple correlations for cognitive and psychomotor ability combined ranged from .43 to .62.

Most of the research on Psychomotor Abilities has focused on predicting success for aircrew occupations (pilots, navigators, and bombardiers). In fact, tests of psychomotor ability have been used to select military aircrew since around 1942 (Fleishman, 1956). The United States Air Force (USAF) uses the Basic Attributes Test (BAT; Ree & Carretta, 1994) to select candidates for pilot training. The BAT measures (among other things) three psychomotor ability measures: Two-Hand Coordination which is an example of Fleishman's multilimb coordination (Fleishman & Quaintance, 1984); Complex Coordination which is an example of Fleishman's Control Precision (Fleishman & Quaintance, 1984); and Time Sharing which is a test derived from Fleishman's Reaction Time and Rate Control (Fleishman & Quaintance, 1984). Caretta (1990) found that psychomotor ability, measured by the BAT, improved predictive validity by .02 above general cognitive ability, to predict passing or failing in pilot training. The Canadian Forces use a computer-based apparatus called the Canadian Automated Pilot Selection System (CAPSS) to measure perceptual and psychomotor ability to predict success in pilot training.

Psychomotor ability plays an important role in other occupations as well (Fleishman, 1956, 1988). Thorndike (1985) studied the psychomotor scales of the GATB as predictors of success across several heterogeneous jobs and concluded that psychomotor ability accounted for a significant proportion of variance in job performance, relatively independent of cognitive ability. Fleishman (1956) measured arm-hand steadiness, manual dexterity, finger dexterity, hand-eye coordination, wrist finger speed, speed of gross arm movement, and response orientation in a large sample of US military Engine Mechanics, Hydraulic Mechanics, and Aircraft Electrician trainees.

He found that some tests achieved significant validities in predicting final grades in training with the highest multiple correlation of .56 for the combination of arm-hand steadiness, finger dexterity, and wrist-finger speed. McHenry et al. (1990) found similar results with the highest multiple R = .57 for psychomotor ability predicting general soldiering proficiency. Mean incremental validities for psychomotor ability beyond g were .01 for predicting Core Technical Proficiency and .02 for predicting General Soldiering across a broad variety of (nine different) military occupations, using a set of ten computerized perceptual / psychomotor tests. Wolfe (1997), used the psychomotor scales of the US Army, Enhanced Computer Aptitude Battery (ECAT), and found incremental validities for psychomotor ability ranging from .003 for final school grade criteria to .016 for hands-on performance tests, above the general cognitive factor measured by the US Armed Services Vocational Aptitude Battery (ASVAB).

Stability of Psychomotor Ability – Performance Relations over Time. A growing body of research has investigated the stability of ability-performance relations over time (Ackerman, 1988, 1992; Barrett & Alexander, 1992; Deadrick & Madigan, 1990; Deadrick, Bennett & Russell, 1997; Murphy, 1989). Ackerman (1988, 1992) found that for a criterion of task performance where significant motor responding was involved, general and spatial abilities have consistently high correlations with task performance throughout task practice; however, correlations between overall performance and perceptual / psychomotor abilities increased with practice. For tasks that did not require significant motor responding, the relationship between performance and psychomotor ability was stable over time (Ackerman, 1992). Deadrick and Madigan (1990) found similar results in a study of sewing machine operators. Psychomotor ability was a significant predictor of both training and work performance with validity coefficients ranging from .16 to .20. This research suggests that psychomotor ability may be a valid predictor of performance depending upon the requirements of the occupation under study. The more motor responding required by the occupation, the more valid would be selection tests of psychomotor ability.

The empirical literature suggests that improvements to selection and classification may be accomplished by measuring psychomotor ability, in addition to tests of general cognitive ability (e.g., Fleishman, 1956; Ghiselli, 1973; Hunter & Hunter, 1984; Lubinski & Dawis, 1992; McHenry, et al., 1990; Thorndike, 1985). In these studies gains appear to be relatively small; however, this may be due in part to the way in which jobs were clustered. In the meta-analysis conducted by Hunter and Hunter (1984), they found that for the studies considered in their analysis, the key dimension in all job analysis methods was complexity.[1] Grouping in this manner is essentially a behaviour description approach; jobs are described based on worker functions or behaviours (Fleishman & Quaintance, 1984). Fleishman and Quaintance (1984) observed that classifying tasks in this manner might be limited because as job complexity increases, an undetermined number of activities may be observed. Each activity is comprised of several tasks; therefore it is difficult to see a commonality that could be measured, short of using work samples, to classify persons into one job family and distinguish that job family from others. In other words, the relatively small validities seen in testing for specific aptitudes for job families that were grouped according to complexity may be explained by the fact that jobs within those families each require different aptitudes. Hartigan and Wigdor

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[1] Complexity was defined by Fine's (1955) "things" and "data" dimensions.

(1989) also concluded that clustering jobs into five job families based on job complexity ratings has not identified job groups with useful differences in predictive composites. Perhaps the specific aptitude hypothesis could be more effectively explored if jobs were grouped according to common aptitudes or abilities before conducting validity analysis on tests of the three ability domains. For example, if jobs are classified (and grouped into job families) based on common ability requirements, classification of personnel into job families should be possible by measuring the predominant abilities required in each job family.

Measures of Psychomotor Ability. Although psychomotor ability testing began with rather simple apparatus tests, the recent trend is to use sophisticated computer-based tests such as the BAT, ECAT, and CAPSS; however, the computer-based tests do not measure all facets of psychomotor ability. For example, the ECAT One-Hand Tracking and Two-Hand Tracking tests measure only two aspects of psychomotor ability; Control Precision and Multilimb Coordination (Alderton, et al., 1997). The BAT Two-Hand Coordination, Complex Coordination and Time Sharing tests (Ree & Carretta, 1994), measure Fleishman's Multilimb Coordination, Control Precision, Reaction Time and Rate Control (Fleishman & Quaintance, 1984). Since there are many other facets of psychomotor ability, it would not be logical to expect these tests to be valid predictors of performance in all occupations. Consider for example abilities such as Arm-Hand Steadiness, Manual Dexterity, Finger Dexterity, Motor Coordination, Wrist-Finger Speed, or Speed-of-Limb Movement that are all associated with speed and accuracy of manipulating objects with the limbs, hands and fingers. Furthermore, since the empirical literature to date has not identified a general psychomotor factor, we should not expect a psychomotor ability test to predict performance unless we are sure it measures the same facet of psychomotor ability required by the job. Also, earlier research by Fleishman (1972) found that computer-based psychomotor tests were not correlated with well-established, construct-valid, apparatus tests of psychomotor abilities. Therefore, the relatively low incremental validities found in previous studies using computer-based psychomotor ability tests may under-estimate the real value of psychomotor ability testing. The General Aptitude Test Battery (GATB) is an example of a test that includes construct-valid apparatus tests of psychomotor ability.

General Aptitude Test Battery (GATB). The GATB is a well-established test of general aptitudes, developed by the United States Employment Service (USES) that has been in use for over 40 years in academic, vocational, and employment counseling settings (Hartigan & Wigdor, 1989). The GATB is also used extensively for employee selection. A recent Canadian survey (Pettersen & Turcotte, 1996) found that the GATB was used in many different organizations ranging in type from private consulting firms to federal government, in size from very small (1-5 employees) to very large (more than 500 employees). It was used mostly for career counseling (87%), and to a lesser extent for selection and promotion of personnel (35%).

The GATB consists of 12 separate timed subtests that are combined to form nine aptitude scores within three ability domains (cognitive, perceptual, psychomotor). Eight of the subtests are paper and pencil tests while the remaining four are apparatus tests. Intelligence, Verbal aptitude, and Numerical aptitude are measured in the Cognitive ability domain measures. In the Perceptual domain aptitudes measured are Spatial Aptitude, Form Perception, and Clerical Perception. In the Psychomotor domain, aptitudes measured are Motor Coordination, Manual Dexterity and Finger Dexterity. Table 1 shows all GATB aptitudes with their corresponding symbols, tests, and dimensional groupings.

Table 1
GATB Aptitudes, symbols, and associated tests grouped by dimensions.

Aptitude	Symbol	Test(s)	Dimension
General Intelligence	G	Vocabulary + Arithmetic Reasoning + Three Dimensional Space	
Verbal Aptitude	V	Vocabulary	
Numerical Aptitude	N	Computation + Arithmetic Reasoning	Cognitive (GVN)
Spatial Aptitude	S	Three Dimensional Space	
Form Perception	P	Tool Matching + Form Perception	
Clerical Perception	Q	Name Comparison	Perceptual (SPQ)
Motor Coordination	K	Mark Making	
Finger Dexterity	F	Assemble + Disassemble	
Manual Dexterity	M	Place + Turn	Psychomotor (KFM)

The three-dimensional factor structure of the GATB has been confirmed in several studies. Watts and Everitt (1980) conducted a maximum likelihood factor analysis of the inter-test correlation matrix, followed by application of Maxwell's formula to assess the determinancy of the factors extracted. They found a three-factor solution including symbolic, psychomotor (including finger dexterity and manual dexterity), and perceptual factors. Hunter (1983) also found a three-factor solution for the GATB. Based on an analysis of the inter-relationships of aptitude validities across jobs, he categorized the nine aptitudes into three dimensions of general abilities; cognitive, perceptual, and psychomotor. Cognitive and psychomotor abilities were relatively independent of each other ($r = .17$); however, the perceptual factor was highly correlated to both cognitive ($r = .83$) and psychomotor ($r = .61$). Therefore, Hunter

(1983) concluded that although the cognitive and psychomotor abilities were significant and independent predictors of performance, perceptual ability appeared to be dependent on, and perfectly predictable by the others. Hunter (1983) also stated that the reliabilities of composite scores (i.e. cognitive, perceptual or psychomotor) are generally higher than the reliabilities of any single aptitude within that composite; therefore, composite scores should be used. Hammond (1984) administered the GATB to a sample of 1084 subjects, using a procedure similar to Watts and Everitt (1980) and found a four-factor solution: symbolic, perceptual, finger dexterity, and manual dexterity.

Development of CF Job Families

Catano and Ibel (1995) clustered 66 entry-level NCM occupations into five job families using a quantitative, ability-requirements approach based on procedures outlined by Fleishman and his colleagues (Fleishman & Mumford, 1988; Fleishman & Quaintance, 1984; Fleishman & reilly, 1992). An Occupation Abilities Survey (OAS) was administered to 2501 Subject Matter Experts (SMEs) who were CF NCMs from all entry-level occupations. Ability data gathered from the OAS were analyzed using Ward's minimum variance method of Hierarchical Cluster Analysis (HCA) resulting in a five-cluster solution. The resultant job families were; 1.) **Military** (e.g., Armored Soldier, Infantry Soldier), 2.) **Operator** (e.g., Aerospace Control Operator, Radio Operator), 3.) **Administrative** (e.g., Resource Management Support Clerk, Postal Clerk), 4.) **Technical** (e.g., Avionics Technician, Naval Electronics Technician), and 5.)

Mechanical (e.g., Hull Technician, Vehicle Technician; Catano, 1995[2]). See appendix B for all occupations included in each job family.

Primary Abilities associated with each job family. Catano (1995) developed nine predictor composites, extracted from the ability data set through Principle Components Factor Analysis (PCA). The nine abilities, accounting for 60.8% of the variance were 1.) Strength and Movement, 2.)Vision, 3.) Audition, 4.) Controlled Reaction, 5.) Analytical Ability, 6.) Information Processing, 7.) Cognition, 8.) Verbal Ability, and 9.) Fine Motor Control. See Appendix C for the abilities associated with each composite.

A step-wise discriminant analysis revealed four significant functions that successfully predicted membership in the five job families (Catano, 1995). The third function, associated with Fine Motor Control, Analytical Ability and Cognition, separated the Technical and Mechanical families from the other three. In addition to the three common primary predictors (Fine Motor Control, Analytical Ability and Cognition), Vision is associated with the Technical family; Strength and Movement and Controlled Reaction are associated with the Mechanical family (Catano, 1995).

[2] The names of some occupations have been changed since Catano's (1995) research. See Appendix B for a list of the original and corresponding new occupation names. The names listed above as examples are the current names.

Table 2
CF Job Families and their Associated Primary Predictors (Catano, 1995).

Military	Operator	Administrative	Technical	Mechanical
Strength and Movement	Audition	No Primary Predictors	Fine Motor Control	Strength and Movement
Controlled Reaction	Information Processing		Analytical Ability	Controlled reaction
Vision	Vision		Cognition	Fine Motor Control
			Vision	Analytical Ability
				Cognition

Table 2 shows the five job families with their corresponding primary predictors. Five of the nine predictors, Strength and Movement, Controlled Reaction, Vision, Audition, and Fine Motor Control are not measured by the recently or currently used CF selection tests (GC3-R, CFCB, CFAT). The GC3-R and the CFAT are tests of general mental ability while the CFCB is a test that assesses arithmetic, automotive, electronic, mechanical, science, word knowledge, and pattern analysis. These tests have been used in the CF to select and to assign applicants into suitable occupations. If all abilities could be accurately measured during selection testing, the probability of correctly classifying applicants into suitable occupations may be improved. Therefore, Catano (1995) suggested that methods of measuring all nine composites should be considered, including non-cognitive measures.

The psychomotor scales of the GATB may be good predictors of the Fine Motor Control ability identified by Catano (1995) that are prominent in the CF Technical and Mechanical job families. Fine motor control was derived from factor loadings that were strongest on Arm-Hand Steadiness, Manual Dexterity, and Finger Dexterity[3] (Catano, 1995). The manual dexterity and finger dexterity scales of the GATB are among those listed by Fleishman and Reilly (1992) as suitable measures of those abilities, and when combined with the motor coordination sub-scale represent a well-founded measure of psychomotor ability according to the research previously discussed.

Criterion Measures

Three important issues in selecting criterion measures are relevance, reliability and practicality. "Relevance is the most important standard for criteria and criterion measures should provide comprehensive coverage of all important performance requirements of the job" (Borman, 1991, p. 272). The criterion measures in the present study are performance on Qualification Level 3 (QL3) training, and success or failure to complete QL3 training.

Training Performance. QL3 training performance is relevant to future job performance due to the method in which training is developed in the CF. Content of QL3 training is outlined in CF training specifications (TS); training specifications are based on a job analysis and subsequent occupational specification (OS, also known as a job description) for each military occupation. The training specifications for the Technical and Mechanical occupations include all facets of the job including the practical "hands-on" aspects which should require significant levels of psychomotor ability. Students are

[3] Arm-Hand Steadiness, Manual Dexterity, and Finger Dexterity are defined in the Handbook of Human Abilities (Fleishman & Reilly, 1992); these are also described at appendix A.

evaluated, and required to demonstrate a minimum standard of knowledge and practical proficiency in all aspects of training before they can successfully complete QL3 training. Course evaluations report performance levels as a letter grade, percentage grade or both. Percentage grades are weighted averages of all knowledge exams and will be treated as continuous variables for the present study. Letter grades are based on a performance classification scheme that varies across CF schools; therefore, letter grades are treated as ordinal variables for the purpose of this study.

Criterion measures must also be reliable and practical (Catano, Cronshaw, Wiesner, Hackett & Methot, 1997, p. 191). For the criterion measure in the current study, reliability is established through thorough training development protocol and standardized assessment procedures. Using training performance as the criterion measure is the most practical means available, particularly due to the size and expanse of the organization. Trainee course evaluation reports can be provided for all trainees by the CF schools at the completion of training, whereas if job performance data were used, they would have to be gathered from individual units across the country, and perhaps overseas, after trainees have been employed long enough to have received an assessment. Training performance is a widely accepted method of measuring performance within and outside of the CF (Catano et al. 1997, p. 194).

Successful Completion of Training. The second criterion measure, success or failure to complete QL3 training, is practical in an economic sense. The cost of a training failure may include the value of training completed to date, plus the cost of recruiting and training replacement personnel. A selection/screening system that could reduce training failures and dropouts may have a significant positive economic impact on the CF.

Research Goals

The empirical literature suggests that psychomotor ability is a valid predictor of performance across many different occupations and that psychomotor ability tests may add significant incremental validity over and above measures of g. The purpose of the present study is to investigate whether the use of psychomotor ability tests improve the current Canadian Forces selection/classification process. Using a sample of NCM QL3 candidates in the CF Technical and Mechanical job families, the goals of the present study are to:

1. Evaluate the validity of the three psychomotor ability scales of the General Aptitude Test Battery (GATB) as predictors of performance in CF QL3 training for Technical and Mechanical occupations. It is hypothesized that psychomotor ability will predict performance in QL3 training.
2. Investigate whether the addition of any of the GATB psychomotor ability measures improves the predictive validity of a cognitive-only model for predicting training performance for Technical and Mechanical occupations. It is hypothesized that psychomotor ability predictors will improve on the prediction of QL3 performance based on cognitive ability.
3. Investigate whether any of the GATB psychomotor ability measures (manual dexterity, finger dexterity or motor coordination), predicts success or failure in QL3 training for Technical and Mechanical occupations. It is hypothesized that psychomotor ability will predict success or failure in QL3 training.

Method

Participants

Approximately 340 members of the Canadian Forces (CF) on QL3 (Apprentice Level) training at various CF training schools across Canada participated in the study. Participants are all new to the (Technical or Mechanical) occupations; however, some are new CF members (recruits) and others have been transferred from other CF occupations and may have several years of CF experience. The sample includes 98 members training for jobs in the Technical Job Family and 242 members training for jobs in the Mechanical Job Family.

Occupations in the Technical job family used in this study included Aerospace Telecommunications and Information Systems Technicians (ATIS TECH), Land Communication and Information Systems Technicians (LCIS TECH), Naval Electronics Technicians (Acoustics; NET A), Naval Electronics Technicians (Communications; NET C), Naval Electronics Technicians (Tactical; NET T), Fire Control Systems Technicians (FCS TECH), and Avionics Technicians (AVS TECH). Trainees in the Technical group included 81% Anglophone males, 8% Anglophone females and 11% Francophone males; there were no Francophone female trainees in the Technical group. (Table 3)

Occupations in the Mechanical job family used in this study included Marine Engineering Mechanics (MAR ENG), Hull Technicians (HULL TECH), Marine Electricians (MAR EL), Vehicle Technicians (VEH TECH), Weapons Technicians (Land; WPNS TECH), Materials Technicians (MAT TECH), Aviation Technicians (AVN TECH), Plumbing and Heating Technicians (PH TECH), Construction Technicians (CONST TECH), and Naval Weapons Technicians (NWT). (Table 3)

Trainees in the Mechanical group included 85% Anglophone males, 6% Anglophone females, 9% Francophone males and .4% Francophone females. Tables 3 and 4 show stratification by gender, primary language, job family and occupation.

Table 3
Stratification of Sample by Job Family and Occupation

Technical Job Family (N = 98)		
Military Occupation Titles	**N**	**(%)**
Aerospace Telecommunications and Information Systems Technician (ATIS TECH)	10	10.2
Land Communication and Information Systems Technician (LCIS TECH)	18	18.4
Naval Electronics Technician (Acoustics) (NET A)	8	8.2
Naval Electronics Technician (Communications) (NET C)	7	7.1
Naval Electronics Technician (Tactical) (NET T)	16	16.3
Fire Control Systems Technician (FCS TECH)	9	9.2
Avionics Technician (AVS TECH	30	30.6
Mechanical Job Family N = 241		
Marine Engine Mechanic (MAR ENG)	18	7.4
Hull Technician (HULL TECH)	11	4.5
Marine Electrician (MAR EL)	10	4.1
Vehicle Technician (VEH TECH)	81	33.5
Weapons technician (Land) (WPNS TECH)	12	5.0
Materials Technician (MAT TECH)	22	9.1
Aviation Technician (AVN TECH)	38	15.7
Plumbing and Heating Technician (PH TECH)	7	2.9
Construction Technician (CONSTTECH)	23	9.5
Naval Weapons Technician (NWT)	20	8.3

Table 4
Stratification of NCM sample across gender and primary language for the Technical and Mechanical job families

Technical

	Anglophone n	%	Francophone n	%
Male	79	81	11	11
Female	8	8	0	0

Mechanical

	Anglophone n	%	Francophone n	%
Male	204	85	22	9
Female	14	6	1	.4

Participation in the study was on a voluntary basis. Trainees assembled as a group (class) in testing rooms so that the researchers could introduce the study and ask for their participation. It was made clear to members that they could refuse to participate and could terminate their participation at any time during testing. Instructors were not present and there were no repercussions for non-participation.

Measures

Criterion Measures

Three criterion measures were used in the present study; successful completion of QL3 training and two performance measures; letter grades and percentage grades. For the first criterion, success or failure to complete QL3 training, successful and unsuccessful groups were compared in analyses. Both success and failure were determined by an indication on the QL3 course evaluation report. Cases with missing data were deleted from analyses. For the second criterion letter grades were used as an ordinal variable, and for the third criterion percentage grades were used as a continuous variable. Percentage grades were also split into two groups (above and below the median score) for comparative analyses.

Predictor measures

Cognitive Measures. The primary cognitive measure used in the current study is the GC3-R (n = 306); however, where GC3-R data were not available (n = 26) the GC3-R score was estimated using CFAT (total score) data.[4] The two measures are both measures of general cognitive ability and they are highly correlated ($r = .56$, $p < .001$). Standardized T-scores were used for analyses.

General Classification Test, Form 3 - Revised (GC 3-R). The GC3-R is a 75-item paper and pencil test of general cognitive ability available in French and in English. The GC3-R is a speeded test with a 30-minute time limit, arranged in ascending order of difficulty. Items not completed are scored as incorrect.

Research on earlier versions of the 80-item GC3 found it to be a valid predictor of NCM QL3 training (Angus & Halliwell, 1987). Legras and Staples (1983) found a strong correlation ($r = .75$) between the GC3 and the Wechsler Adult Intelligence Scale – Revised (WAIS-R), suggesting it is valid measure of general cognitive ability. Angus and Halliwell (1987) reported reliabilities of .87 for the English version and .84 for the French version of the revised GC3 (GC3-R). Spinner (1991) found alpha coefficients of .86 for Anglophone Males, .84 for Anglophone Females, .83 for Francophone males, and

[4] The GC3-R was administered to all new-entry and re-classification applicants in the CF until 1996 when it was replaced with the CFAT. Most participants in this study were re-classified from other occupations; therefore, GC3-R data were available from previous testing. CFAT data would only have been available for those participants who enrolled or who were retested since 1996.

.79 for Francophone Females. Woycheshin (1999) validated the GC3-R on training performance for the Technical, Mechanical and Operator job families and found coefficients ranging from .15 to .53.

Canadian Forces Aptitude Test (CFAT). The CFAT is a 60-item, paper and pencil test that measures Problem Solving (PS - 30 items), Spatial Ability (SA - 15 items), and Verbal Skills (VS - 15 items). The CFAT is a speeded test arranged in ascending order of difficulty. Items not completed are scored as incorrect.

Black (1999) found internal consistency reliabilities of .87, .88, and .91 for the VS, SA, and PS scales respectively. MacLennan (1997) evaluated the original four CFAT sub-scales and found internal consistency reliabilities of r = .84 (Problem Solving), r = .70 (Knowledge), r = .69 (Pattern Analysis), and r = .75 (Technical).[5] These data suggest the CFAT is a highly reliable measure. Several studies have concluded that the CFAT was a valid predictor of NCM occupational performance (e.g., Ibel & Cotton, 1994; MacLennan, 1997). Most recently, Woycheshin (1999) conducted validity analysis of the CFAT on the Operator, Technical and Mechanical job families and found validities for the CFAT total score ranging from .30 to .54 for the Technical, Mechanical, and Operator job families.

General Aptitude Test Battery (GATB). GATB Data were collected by the Canadian Forces Directorate of Human Resources research and Evaluation (DHRRE), using the psychomotor scales (subtests 8-12) of the GATB. The psychomotor abilities measured are Manual Dexterity, Finger Dexterity and Motor Coordination. All tests are

[5] Spinner (1991) originally proposed the four subscales of the CFAT based on a Principal Components Analysis (PCA) of items from the previously used Canadian Forces Classification Battery (CFCB) and General Classification Test, form 3 (GC-3). The four-subscales were subsequently validated against scales

described at Appendix C; however, for a more detailed description with diagrams, refer to the Manual for the General Aptitude Test Battery, Section 1: Administration and Scoring (United States Department of Labour, 1986).

The test publisher reports reliabilities of .86, .76, and .77 respectively for the motor coordination, finger dexterity, and manual dexterity tests of the GATB (USES, 1970, p.34). Test-retest reliability for the psychomotor scales of the GATB is moderately strong, ranging from .70 to .84 across time periods of up to three years (Jaeger, Linn, & Tesh, 1989). Although few construct validity studies have been conducted, Jaeger et al (1989) found convergent validities of .58, .41, and .50 for motor coordination, finger dexterity, and manual dexterity

respectively. Jaeger et al (1989) reported predictive validities of the psychomotor composite ranging from .10 to .30 for training performance and from .11 to .33 for work performance.

Procedure

Archival cognitive ability data were gathered from DHRRE data banks and psychomotor ability data were collected by testing at CF schools across Canada.

Psychomotor Ability Data Collection

The psychomotor ability sub-scales of the GATB (manual dexterity, finger dexterity and motor coordination) were administered to QL3 trainees at CF schools across Canada. Subtests 8, 9, 10, 11 & 12 of the GATB were administered by qualified CF Personnel Selection Officers, in accordance with procedures outlined in the GATB testing manual (United States Department of Labour, 1986). GATB data were provided

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in the CFCB and GC-3 and the technical scale was dropped due to unreliability for women (Ibel & Cotton, 1994). The other scales were re-named to the current Problem Solving, Verbal Skills, and Spatial Ability.

to the researcher in the form of completed score sheets. Score sheets were scored and converted in accordance with the GATB testing manual (United States Department of Labour, 1986). Psychomotor ability scores were available for 339 participants.

Cognitive Ability Data

Cognitive ability data (GC3-R, CFAT) were collected either when members joined the CF or when they were assessed for occupation transfer. All data collection was conducted by qualified test administrators in accordance with standardized CF testing procedures. Cognitive ability data are stored in the NDHQ / DHRRE data bank and were provided by DHRRE. Data were incomplete for both the GC-3 (n = 306) and the CFAT (n = 57). There were 31 cases where both GC-3 and CFAT scores were available and they were highly correlated ($r = .56$, $p < .001$). Therefore all GC-3 and CFAT scores were standardized by converting to Z scores and then to T-Scores ranging from zero to 100, with a mean of 50 and standard deviation of 10.

Criterion Data

Criterion data were gathered from QL3 course reports collected at several CF training schools across Canada. Two different criteria were evaluated; success / failure in training (pass/fail, n = 301), and performance in training (percentage grades, n = 254; letter grades, n = 209). Missing data are attributable to early failures, and inconsistency across schools with regard to what measures are included on course reports. For each analysis, cases with missing data were deleted.

Data Analysis

Assumptions

Prior to each analysis data were examined to determine whether they met the necessary assumptions. In all cases the data satisfied the assumptions for each analysis.

Descriptive Statistics

Descriptive statistics were calculated to determine subgroup differences due to job family, gender, and first official language. Pearson product-moment correlations were computed to assess the relationships between predictors and criterion scores. Comparative analyses (t-tests) were not conducted with success vs failure groups due to the small number of failures (n = 15) in relation to the large number of successes (n = 285). However, as an alternative, a median split was carried out on the performance grade criterion and t-tests were calculated to determine whether the predictor variables could identify below and above average performers.

Hierarchical Regression Analyses (HRA)

Hierarchical Regression Analyses (HRA) were conducted to investigate the criterion validity of the Cognitive Ability measure and the Psychomotor Ability measures (GATB; Manual Dexterity, Finger Dexterity, and Motor Coordination) with performance on QL3 as the criterion variable. Separate analyses were carried out for two different criterion measures (Letter Grade, and Percentage Grade). Analyses were conducted for the Technical and Mechanical job families, together and separately. All analyses were conducted twice; once with psychomotor ability entered after cognitive ability and again with the entry order reversed.

In the first set of analyses, the Technical and Mechanical job families were treated as one group. For the first analysis performance (letter grades) was regressed onto gender, language and job family, cognitive ability, manual dexterity, finger dexterity, and motor coordination. The aim was to determine the predictive validity of the cognitive measure, and the incremental validity of each psychomotor ability measure. Variables were entered in three steps; gender, language and job family on step one, followed by cognitive ability on step two and then all psychomotor ability variables on the third step. These first two analyses were repeated using percentage grades as the criterion variable. In the second set of analyses, all the above were repeated for the Technical and Mechanical job families separately. The purpose of the second set was to investigate and compare the predictive validity of cognitive and psychomotor ability scores for Technical and Mechanical Job families separately.

All analyses discussed above were replicated with the entry order reversed; that is Job Family, Gender and Language were entered as controls, followed by Manual Dexterity, Finger Dexterity, Motor Coordination and Cognitive Ability. The purpose for these analyses was to determine whether the validity of psychomotor ability was being hidden by cognitive ability. Table 5 shows an outline of all regression analyses.

Table 5
Regression Analyses Outline

Hierarchical Regression Analysis				
		Set One		
Analysis Number	**Job Family**	**Analysis Type**	**Criterion**	**Predictors**
1 - 2	Combined	HRA	*Letter Grades* *% grade*	Language gender, job family; cognitive ability; manual dexterity, finger dexterity, and motor coordination
		Set Two		
3 - 4	Technical Mechanical Separately	HRA	Letter Grade % Grade	Language, gender; cognitive ability; manual dexterity, finger dexterity, and motor coordination
		Set Three (Entry-Order Reversed)		
5 - 6	Combined	HRA	*Letter Grades* *% grade*	Language, gender, job family; manual dexterity, finger dexterity, and motor coordination; cognitive ability.
		Set Four (Entry-Order Reversed)		
7 - 8	Technical Mechanical Separately	HRA	Letter Grade % Grade	Language, gender; manual dexterity; finger dexterity, and motor coordination; cognitive ability.

Results

Demographics

Gender Differences. Table 6 presents mean scores for male vs female participants by success / failure. For successful candidates in the combined technical and mechanical group, differences between males and females were not calculated due to the extreme uneven groups (male, n = 269; females, n = 15). T-tests were calculated for the unsuccessful group; there were no significant differences found between males and females on scores of Manual Dexterity (males, M = 103.67; females, M = 103.67), Finger Dexterity (males, M = 97.42; females, M = 101.33), or Motor Coordination (males, M = 93.67; females, M = 88.33). However, males (M = 48.26) did score significantly higher than females (M = 35.75) on cognitive ability ($t = 2.628$, $p < .05$).

For the group of candidates from the Mechanical job family who successfully completed QL3, uneven groups prohibited t-tests from being calculated (males, n = 186; females, n = 9); however, of the unsuccessful candidates in the mechanical job family, males (M = 48.26) scored higher than females (M = 35.75) on Cognitive Ability. No other significant differences were found between males and females in that group (Table 6).

Similarly, for successful candidates in the Technical job family who successfully completed QL3, differences between males and females were not calculated due to uneven group sizes (males, n = 83; females, n = 7; See Table 6). There were no unsuccessful candidates in the Technical family.

These data analyses were inconclusive with regard to differences attributable to gender: therefore, as a precautionary measure, gender was entered as a control variable in regression analyses. This will be discussed in more detail to follow.

Table 6
Descriptive Statistics for male vs female participants by success / failure

Combined Technical and Mechanical Job Families												
	Successful						Unsuccessful					
	Males			Females			Males			Females		
Measure	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Cognitive Ability	50.18	10.04	265	48.57	7.30	15	48.26	7.84	12	35.75	3.91	3
Manual Dexterity	113.97	21.91	269	126.31	20.02	16	103.67	16.44	12	103.67	8.33	3
Finger Dexterity	104.78	19.19	269	118.81	17.19	16	97.42	17.14	12	101.33	25.32	3
Motor Coordination	101.32	19.82	269	103.56	14.91	16	93.67	18.59	12	88.33	1.15	3
Letter Grade	3.12	54	200	3.11	60	9						
% Grade	87.68	4.99	237	86.35	5.08	16						

Mechanical Job Family												
	Successful						Unsuccessful					
	Males			Females			Males			Females		
Measure	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Cognitive Ability	48.98	10.01	184	45.97	7.12	8	48.26	7.84	12	35.75	3.91	3
Manual Dexterity	112.92	23.43	186	133.33	22.22	9	103.67	16.44	12	103.67	8.33	3
Finger Dexterity	104.30	19.42	186	117.44	12.93	9	97.42	17.14	12	101.33	25.32	3
Motor Coordination	99.13	19.99	186	100.11	15.80	9	93.67	18.59	12	88.33	11.15	3
Letter Grade	3.10	60	137	3.00	82	4						
% Grade	154.00	87.78	154	9.00	86.70	9						

Technical Job Family						
	Successful					
	Males			Females		
Measure	Mean	SD	N	Mean	SD	N
Cognitive Ability	52.89	9.60	81	51.55	6.77	7
Manual Dexterity	116.31	17.95	83	117.29	13.20	7
Finger Dexterity	105.88	18.76	83	120.57	22.57	7
Motor Coordination	106.20	18.62	83	108.00	13.49	7
Letter Grade	3.16	37	63	3.20	45	5
% Grade	87.49	5.43	83	85.91	6.48	7

Differences Attributable to Language. Table 7 presents means scores of all variables comparing Anglophone participants to Francophone participants by success / failure. For successful candidates in the combined Technical and Mechanical job family group, differences between Anglophone and Francophone candidates were not calculated due to uneven comparison groups (Anglo, n = 257; Franco, n = 28). Differences were not calculated for the unsuccessful group due to some cells (Francophone) having n equal to one.

Similarly, for successful participants in the Mechanical family, extreme differences in group sizes precluded the calculation of mean differences (Anglo, n = 178; Franco, n = 17). Differences were not calculated for the unsuccessful group due to some cells (Francophone) having n equal to one.

Of the successful candidates in the Technical Family, Francophone candidates (M = 126.45) scored significantly higher than Anglophone candidates (M = 114.99) on the Manual Dexterity score (t = 2.07, p < .05). No other significant differences were found in that group (Table 7). There were no unsuccessful candidates in the Technical family.

Table 7
Descriptive Statistics for Anglophone vs Francophone groups by success / failure

Combined Technical and Mechanical Job Families

	Successful						Unsuccessful					
	Anglophone			Francophone			Anglophone			Francophone		
Measure	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Cognitive Ability	50.35	9.85	251	47.82	10.22	29	44.86	8.38	14	58.32		1
Manual Dexterity	114.66	19.78	257	114.68	36.89	28	104.00	15.42	14	99.00		1
Finger Dexterity	104.91	19.26	257	111.61	19.25	28	98.79	18.56	14	90.00		1
Motor Coordination	101.09	20.02	257	104.64	14.55	28	92.14	17.71	14	99.00		1
Letter Grade	3.12	.54	188	3.05	.59	21						
% Grade	87.57	5.02	232	87.85	4.89	21						

Mechanical Job Family

	Successful						Unsuccessful					
	Anglophone			Francophone			Anglophone			Francophone		
Measure	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Cognitive Ability	49.38	9.83	174	43.78	9.53	18	44.86	8.38	14	58.32		1
Manual Dexterity	114.52	20.76	178	107.06	44.66	17	104.00	15.42	14	99.00		1
Finger Dexterity	104.39	19.16	178	110.24	21.04	17	98.79	18.56	14	90.00		1
Motor Coordination	98.79	20.27	178	103.24	13.45	17	92.14	17.71	14	99.00		1
Letter Grade	3.11	.61	126	2.93	.59	15						
% Grade	87.60	4.76	153	89.52	3.63	10						

Technical Job Family

	Successful					
	Anglophone			Francophone		
Measure	Mean	SD	N	Mean	SD	N
Cognitive Ability	52.55	9.61	77	54.42	7.79	11
Manual Dexterity	114.99	17.50	77	126.45	15.19	11
Finger Dexterity	106.09	19.57	77	113.73	16.86	11
Motor Coordination	106.28	18.54	77	106.82	16.54	11
Letter Grade	3.15	.36	62	3.33	.52	6
% Grade	87.51	5.51	79	86.33	5.53	11

These data analyses are inconclusive with regard to determining intergroup differences attributable to language; therefore as a precautionary measure, language was entered as a control variable in regression.

In all regression analyses conducted to test Goal 2, language, gender and job family were entered as control variables. In all cases these were not significant predictors so the regressions were re-calculated without controls.

Differences Between Successful and Unsuccessful QL3 Candidates. Table 8 presents demographics of the successful and unsuccessful groups broken down by gender and first official language. There were 286 successful candidates and only 15 failures resulting in uneven comparison groups. Males succeeded at a rate of 96%, females at 84%. Ninety-seven percent of the Francophones were successful compared to 95% of the Anglophone candidates. (See Table 8)

Table 8
Demographics of success and Failure groups

	Successful		Unsuccessful	
	n	%	n	%
Male	270	96	12	4
Female	16	84	3	16
Anglophone	257	95	14	5
Francophone	29	97	1	3

Differences between successful and unsuccessful candidates were not calculated due to the extreme difference in group sample sizes (successful, n = 286; unsuccessful, n = 15). Table 9 presents mean scores of all predictor variables for successful and unsuccessful groups. Tables 10 to 12 present means and standard deviations for successful vs unsuccessful trainees broken down by gender and language.

Table 9
Descriptive statistics for successful vs unsuccessful candidates

Combined Technical and Mechanical Families

	Successful Candidates			Unsuccessful Candidates		
Measure	Mean	S.D.	N	Mean	S.D.	N
Cognitive Ability (T)	50.09	9.90	280	45.76	8.79	15
Manual Dexterity	114.66	21.96	285	103.67	14.91	15
Finger Dexterity	105.57	19.33	285	98.20	18.03	15
Motor Coordination	101.44	19.56	285	92.60	17.15	15

Mechanical Family

	Successful Candidates			Unsuccessful Candidates		
Measure	Mean	S.D.	N	Mean	S.D.	N
Cognitive Ability (T)	48.85	9.92	192	45.76	8.79	15
Manual Dexterity	113.87	23.71	195	103.67	14.91	15
Finger Dexterity	104.90	19.34	195	98.20	18.03	15
Motor Coordination	99.18	19.78	195	92.60	17.15	15

Technical Family

	Successful Candidates		
Measure	Mean	S.D.	N
Cognitive Ability (T)	52.78	9.38	88
Manual Dexterity	116.39	17.57	90
Finger Dexterity	107.02	19.34	90
Motor Coordination	106.34	18.22	90

Table 10

Descriptive Statistics for successful vs unsuccessful candidates by gender by language

Combined Technical and Mechanical Job Families

	Anglophone Males						Francophone Males					
	Successful			Unsuccessful			Successful			Unsuccessful		
Measure	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Cognitive Ability	50.46	10.00	236	47.34	7.52	11	47.82	10.22	29	58.32	.	1
Manual Dexterity	113.89	19.56	241	104.09	17.18	11	114.68	36.89	28	99.00	.	1
Finger Dexterity	103.99	19.07	241	98.09	17.81	11	111.61	19.25	28	90.00	.	1
Motor Coordination	100.93	20.33	241	93.18	19.42	11	104.64	14.55	28	99.00	.	1
Letter Grade	3.12	.53	179				3.05	.59	21			
% Grade	87.66	5.01	216				87.85	4.89	21			

Anglophone Females

	Successful			Unsuccessful		
Measure	Mean	SD	N	Mean	SD	N
Cognitive Ability	48.57	7.30	15	35.75	3.91	3
Manual Dexterity	126.31	20.02	16	103.67	8.33	3
Finger Dexterity	118.81	17.19	16	101.33	25.32	3
Motor Coordination	103.56	14.91	16	88.33	11.15	3
Letter Grade	3.11	.60	9			
% Grade	86.35	5.08	16			

Table 11

Descriptive Statistics for successful vs unsuccessful candidates by gender by language

Technical Job Family

	Anglophone Males			Francophone Males		
	Successful			Successful		
Measure	Mean	SD	N	Mean	SD	N
Cognitive Ability	52.65	9.88	70	54.42	7.79	11
Manual Dexterity	114.76	17.92	72	126.45	15.19	11
Finger Dexterity	104.68	18.85	72	113.73	16.86	11
Motor Coordination	106.11	19.02	72	106.82	16.54	11
Letter Grade	3.14	.35	57	3.33	.52	6
% Grade	87.66	5.43	72	86.33	5.53	11

Anglophone Females

	Successful		
Measure	Mean	SD	N
Cognitive Ability	51.55	6.77	7
Manual Dexterity	117.29	13.20	7
Finger Dexterity	120.57	22.57	7
Motor Coordination	108.00	13.49	7
Letter Grade	3.20	.45	5
% Grade	85.91	6.48	7

Table 12
Descriptive Statistics for successful vs unsuccessful candidates by gender by language

Mechanical Job Family												
	Anglophone Males						Francophone Males					
	Successful			Unsuccessful			Successful			Unsuccessful		
Measure	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Cognitive Ability	49.54	9.93	166	47.34	7.52	11	43.78	9.53	18	58.32	.	1
Manual Dexterity	113.51	20.26	169	104.09	17.18	11	107.06	44.66	17	99.00	.	1
Finger Dexterity	103.70	19.21	169	98.09	17.81	11	110.24	21.04	17	90.00	.	1
Motor Coordination	98.72	20.52	169	93.18	19.42	11	103.24	13.45	17	99.00	.	1
Letter Grade	3.12	.60	122				2.93	.59	15			
% Grade	87.66	4.81	144				89.52	3.63	10			

Anglophone Females						
	Successful			Unsuccessful		
Measure	Mean	SD	N	Mean	SD	N
Cognitive Ability	45.97	7.12	8	35.75	3.91	3
Manual Dexterity	133.33	22.22	9	103.67	8.33	3
Finger Dexterity	117.44	12.93	9	101.33	25.32	3
Motor Coordination	100.11	15.80	9	88.33	11.15	3
Letter Grade	3.00	.82	4			
% Grade	86.70	4.07	9			

Research Goal 1

Pearson product-moment correlations were calculated to determine whether psychomotor ability predicts training performance in the Technical and Mechanical occupations.

Relationships between Cognitive Ability, Psychomotor Ability and Training Performance. Pearson Product-Moment correlations for cognitive, psychomotor and performance measures are presented at Tables 13 through 15. For the combined technical and mechanical families, Cognitive ability also was significantly related to the Pass/Fail criterion (r = .10) and letter grades (r = .18, p < .01). Manual Dexterity was also a significant predictor of the pass/fail criterion (r = .11) and letter grades (r = .18, p < .01). Motor Coordination was a significant predictor of the pass/fail criterion (r = .10); however, Finger dexterity did not predict performance on any of the criterion variables. Cognitive ability had a small but significant relationship with manual dexterity (r = .15), finger dexterity (r = .14), and motor coordination (r = .09; Table 13)

Table 13
Correlations for the combined Technical and Mechanical job families

	Mean	SD	1	2	3	4	5	6	7
1. Cognitive Ability	49.91	9.98	1						
2. Manual Dexterity	112.95	24.18	.15**	1					
3. Finger Dexterity	105.97	19.35	.14**	.35**	1				
4. Motor Coordination	101.57	19.32	.09*	.31**	.21**	1			
5. Pass / Fail	1.95	.22	.10*	.11*	.08	.10*	1		
6. Letter Grade	3.12	.54	.18**	.18**	.02	.05	.a	1	
7. % Grade	87.50	5.19	.07	.06	.04	.03	.28**	.48**	1

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).
a Cannot be computed because at least one of the variables is constant.

In the Technical job family occupations the only significant predictor of performance was Manual Dexterity, which was moderately correlated with the Letter

Grade criterion (r = .22). There was also a significant correlation between Cognitive Ability and Finger Dexterity (r = .20). (Table 14)

Table 14
Correlations for the Technical Job Family

	Mean	SD	1	2	3	4	5	6	7
1. **Cognitive Ability**	53.22	9.65	1						
2. **Manual Dexterity**	115.05	18.23	.07	1					
3. **Finger Dexterity**	107.21	19.10	.20*	.45**	1				
4. **Motor Coordination**	105.84	18.25	-.03	.39**	.22*	1			
5. **Pass / Fail**	2.00	.00	.a	.a	.a	.a	a		
6. **Letter Grade**	3.16	.37	.12	.22*	.09	.04	a	1	
7. **Percentage Grade**	87.36	5.49	.05	-.03	-.09	-.04	a	.37**	1

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).
a Cannot be computed because at least one of the variables is constant.

For the Mechanical family, Cognitive Ability (r = .20, p < .01), and Manual Dexterity (r = .17) were both significantly correlated with Letter Grades. Cognitive Ability was also significantly correlated with Manual Dexterity (r = .16, p < .01). No other significant relationships were found in the Mechanical job family occupations. (Table 15)

Table 15
Correlations for the Mechanical Job Family

	Mean	SD	1	2	3	4	5	6	7
1. Cognitive Ability	48.56	9.81	1						
2. Manual Dexterity	112.10	26.20	.16**	1					
3. Finger Dexterity	105.47	19.47	.1	.32**	1				
4. Motor Coordination	99.83	19.51	.1	.28**	.21**	1			
5. Pass / Fail	1.93	.26	.08	.11	.09	.09	1		
6. Letter Grade	3.09	61	.20**	.17*	0	.04	a	1	
7. Percentage Grade	87.58	5.03	.1	.11	.12	.07	.36**	.59**	1

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).
a Cannot be computed because at least one of the variables is constant.

Research Goal 2

Hierarchical Regression Analysis. Hierarchical Regression Analyses were carried out to determine whether psychomotor ability measures predict training performance over and above cognitive ability. For each analysis Language. Gender. and job family were entered in the first step as control variables followed by cognitive ability on step two. and manual dexterity. finger dexterity. and motor coordination on step three. In all analyses. the control variables at step one did not account for a significant proportion of the variance in performance: therefore control variables were eliminated and the analysis was repeated with cognitive ability at step one. and the three psychomotor ability measures entered as a block at step two.

Set One (Regression Analysis). The first set of analyses assessed the incremental validity of cognitive ability and psychomotor ability in predicting training performance. based on two different measures (letter grades and percentage grades) with the Technical and Mechanical job families grouped together with letter grades as the criterion. Cognitive ability was entered at step one, and the three psychomotor ability measures entered as a block at step two. The entire model accounted for 8% of the variance in letter grade performance ($R = .28$, $F_{4, 201} = 4.37$, $p < .01$). Cognitive Ability was a valid predictor accounting for 3% of the variance in performance ($\Delta R^2 = .03$, $F_{1, 204} = 7.06$, $p < .01$) as was Psychomotor Ability ($\Delta R^2 = .05$, $F_{3, 201} = 8.17$, $p < .05$). Of the psychomotor ability measures, only manual dexterity made a significant contribution to the model ($p < .01$). Table 16 presents the results of analysis number one.

Analysis 2 was identical to analysis one except the criterion variable was percentage grade. Cognitive ability was entered on step one, and the three psychomotor measures in step two. The complete model accounted for .8% of the variance in percentage grade performance ($R= .09$, $F_{3, 242} = .214$, ns). None of the variables were found to be valid predictors of performance. Table 17 presents the results of analysis two.

Table 16

Hierarchical Regression 1: Predicting performance for the combined technical and mechanical job families with a letter grade criterion measure

	Predictor	Beta	R	R^2	ΔR^2	F	p
Step 1			.19	.03	.03	7.06	**.01**
	Cognitive Ability	.19					**.01**
Step 2			.28	.08	.05	3.38	**.02**
	Manual Dexterity	.26					**.002**
	Finger Dexterity	-.13					ns
	Motor Coordination	-.02					ns

Full Model: R = .28, F (4, 201) = 4.37, p<.01

Table 17
Hierarchical Regression 2: Predicting performance for members of the combined technical and mechanical job families with a percentage grade criterion measure

	Predictor	Beta	R	R^2	ΔR^2	F	p
Step 1			.07	.01	.01	1.36	ns
	Cognitive Ability	.07					ns
Step 2			.09	.01	.00	.21	ns
	Manual Dexterity	.06					ns
	Finger Dexterity	-.02					ns
	Motor Coordination	-.01					ns
Full Model: R = .09, F (4, 242) = .50, ns							

Set Two (Regression Analysis). In set 2 the analyses described above were repeated for the Technical and Mechanical job families separately using letter grades and percentage grades as dependant variables.

In analysis three cognitive ability was entered on step one, and the three psychomotor measures in step two. Letter grades were the criterion measure in analysis three. For members of the Technical job family the model accounted for 6.8% of the variance in letter grade performance ($R = .26$, $F_{4, 63} = 1.16$, ns). For members of the Technical job family none of the variables were valid predictors of letter grade performance. When computed for the members of the Mechanical job family, the model accounted for 8.5% of the variance in letter grade performance ($R = .29$, $F_{4, 133} = 3.09$, $p < .05$). Cognitive ability was a valid predictor of performance accounting for 3.9% of the variance in performance ($\Delta R^2 = .039$, $F_{1, 136} = 5.52$, $p < .05$). Psychomotor ability did not appear to be a valid predictor at step two ($\Delta R^2 = .046$, $F_{3, 133} = 2.23$, ns); however, manual dexterity did appear to provide a significant contribution ($p < .05$). Results for analysis 3 are presented in Table 18.

Table 18
Hierarchical Regression 3: predicting performance for the technical and mechanical job families separately with a letter grade criterion measure

Predictor		Beta	R	R^2	ΔR^2	F	p
Technical Family							
Step 1			.12	.02	.02	1.0	ns
	Cognitive Ability	.15					ns
Step 2			.26	.07	.05	1.2	ns
	Manual Dexterity	.26					ns
	Finger Dexterity	-.07					ns
	Motor Coordination	-.01					ns
Full Model: R = .26, F (4, 63) = 1.16, ns							
Mechanical Family							
Step 1			.20	.04	.04	5.52	**.02**
	Cognitive Ability	.20					**.03**
Step 2			.29	.09	.05	2.23	ns
	Manual Dexterity	.28					**.01**
	Finger Dexterity	-.14					ns
	Motor Coordination	-.03					ns
Full Model: R = .29, F (4, 133) = 3.09, p<.05							

In analysis 4, percentage grades were regressed onto all predictors for technical and mechanical families separately. Cognitive ability was entered on step one, and the three psychomotor measures on step two. For members of the Technical job family, the model accounted for 1.6% of the variance in percentage grade performance (R = .13, $F_{4, 83}$ = .35, ns). Neither of the predictor variables accounted for a significant proportion of the variance in performance. For members of the Mechanical job family, the model accounted for 2.4 % of the variance in percentage grade performance (R = .16, $F_{4, 154}$ = .96, ns). Similarly, none of the predictors provided a significant individual contribution to the model. Table 19 presents a summary of analysis 4.

Table 19
Hierarchical Regression 4: Predicting performance for members of the technical and mechanical job families separately with a percentage grade criterion measure

Predictor		Beta	R	R^2	ΔR^2	F	p
Technical Family							
Step 1			.05	.00	.00	.24	ns
	Cognitive Ability	.07					ns
Step 2			.13	.02	.01	.39	ns
	Manual Dexterity	-.04					ns
	Finger Dexterity	-.10					ns
	Motor Coordination	-.01					ns
Full Model: R = .13, F (4, 83) = .35, ns							
Mechanical Family							
Step 1			.10	.01	.01	1.67	ns
	Cognitive Ability	.08					ns
Step 2			.16	.02	.01	.72	ns
	Manual Dexterity	.09					ns
	Finger Dexterity	.05					ns
	Motor Coordination	-.02					ns
Full Model: R = .16, F (4, 154) = .96, ns							

Set Three (Regression Analysis). In set 3, letter grades were regressed onto psychomotor ability and cognitive ability for the combined Technical and Mechanical job families. For analysis five, the three psychomotor measures were entered on step one, and cognitive ability on step two. The entire model accounted for 8% of the variance in letter grade performance ($R = .29$, $F_{4, 201} = 4.37$, $p < .01$). Psychomotor ability was a valid predictor ($\Delta R^2 = .05$, $F_{3, 202} = 3.23$, $p < .05$), as was Cognitive Ability ($\Delta R^2 = .03$, $F_{1, 201} = 7.39$, $p < .01$). Of the three psychomotor ability measures, only manual dexterity made a significant contribution to the model ($p < .01$). (Table 20)

Table 20
Hierarchical Regression 5: Prediciting performance for the combined technical and mechanical job families with a letter grade criterion measure, entering psychomotor abilities first

	Predictor	Beta	R	R^2	ΔR^2	F	p
Step 1			.22	.05	.05	3.23	**.02**
	Manual Dexterity	.26					**.002**
	Finger Dexterity	-.13					ns
	Motor Coordination	-.02					ns
Step 2			.28	.08	.03	7.39	**.01**
	Cognitive Ability	.19					**.01**
Full Model: R = .28, F (4, 201) = 4.37, p < .01							

In analysis 6 percentage grades were regressed onto all predictor variables for the combined Technical and Mechanical job families. Manual Dexterity, Finger Dexterity, and Motor Coordination were entered on step one, followed by Cognitive Ability on step two. The model accounted for .8% of the variance in percentage grades (R = .09, $F_{4, 242}$ = .50, ns). Neither of the predictors explained a significant proportion of variance in percentage grade performance. (Table 21)

Table 21
Hierarchical Regression 6: Predicting performance for the combined technical and mechanical job families with a percentage grade criterion measure, entering psychomotor abilities first

	Predictor	Beta	R	R^2	ΔR^2	F	p
Step 1			.06	.00	.00	.31	ns
	Manual Dexterity	.06					ns
	Finger Dexterity	-.02					ns
	Motor Coordination	-.01					ns
Step 2			.09	.01	.00	1.06	ns
	Cognitive Ability	.07					ns
Full Model: R = .09, F (4, 242) = .50, ns							

<u>Set Four (Regression Analysis).</u> Analysis 7 examined the Technical and Mechanical job families separately, regressing letter grade performance onto psychomotor and cognitive ability, with variables entered in the same order as in set three. For the Technical family, the model accounted for 6.8% of the variance in letter grades ($R = .26$, $F_{4, 63} = 1.16$, ns). None of the variables were significant predictors of letter grade performance. For the Mechanical job family, the model accounted for 8.5% of the variance in Letter Grades ($R = .29$, $F_{4, 133} = 3.09$, $p < .05$). Psychomotor ability was not a valid predictor ($\Delta R^2 = .05$, $F_{3, 134} = 2.39$, ns); however, manual dexterity did provide a significant individual contribution ($p < .05$). Cognitive Ability at step two was a valid predictor of performance ($\Delta R^2 = .03$, $F_{1, 133} = 4.98$, $p < .05$). (Table 22)

Table 22

Hierarchical Regression 7: Predicting performance for the technical and mechanical job families separately with a letter grade criterion, entering psychomotor abilities first

Predictor		Beta	R	R²	ΔR²	F	p
Technical Family							
Step 1			.22	.05	.05	1.09	ns
	Manual Dexterity	.26					ns
	Finger Dexterity	-.07					ns
	Motor Coordination	.01					ns
Step 2			.26	.09	.03	1.34	ns
	Cognitive Ability	.15					ns
Full Model: R = .26, F (4, 63) = 1.16, ns							
Mechanical Family							
Step 1			.23	.05	.05	2.39	**.07**
	Manual Dexterity	.26					**.01**
	Finger Dexterity	-.14					ns
	Motor Coordination	-.04					ns
Step 2			.29	.09	.03	4.98	**.03**
	Cognitive Ability	-.19					**.03**
Full Model: R = ..29, F (4, 133) = 3.09, p < .05							

For analysis 8, percentage grades were regressed onto psychomotor and cognitive ability for the Technical and Mechanical job families separately with variable entry similar to previous analyses. For the Technical job family, the model accounted for 1.6% of the variance in percentage grades ($R = .13$, $F_{4, 83} = .35$, ns). None of the variables were found to be valid predictors of performance in this analysis. For the Mechanical job family, the model accounted for 2.4% of the variance in Percentage Grades ($R = .16$, $F_{4, 154} = .96$, ns). None of the individual predictors accounted for any significant proportion of variance in performance in this model. (Table 23)

Table 23
Hierarchical Regression 8: Predicting performance for the technical and mechanical job families separately with a percentage grade criterion measure, entering psychomotor abilities first

Predictor		Beta	R	R^2	ΔR^2	F	p
Technical Family							
Step 1			.11	.01	.01	.33	ns
	Manual Dexterity	-.04					ns
	Finger Dexterity	-.10					ns
	Motor Coordination	-.01					ns
Step 2			.13	.02	.01	.42	ns
	Cognitive Ability	.07					ns
Full Model: R = .13, F (4, 83) = .35, ns							
Mechanical Family							
Step 1			.14	.02	.02	.99	ns
	Manual Dexterity	.09					ns
	Finger Dexterity	.05					ns
	Motor Coordination	-.02					ns
Step 2			.16	.02	.01	.86	ns
	Cognitive Ability	.08					ns
Full Model: R = .16, F (4, 154) = .96, ns							

Research Goal 3

Comparative Analysis; Median Split on Percentage Grades. As an alternative to comparing successful and unsuccessful candidates, a median split was carried out on the percentage grade criterion so that differences between below and above average performers could be analyzed. The purpose of this analysis was to gain an indication of whether psychomotor ability would predict the degree of success in training. For the combined Technical and Mechanical occupations, those trainees scoring above the median Percentage Grade (Cognitive Ability: M = 51.09) scored significantly higher on Cognitive Ability than those who scored below the median Percentage Grade (Cognitive Ability: M = 48.95). There were no significant mean differences between below and above median Percentage Grade groups on Manual Dexterity (Below: M = 112.06; Above M = 116.30), Finger Dexterity (Below: M = 103.50; Above: M = 105.81), or Motor Coordination (Below: M = 101.23; Above: M = 103.11).

For the Technical family no significant differences were found between those scoring below and those above the median on the Cognitive Ability Measure (Below: M = 52.47; Above: M = 53.09), Manual Dexterity (Below: M = 116.51; Above: M = 116.28), Finger Dexterity (Below: M = 108.53; Above: M = 105.64), or Motor Coordination (Below: M = 106.47; Above: M = 106.23).

For the Mechanical family, mean scores for those scoring below the median were lower than mean scores for those scoring above the median on Cognitive Ability (Below: M = 47.08; Above: M = 49.96), Manual Dexterity (Below: M = 109.75; Above: M = 116.31), and Finger Dexterity (Below: M = 100.89; Above: M = 105.91). There was no significant difference between mean Motor Coordination scores of trainees scoring below the median Percentage Grade (M = 98.52) and those scoring above the median Percentage Grade (M = 101.28). Table 24 shows means, standard deviations and t statistics for below and above median Percentage Grade groups.

Table 24
Descriptive statistics for predictor variable scores by below and above median Percentage Grade Groups

Combined Technical and Mechanical Families								
	Below Median			Above Median				
Measure	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**df**	**t**
Cognitive Ability (T)	48.95	9.92	124	51.09	9.99	124	246	1.70 *
Manual Dexterity	112.06	20.49	126	116.30	24.01	127	251	1.51
Finger Dexterity	103.50	19.72	126	105.81	19.13	127	251	.95
Motor Coordination	101.23	18.25	126	103.11	19.99	127	251	.78
Technical Family								
	Below Median			Above Median				
Measure	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**df**	**t**
Cognitive Ability (T)	52.47	8.79	43	53.09	10.01	45	86	.31
Manual Dexterity	116.51	18.27	43	116.28	17.09	47	88	.06
Finger Dexterity	108.53	19.96	43	105.64	18.86	47	88	.71
Motor Coordination	106.47	17.28	43	106.23	19.23	47	88	.06
Mechanical Family								
	Below Median			Above Median				
Measure	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**	**df**	**t**
Cognitive Ability (T)	47.08	10.03	81	49.96	9.86	79	158	1.83 *
Manual Dexterity	109.75	21.28	83	116.31	27.37	80	161	1.71 *
Finger Dexterity	100.89	19.20	83	105.91	19.41	80	161	1.66 *
Motor Coordination	98.52	18.25	83	101.28	20.32	80	161	.91

* t is significant at the .05 level.

DISCUSSION

The results of this study suggest that measures of psychomotor ability add incremental validity to cognitive measures in the prediction of military training performance for the Mechanical job family but not for the Technical job family. Cognitive ability measured with the GC3-R and Psychomotor ability measured with the GATB both predicted training performance measured with letter grades. Manual Dexterity was a valid predictor: however, neither Finger Dexterity nor Motor Coordination predicted performance. Training success was predicted by Cognitive and Psychomotor Ability measures as well.

Research Goal 1

The three psychomotor ability measures of the GATB (manual dexterity, finger dexterity, and motor coordination) were expected to predict QL3 training performance for both Technical and Mechanical occupations. This hypothesis was supported by the data analysis. Manual dexterity was moderately correlated with letter grade performance and accounted for a significant proportion of the variance for the combined Technical and Mechanical groups, as well as for each group analyzed separately. Manual dexterity was also significantly related to letter grades for the Technical family alone. Motor Coordination had a weak but significant correlation with Letter Grades for the combined Technical and Mechanical families, but was not related to either family in separate analyses. Finger Dexterity was not correlated with Letter Grade performance. The strongest relationships in these analyses were between Manual Dexterity and Letter Grade performance and the weakest relationship was between Finger Dexterity and Letter

Grade performance. Participants who scored higher in Manual Dexterity achieved higher Letter Grades in training on average. .

Analyses using percentage grades as the performance criterion found no significant relationships with any of the psychomotor ability measures for the (separate or combined) Technical and Mechanical job families.

These data suggest that Psychomotor Ability: particularly Manual Dexterity, is a valid predictor of training performance for the Mechanical job family. Those who score highly on measures of manual dexterity are likely to score highly on QL3 training in the CF Mechanical occupations. There is some indication that manual dexterity predicts performance in the Technical job family: however, the results are not as strong as for the mechanical family.

Research Goal 2

Psychomotor ability measures were predicted to improve the predictive validity of selection on training performance for both the Technical and Mechanical groups when used in addition to cognitive measures. This hypothesis was supported by the data. Psychomotor ability provided a significant increase in validity above Cognitive Ability for the combined Technical and Mechanical families ($\Delta RSq = .05$) on the Letter Grade criterion: however, only Manual dexterity was a significant predictor ($p < .01$). For the Mechanical group Psychomotor ability did not account for a significant proportion of variance in performance above g ($\Delta RSq = .05$, $p = .09$): however, Manual Dexterity did provide a significant contribution to the model ($p < .05$). When Cognitive Ability was entered after the Psychomotor Ability measures, results were similar.

When percentage grades were used as the performance criterion and cognitive ability was entered first, Psychomotor ability did not improve the predictive validity of the model. However, when the entry order was reversed, entering Cognitive Ability after Psychomotor ability, Psychomotor ability approached significance, accounting for 3% of the variance in Percentage Grades (ΔRSq = .03, $p < .07$).

Overall the data suggest that testing Manual Dexterity improves the predictive validity of Cognitive Ability for members of the Mechanical job family: those who score higher on Manual Dexterity tend to perform better in training. These findings are consistent with previous studies. In a military sample of nine different occupations, McHenry et al (1990) found mean incremental validities of .01 and .02 for psychomotor ability using Core Technical Proficiency and General Soldiering as criteria. Wolfe (1997), used the psychomotor scales of the US Army, Enhanced Computer Aptitude Battery (ECAT), and found incremental validities for psychomotor ability ranging from .003 for final grade score criteria to .016 for hands-on performance tests, above the general cognitive factor measured by the US Armed Services Vocational Aptitude Battery (ASVAB). Caretta (1990) found that psychomotor ability, measured by the BAT added .02 above general cognitive ability to predict passing or failing in pilot training. Hunter and Hunter (1984) also found significant improved validity across jobs when using a combination of cognitive and psychomotor tests.

Research Goal 3

Psychomotor ability measures were expected to predict success or failure in QL3 training. This hypothesis was supported by the data. Manual Dexterity and Motor Coordination were correlated with, and accounted for a significant proportion of the variance in the pass/fail criterion for the combined Technical and Mechanical job family groups. Manual Dexterity was also correlated with the pass / fail criterion, accounting for a significant proportion of the variance for the Mechanical job family alone. Motor Coordination was not related to the pass / fail criterion in analyses of either job family alone, and Finger Dexterity was not related to the pass / fail criterion.

A median split was carried out on percentage grade scores to identify two groups for comparative analyses. For the combined Technical and Mechanical job families, there was a significant difference in mean Cognitive Ability scores but not Psychomotor Ability scores, between those above and those below the median Percentage Grade. No significant differences were found between below and above median score groups for the Technical job family alone; however, several differences were found for the Mechanical family. On average the group of trainees scoring above the median Percentage Grade also scored higher on Cognitive Ability, Manual Dexterity and Finger dexterity. No significant differences were found between those scoring above and below the median on Motor Coordination. These data suggest that Psychomotor ability is a valid predictor of success for the Mechanical job family.

Differences Between Technical and Mechanical Job Families

It was very clear in this study that psychomotor abilities are related to performance in the Mechanical occupations but not the Technical occupations. This may be attributed to the requirements of the different jobs. Although both job families require high levels of cognitive ability, analytical ability and fine motor control (Catano, 1995), these abilities are required at different levels for each occupation. It is not difficult to understand why cognitive ability would play a larger role than psychomotor ability for the Technical occupations where strong performance is dictated by the ability to solve complex problems with electrical, electronic and computer technology. A typical problem may involve hours of testing and theorizing (cognitive functions) to narrow down the cause of an equipment fault, followed by a relatively simple repair (psychomotor functions). As a result, the variance in performance accounted for by cognitive ability serves to mask any variance that may be attributed to psychomotor ability, even though the psychomotor abilities were essential to complete the task. On the other hand performance in the Mechanical occupations, while still requiring high levels of cognitive ability, also depends on high levels of ability on more labor-intensive tasks. For example it may take only seconds to determine that an aircraft fuel cell requires replacement (cognitive function); however, it may take several days and significant physical skills to repair the cell correctly (psychomotor function). In such an instance the variance in performance attributable to psychomotor ability is less likely to be hidden by cognitive ability.

Range Restriction

The results of this study may be underestimated as a result of range restriction. The sample of QL3 candidates is not a perfect representation of the Canadian population due to self-selection and screening. Canadian Forces Recruiting Centers provide a comprehensive realistic job preview (RJP) to all candidates that may result in a more homogeneous group of applicants due to self-screening. The selection ratio also has an effect on restriction of range; there are typically large numbers of applicants for the relatively small number of job vacancies in the Technical and Mechanical occupations. Thorough screening of applicants is conducted using minimum education requirements, a semi-structured interview, and a cognitive selection test as criteria for top-down selection. The result is a sample of candidates with mostly above average abilities, and who subsequently have very few failures in training. This is particularly true for applicants to the Technical job family who require, as a minimum requirement, a higher level of math education background than other NCM occupations. In the present study this was evident with very few failures overall, and none in the Technical job family group.

The Criterion Problem

Although the criterion used here (i.e., training performance) is thought to be valid, it is not ideal. The QL3 level training is an apprentice level of training. At that level practical skills (i.e., psychomotor abilities) are required and are evaluated on a pass/fail basis only. That is, a minimum level of performance is required on practical tasks to successfully complete each performance objective, and an overall ranking is assigned to each student; however, performance on practical tasks is not clearly reflected in the percentage grade calculations. The problem with a pass/fail criterion is that it provides very little variance in scores and the variance becomes well hidden within the variance attributable to cognitive ability. If psychomotor ability is to be effectively validated, as a predictor of performance, a criterion variable must be measured that is sensitive to psychomotor ability requirements of the occupation (s). A better method would be to measure psychomotor ability rigorously through a behavioral checklist rating of practical task performance. Tasks should be chosen based on their association with the common ability requirements of the job family, as determined in the job analysis. The result would be a multiple criteria measure of performance (i.e., cognitive and psychomotor ability) which could be combined into a composite if desired. This would facilitate a much greater ability to see the variance in performance attributable to cognitive and psychomotor ability.

Work performance may be a more appropriate criterion. Psychomotor skills become much more important in the workplace where strong performance for members of the Technical and Mechanical occupations requires not only the knowledge of how to resolve problems, but also the ability to execute maintenance activities and repairs. Therefore, workplace performance evaluations may be more likely than training evaluations to accurately reflect psychomotor abilities.

The relationship between psychomotor abilities and work performance is supported in previous research. Ackerman (1992) found that psychomotor ability was a valid predictor of performance remaining stable with practice and improving for tasks with significant motor responding requirements. Deadrick and Madigan (1990) found similar results: psychomotor ability was a valid predictor of training and work performance remaining stable with practice. Deadrick et al. (1997) found that psychomotor ability was a valid predictor of initial job performance that improved with experience. These studies suggest that the predictive validity of psychomotor ability will probably increase with experience on the job. In this light the results of this study are very encouraging.

Implications for Future Research

The current study provides additional support for previous research suggesting that psychomotor ability is a valid predictor of performance beyond g. The average validity of manual dexterity in this study was .20, consistent with previous studies that found the validity of psychomotor ability ranging from .17 to .44 (Alderton. Wolfe. and Larson. 1997; Caretta. 1990; Hunter. 1981. 1983; Hunter & Hunter. 1984; McHenry. Hough. Toquam. Hanson. & Ashworth. 1990; Ree & Carretta. 1994; Wise. McHenry. & Campbell. 1990; Wolfe. 1997). Manual Dexterity in this study improved the proportion of variance accounted for by .04; this is also consistent with past research. McHenry et al. (1990) found mean incremental validities for psychomotor ability beyond g of .01 for predicting Core Technical Proficiency and .02 for predicting General Soldiering across a broad variety of (nine different) military occupations. Wolfe (1997). used the psychomotor scales of the US Army. Enhanced Computer Aptitude Battery (ECAT). and found incremental validities for psychomotor ability ranging from .003 for final school grade criteria to .016 for hands-on performance tests. above the general cognitive factor.

Results of this study are actually stronger than past studies. Psychomotor ability accounted for approximately 5% of the variance in performance compared to an average of approximately 2% in previous research. This may be due to the type of jobs being studied: i.e.. Technical and Mechanical jobs only. as opposed to a broad cross-section of jobs. It may also be attributed to the psychomotor abilities that were measured. Previous studies have all talked about psychomotor ability as if it were a general construct. even though there has not been research to identify a general psychomotor factor. The present study looked at three facets of psychomotor ability (manual dexterity. finger dexterity. and motor coordination) that were all closely related to the technical and mechanical job families studied. and found different results for each facet. This suggests that jobs presumed to require psychomotor ability may only require some specific facets of psychomotor ability and different jobs may require different facets. Future research should investigate to determine whether there is a general psychomotor factor or several important facets of psychomotor ability.

Implications for the Canadian Forces

Predicting Training Success

The importance of accurately predicting success in training cannot be overstated. The costs associated with training in the CF are very high: $38,000.00 for each recruit for basic recruit training alone before QL3 training even begins (Black, 1999). The cost of QL3 training for Technical and Mechanical occupations is among the highest in the CF. To the extent that a selection measure such as manual dexterity improves the predictive validity of a selection system and reduces training failures or dropouts by screening out unsuitable candidates, there will be an obvious economic benefit to the CF. This study suggests that the addition of manual dexterity to the current selection system may improve the prediction of training success in the mechanical occupations and therefore also provide an economic benefit to the CF.

Predicting Performance

Manual dexterity testing improved the validity of selection using cognitive tests for predicting performance of QL3 candidates in Mechanical occupations. The literature on utility analysis suggests that even small increases in validity will result in substantial practical gains (Boudreau, 1991; Catano et al., 1997; Schmidt & Hunter, 1998). These studies show that increased validity will result in better performing employees and a consequent improvement in organizational effectiveness that can be translated into cost savings. In this light, the present study strongly suggests that adding a measure of manual dexterity to the current selection system may result in the selection of stronger performers in the mechanical job family, and could result in significant cost savings.

Recommendations:

1. The CF should continue to use cognitive ability measures as a screening device. Non-cognitive measures should be considered to supplement the existing cognitive tests for predicting performance in specific occupation families.

2. The present study suggests that psychomotor ability will predict training performance in the Mechanical job family but not in the Technical job family. However, further research should be conducted to establish the relationship between psychomotor ability and work performance in the Technical and Mechanical job families. Similar studies should be completed using a larger sample with members of all CF occupations to determine the validity of psychomotor ability testing across jobs and to determine whether psychomotor abilities will discriminate between job families.

3. If psychomotor ability testing is to be considered as a selection tool, tests of manual dexterity should be used rather than tests of finger dexterity or motor coordination. Although it would be prudent to conduct a thorough utility analysis before implementing a test of manual dexterity into the CF recruiting system, the present study suggests that prediction of performance in the mechanical occupations could be significantly improved with the addition of psychomotor ability (i.e., manual dexterity) measures.

4. CF schools across Canada should agree on a standard for reporting training evaluations. Ideally, all schools should report percentage grades for each performance objective as well as an overall score. Additionally, practical tasks should be rated with behavioral checklists and scores incorporated into the final course grades. Future research studies should also use a behavioral checklist to measure practical (training or workplace) task performance.

REFERENCES

Ackerman, P.L. (1988). Determinants of individual differences in skill acquisition: Cognitive abilities and information processing. Journal of Experimental Psychology, General, 117, 288-318.

Ackerman, P.L. (1992). Predicting individual differences in complex skill acquisition: Dynamics of ability determinants. Journal of Applied Psychology, 77, (5), 598-614.

Alderton, D.L., Wolfe, J.H., & Larson, G.E. (1997) The ECAT battery. Military Psychology, 9 (1), 5-37.

Angus, R.J. & Halliwell, S.T. (1987). Psychometric analysis of the general classification test - form 3 (GC3). Technical Note 13/87, Willowdale On: Canadian Forces Personnel Applied Research Unit.

Barrett, G.V.,& Alexander, R.A. (1992). The implications for personnel selection of apparent declines in predictive validities over time: A critique of Hulin. Personnel Psychology, 45, (3), 601-617.

Black, M.S. (1999) The efficacy of personality and interest measures as a supplement to cognitive measures in the prediction of military training performance. Unpublished master's thesis, Saint Mary's University: Halifax, Nova Scotia.

Borman, W.C. (1991). Job behavior, performance and effectiveness. In Dunnette, M.D. & Hough, L.M. (Eds) Handbook of Industrial and Organizational Psychology Volume 2, Palo Alto Ca.: Consulting Psychologists Press.

Boudreau, J.W. (1991) Utility analysis for decisions in human resource management. In Dunnette, M.D. & Hough, L.M. (Eds) Handbook of Industrial and Organizational Psychology Volume 2. Palo Alto Ca.: Consulting Psychologists Press.

Campbell, J. P. (1990). An overview of the army selection and classification project (Project A). Personnel Psychology, 43, 231-239.

Catano, V.M. (1995). Describing the primary abilities associated with five clusters of entry-level military occupations. Technical Supplement 95-4. North York, On.: Canadian Forces Personnel Applied Research Unit.

Catano, V.M. (1999). Developing entry-level military occupational families based on abilities profiles. Paper presented at the 1999 Annual Conference of the Canadian Psychological Association, Halifax, Nova Scotia.

Catano, V.M., Cronshaw, S.F., Wiesner, W.H., Hackett, R.D. & Methot, L.L. (1997). Recruitment and Selection in Canada. Toronto: ITP Nelson.

Catano, V.M., & Ibel, R.H. (1995). Clustering Canadian forces military occupations using statistical analyses of ability profiles. Technical Note 6/95. Willowdale On.: Canadian Forces Personnel Applied research Unit.

Deadrick, D.L., Bennett, N. & Russell, C.J. (1997). Using hierarchical linear modeling to examine dynamic performance criteria over time. Journal of Management, 23, (6), 745-757.

Deadrick, D.L. & Madigan, R.M. (1990). Dynamic criteria revisited: A longitudinal study of performance stability and predictive validity. Personnel Psychology, 43, (4), 717-745.

Fine, S.A. (1955). A structure of worker functions. Personnel and Guidance Journal, Oct. 66-73.

Fleishman, E.A. (1953). Testing for psychomotor abilities by means of apparatus tests. Psychological Bulletin, 50 (4), 241-262.

Fleishman, E.A. (1954). Dimensional analysis of psychomotor abilities. Journal of Experimental Psychology, 48, 437-454.

Fleishman, E.A., (1956). Psychomotor selection tests: Research and application in the United States Airforce. Personnel Psychology, 9, 449-467.

Fleishman, E.A. (1972). Structure and measurement of psychomotor abilities. In Singer RN (Ed.) The psychomotor domain: Movement behaviour. (pp. 78-106). Philadelphia, PA: Lea and Febiger.

Fleishman, E.A. (1975). Toward a taxonomy of human performance. American Psychologist, 30 (12), 1127-1149.

Fleishman, E.A., (1982). Systems for describing human tasks. American Psychologist, 37 (7), 821-834.

Fleishman, E.A. (1988). Some new frontiers in personnel selection research. Personnel Psychology, 41 (4), 679-701.

Fleishman, E.A. (1992). The Fleishman Job Analysis System. Palo Alto, Ca.: Consulting Psychologists Press.

Fleishman, E.A., & Hempel, W.E. (1956). Factorial analysis of complex psychomotor performance and related skills. Journal of Applied Psychology, 40 (2), 96-104.

Fleishman, E.A., & Quaintance, M.K. (1984). Taxonomies of human performance: The description of human tasks. Orlando, Fl: Academic Press.

Fleishman, E.A. & Mumford, M.D. (1988) Ability requirement scales. In S. Gael (Ed.), The job analysis handbook for business industry and government. (pp. 917-935). New York: Wiley.

Fleishman E.A. & Mumford M.D. (1991). Evaluating classifications of job behavior: A construct validation of the ability requirements scales. Personnel Psychology, 44, 523-575.

Fleishman, E.A. & Reilly, M.E. (1992) Handbook of Human Abilities: Definitions, Measurements and Job Task Requirements. Palo Alto CA: Consulting Psychologists Press Inc.

Ghiselli, E.E. (1966). The validity of occupational aptitude tests. New York: John Wiley and Sons.

Gottfredson, L.S. (Ed.). (1986). The g factor in employment. (Special Issue) Journal of Vocational Behavior, 29 (3), 293-450.

Guion, R.M., (1992) Personnel assessment, selection and placement. In Dunnette, M.D. & Hough, L.M. (Eds) Handbook of Industrial and Organizational Psychology Volume 2. Palo Alto Ca.: Consulting Psychologists Press.

Halliwell, S.T., & Spinner, B. (1991). A research plan for the psychometric analysis of the CFCB and the GC3 tests. Technical Note 15/91 Willowdale On.: Canadian Forces Personnel Applied Research Unit.

Hammond S.M. (1984). An investigation into the factor structure of the General Aptitude Test Battery. Journal of Occupational Psychology, 57, 43-48.

Hartigan, J.A., & Wigdor, A.K. (Eds.) (1989). Fairness in Employment Testing: Validity Generalization, Minority Issues, and the General Aptitude Test battery. Washington, D.C.: National Academy Press.

Hempel, W.E., & Fleishman, E.A. (1955). A factor analysis of physical proficiency and manipulative skill. Journal of Applied Psychology, 39 (1), 12-16.

Hull, C.L. (1928). Aptitude Testing. Yonkers-on-Hudson, NY: World Book.

Hunter, J.E., (1980). Test validation for 12000 jobs: An application of synthetic validity and validity generalization to the General Aptitude Test Battery (GATB). Washington, D.C.: U.S Employment Service, U.S. Department of Labour

Hunter, J.E. (1983). The dimensionality of the General Aptitude Test battery (GATB) and the dominance of the general factors over specific factors in the prediction of job performance for the U.S Employment Service. (USES test research report no. 44) Division of Counseling and Test Development, Employment and Training Administration. Washington, D.C.: U.S. Department of Labor.

Hunter, J.E. (1986). Cognitive ability, cognitive aptitudes, job knowledge and job performance. Journal of Vocational Behavior, 29, 340-362.

Hunter, J.E., & Hunter, R.F., (1984). Validity and utility of alternative predictors of job performance. Psychological Bulletin, 98 (1), 72-98.

Hunter, J.E., Schmidt, F.L. & Judiesch, M.K. (1990). Industrial differences in output variability as a function of job complexity. Journal of Applied Psychology, 75, 28-42.

Ibel, R.H. (1993). Revised norms for the general classification tests – forms 2 – (R) and 3 – (R). Technical Note 12/93, Willowdale, On; Canadian Forces Personnel Applied Research Unit

Ibel, R.H., & Cotton, C.A. (1994). Validation of experimental scales of non-commissioned member applicant selection and classification. Technical Note 17/94. Willowdale, On.: Canadian Forces Personnel Applied Research Unit.

Jaeger, R.M., Linn, R.L., & Tesh, A.S. (1989). A synthesis of research on some psychometric properties of the GATB. In J.A. Hartigan, & A.K. Wigdor (Eds.) Fairness in Employment Testing: Validity Generalization, Minority Issues and the General Aptitude test Battery. Washington, D.C.: National Academy Press.

Legras, L.P. & Staples, R.E. (1983). A correlational analysis of the relationship of the Wechsler Adult Intelligence Scale – Revised with the General Classification Battery – English and the Canadian Forces Classification Battery. Personnel Selection Services Report. Borden, On; Base Personnel Selection Office.

Lubinsky, D. & Dawis, R.V. (1992). Aptitudes skills and proficiencies. In M.D. Dunnette, & L.M. Hough (Eds.) Handbook of Industrial and Organizational Psychology Volume 3 (2nd Ed). Palo Alto Ca: Consulting Psychologists Press.

MacLennan, R.N. (1997). Validity generalization across military occupational families. Technical Note 00/97. Ottawa, On.: Canadian Forces Personnel Research Team.

McHenry, J.J., Hough, L.M., Toquam, J.L., Hanson, M.A., & Ashworth, S. (1990). Project A validity results: The relationship between predictor and criterion domains. Personnel Psychology, 43, 335-354.

Murphy, K.R. (1989). Is the relationship between cognitive ability and job performance stable over time? Human Performance, 2, 183-200.

Olea, M.M., & Ree, M.J., (1994). Predicting pilot and navigator criteria: Not much more than g. Journal of Applied Psychology, 79, (6), 845-851.

Ree, M.J. & Carretta, T.R. (1994). The correlation of cognitive and psychomotor tests. Interim Technical Paper. Human Resources Directorate Manpower and Personnel Research Division, Brooks Air Force Base, TX, 78235-5000

Ree, M.J., & Earles, J.A., (1991). Predicting training success: Not much more than g. Personnel Psychology, 44, 321-332.

Ree, M.J., Earles, J.A., & Teachout, M. (1994). Predicting job performance: Not much more than g. Journal of Applied Psychology, 79, 518-524.

Rosenthal, R. & Rosnow, R.L., (1991). Essentials of Behavioral Research: Methods and Data Analysis (2 ed). New York: McGraw-Hill, Inc.

Sackett, P.R., (Ed.) (1990). Personnel Psychology, 43.

Schmidt, F.L., (1988). Validity generalization and the future of criterion-related validity. In H. Wainer & H. Braun (Eds.) Test Validity. Hillsdale, NJ: Erlbaum.

Schmidt, F.L. & Hunter, J.E. (1998). The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings. Psychological Bulletin, 124, (2), 262-274.

Schmidt, F.L., Ones, D.S., & Hunter, J.E. (1992). Personnel selection. Annual Review of Psychology, 43, 627-670.

Schmitt, N., Gooding, R.Z., Noe, R.A., & Kirsch, M. (1984). Meta analysis of Validity studies published between 1964 and 1982and the investigation of study characteristics. Personnel Psychology, 37, 407-422.

Spinner, B. (1991). A psychometric analysis of the CFCB and GC3 tests. Technical Note 16/91. Willowdale On.: Canadian Forces Personnel Applied Research Unit.

Tabachnik BG, Fidell LS. (1996). Using multivariate statistics (pp.57-125). New York: HarperCollins College.

Thorndike, R.L., (1985). The central role of general ability in prediction. Multivariate Behavioral Research, 20, 241-254.

United States Department of Labour. (1986). Manual for the General Aptitude Test Battery (Section 1). Scarborough On.: Nelson Canada.

U.S Employment Service (1970). Section 3: Development: Manual for the USES General Aptitude Test Battery. U.S Department of Labor, Manpower Administration.

Watts F.N. & Everitt B.S. (1980). The factorial structure of the General Aptitude Test Battery. Journal of Clinical Psychology, 36, 763-767.

Wise, L.L., McHenry, J., & Campbell, J.P. (1990). Identifying optimal predictor composites and testing for generalizability across jobs and performance factors. Personnel Psychology, 43, 355-366.

Woycheshin, D. (1999). Validation of the Canadian Forces aptitude test against QL3 course performance. Technical Note 99/11. Ottawa On: Director of Human Resources Research and Evaluation.

Appendix A:

<u>Psychomotor Abilities (Fleishman & Reilly, 1992)</u>

Fleishman and Reilly (1992) list each of the abilities as well as tasks, jobs, and tests associated with each. Following is information provided for the ten abilities within the domain of psychomotor ability.

Control Precision is defined as the ability to make highly controlled and precise adjustments in moving the controls of a machine or vehicle quickly and repeatedly to exact positions. It involves quick or continuous adjustments rather than the aiming or rapid choice of movements. Typical tasks are an astrionaut making adjustments with a stick control, a dentist drilling a tooth, a factory worker turning a valve to adjust a pressure setting, a truck driver shifting gears, or a pilot making adjustments to rudder pedals. Jobs that require high levels of control precision are a sound mixer, pilot, fork-lift operator, bombardier, crane operator and truck driver.

Multilimb Coordination is defined as the ability to coordinate movements of two or more limbs such as when moving equipment controls. Two or more limbs are in motion while the individual is sitting, standing, or lying down. This ability does not involve performing these activities while the body is in motion. Typical tasks that require this ability are piloting a plane, playing a drum set, operating a fork lift, and operating a sewing machine with a foot pedal. Some jobs that require high levels of multilimb coordination are pilot drummer, seamstress, orchestra conductor, or racecar driver.

Response Orientation is defined as the ability to choose between two or more movements quickly and correctly when two or more different signals (lights sounds, pictures) are given. The ability is concerned with the speed with which the correct response can be started with the hand, foot, or other parts of the body. This ability has also been referred to as choice reaction time. Response orientation can involve rapid selection of the direction to move a control or which control to move; deciding whether or not to push a button, or hit a pedal, depending on the signals received or the situation encountered. Typical tasks that require this ability include a pilot deciding what controls to move and in which direction after seeing a light or hearing a sound cue, and a driver who must decide to hit the gas or the brake in a skid situation. Examples of jobs that require high levels of response orientation are racecar driver, switchboard operator, and anesthesiologist.

Rate Control is the ability to adjust an equipment control in response to changes in speed and/or direction of a continuously moving object or scene. The ability involves timing the adjustments and anticipating changes. This ability does not extend to situations in which the speed and direction are perfectly predictable. Tasks that require this ability include tracking a moving aircraft in a gun sight, keeping an airplane at a given altitude in turbulent weather, keeping up with a followed car when the followed car is changing speeds, riding a bike alongside of a runner, and hitting a baseball. Jobs that require high levels of rate control are dentist, motion picture photographer, artillery gunner, baseball player, and truck driver.

Reaction Time is the ability to give a fast response to a signal (sound, light picture) when it appears. The ability is concerned with the speed with which the movement can be started with the hand, foot, or other parts of the body, but not with the speed with which the movement is carried out once started. It does not involve choosing which response to make. This ability is not measured when more than one type of signal must be discriminated or more than one type of response is chosen. Tasks associated with reaction time are firing a weapon as soon as a target appears, hitting the brake when a pedestrian walks in front of a car, hitting back a ball in a ping pong game, and ducking to miss a snowball thrown at close range. Examples of jobs that require fast reaction time include taxi driver, police officer, combat rifleman, and bodyguard.

Arm-Hand Steadiness is the ability to keep the hand and arm steady. It includes steadiness while making an arm movement or while holding the arm and hand in one position. This ability does not involve strength or speed, and is not involved in adjusting equipment controls. (e.g. levers). However, it can involve using small light tools. Typical tasks that require this ability are cutting facets in diamonds, firing a rifle, threading a needle, lighting a cigarette, and some kinds of welding. Jobs that require high levels of arm-hand steadiness include dentist, paintings restorer, electrologist, watchmaker, gem cutter, and bomb diffuser.

Manual Dexterity is the ability to make skillful coordinated movements with one hand, a hand together with its arm, or two hands in grasping and manipulating objects. The required movement can be to place, move, or assemble objects such as hand tools or blocks. This ability requires the use of the whole hand in using tools, manipulating objects requiring the whole hand, or assembling or fitting objects together. It involves the degree the degree to which these arm-hand movements can be carried out quickly. It does not involve moving machine or equipment controls such as levers. Manual dexterity is involved in performing open-heart surgery, putting the parts of an engine back together, using tools in making a bookcase, packaging oranges in crates as rapidly as possible, disassembling and assembling a rifle, and tying a necktie. Typical jobs requiring high levels of manual dexterity are surgeon. carpenter. plumber. dog groomer. firearms cleaner. and auto mechanic.

Finger Dexterity is the ability to make skillful coordinated movements of the fingers of one or both hands and to grasp. place. or move very small objects. This ability involves the degree to which these finger movements can be carried out quickly. Tasks requiring good finger dexterity include fixing a watch. assembling small electronic components. and using tweezers. Jobs that require high levels of finger dexterity are dentist. surgeon. electronics assembler. interpreter (deaf). manicurist. make up artist. jewelry repairer. and seamstress.

Wrist-Finger Speed is the ability to make fast simple repeated movements of the fingers. hands. and wrists. It involves little if any accuracy or hand eye coordination. Speed of carrying out a movement is involved rather than starting a movement. Wrist finger speed is involved in rapidly sending Morse code messages using a manual telegraph key. scrambling eggs with a fork. and using a pencii sharpener. Typical jobs that require high levels of wrist-finger speed are orchestra conductor. stenographer. typist. butcher. hairdresser. seamstress. and telegrapher.

Speed of Limb Movement refers to the ability to quickly execute a single movement of the arms or legs. This ability does not include accuracy. careful control or coordination of movement. It involves movement of the arms or legs rather than the whole body. It also involves speed in carrying out. rather than starting a movement. Typical tasks associated with this ability are reaching for a switch as quickly as possible. quickly moving a control handle from left to right. and moving the foot from the accelerator to the brake pedal to avoid an obstacle. Jobs that require high levels of this ability include racecar driver, shoe shiner, and switchboard operator.

Appendix B:

Five occupational families based on hierarchical cluster analysis of standardized ability profiles (Catano & Ibel, 1995)[6]

Job Family	Military Occupation Code (MOC) and Name (original)	New MOC and Name
Military	011 Crewman	Armored Soldier
	021 Artilleryman	Artillery Soldier
	022 Artilleryman Air Defense	Artillery Soldier Air Defense
	031 Infantryman	Infantry Soldier
	041 Field Engineer	
	052 Lineman	
	181 Boatswain	
	651 Firefighter	
	811 Military Police	
	935 Mobile Support Equipment Operator	
Operator	121 Meteorological Technician	
	161 Air Traffic Controller	168 Aerospace Control Operator
	171 Air Defence technician	168 Aerospace Control Operator
	191 Oceanographic Operator	278 Tactical Acoustic Systems Operator
	211 Radio Operator	
	262 Naval Signalman	277 Naval Communicator
	273 Naval Acoustics Operator	278 Tactical Acoustic Systems Operator
	274 Naval Radio Operator	277 Naval Communicator
	275 Naval Combat Information Operator	
	276 Naval Electronic Sensor Operator	
	283 Naval Electronics Technician (Acoustics)	
	284 Naval Electronics Technician (Communications)	
	285 Naval Electronics Technician (Tactics)	
	291 Communications Research	
Administrative	212 Teletype Operator	Deleted
	831 Administrative Clerk	836 Resource Management Support Clerk
	841 Finance Clerk	836 Resource Management Support Clerk
	862 Steward	
	881 Postal Clerk	
	911 Supply Technician	
	933 Traffic Technician	

[6] **Occupations have been re-organized since the time of the cited research; therefore, some occupations included in the present study may be composites of several occupations that the cited research was based on.**

Job Family	Military Occupation Code (MOC)	New MOC and Name
Technical (Technical A)	221 Radio Technician	227 Land Communications and Information Systems Technician
	222 Terminal Equipment Technician	227 Land Communications and Information Systems Technician
	223 Teletype and Cipher Technician	227 Land Communications and Information Systems Technician
	231 Radar Technician	226 Aerospace Telecommunications and Information Systems Technician
	521 Integral Systems Technician	526 Avionics Technician
	524 Communications and Radar Systems Technician	526 Avionics Technician
	541 Photographic Technician	
	551 Instrument Electrical Technician	526 Avionics Technician
	722 Dental Clinic Assistant	
Mechanical (Technical B)	065 Naval Weapons Technician	
	312 Marine Engineering Mechanic	
	321 Hull Technician	
	332 Marine Electrician	
	411 Vehicle Technician	
	421 Weapons Technician (Land)	
	431 Electro-Mechanical Technician	
	441 Material Technician	
	511 Aero-Engine Technician	514 Aviation Technician
	512 Airframe Technician	514 Aviation Technician
	531 Safety Systems Technician	514 Aviation Technician
	561 Metals Technician	565 Aircraft Structures Technician
	562 Machinist	565 Aircraft Structures Technician
	563 Refinisher Technician	565 Aircraft Structures Technician
	572 Air Weapons Technician	514 Aviation Technician
	611 Construction Engineering Technician	648 Construction Technician
	612 Structures Technician	648 Construction Technician
	613 Plumber Gas Fitter	646 Plumbing and Heating Technician
	614 Electrician	642 Electrical Distribution Technician
	621 Refrigeration and Mechanical Technician	641 Refrigeration and Mechanical Technician
	622 Electrical Generating Systems Technician	643 EGS Tech
	623 Stationary Engineer	647 Water Fuels and Environment Technician
	624 Water. Sanitation and POL Technician	647 Water Fuels and Environment Technician
	711 Medical Assistant	
	861 Cook	
	921 Ammunition Technician	

Appendix C

GATB Testing Procedures

Motor Coordination; Subtest #8. The first test (Subtest #8; Mark-Making) is a pencil and paper measure consisting of several small boxes in which the examinee is to make the same three pencil marks (two vertical lines with a horizontal line across the bottom) in each box as fast as possible. Participants are given two practice runs and then one timed trial. They must make the same three marks in as many of the 130 boxes as possible in 60 seconds. Total score is a count of the number of boxes filled. Subtest 8 is a measure of motor coordination.

Manual Dexterity; Subtests 9 & 10. The second and third tests (Subtests 9 & 10) are measures of Manual Dexterity. They both use a rectangular pegboard divided into two sections, each containing 48 holes. There are 48 cylindrical pegs filling one side of the board. Pegs are painted white on one side (end) and red on the other. Subtest 9 (Place) starts with all pegs in the upper half of the board. Examinees are to move all pegs from the upper board to the corresponding holes in lower board as fast as they can, moving two pegs at a time and using both hands simultaneously. Participants receive one trial run and then three timed trials of 15 seconds each. Scores are summed across all three trials. Subtest 10 (Turn) starts with all pegs in the lower part of the board, all with the same color facing up. Subjects are to pick up each peg, turn it over, and replace it, using only one hand. They are given one practice run, and then three timed trials of 30 seconds each. Score is the number of pegs turned, summed across three trials.

Finger Dexterity; Subtests 11 and 12. The fourth and fifth scales are measures of Finger Dexterity and they are measured by subtests 11 and 12. The finger dexterity board is a small rectangular board with 50 holes in the top section and another 50 holes in the lower board. There are 50 rivets that fit into the holes and there is a rod standing to the side that is full of washers that fit onto the rivets. Subtest 11 (Assemble) starts with all 50 rivets in the holes in the top of the board. The examinee takes a rivet from the top of the board with one hand, a washer from the rod with the other hand, places the washer on the rivet. Then with the one hand, places the assembled rivet and washer into the corresponding hole in the bottom part of the board. Participants are given one practice run and then one timed trial of 90 seconds to assemble as many rivets and washers as possible. Their score is calculated by counting the number of assembled rivets and washers. The final test (subtest 12: Disassemble) is the exact opposite of subtest 11. Participants are to disassemble each washer/rivet combination and return them to the post and upper board. They have one practice and one timed trial of 60 seconds and their score is equal to the total number of disassembled rivet/washer sets.

Appendix D

Abilities Associated with Nine factor Ability Solution (Catano, 1995)

Composite Ability	Associated Abilities
Strength and Movement	Dynamic Strength Trunk Strength Explosive Strength Dynamic Flexibility Static Strength Stamina Extent Flexibility Gross Body Coordination Gross Body Equilibrium Speed of Limb Movement Rate Control Reaction Time Response Orientation Time Sharing Depth Perception
Vision	Near Vision Far Vision Visual Color Discrimination Night Vision Peripheral Vision Depth Perception Glare Sensitivity
Audition	Speech Recognition Auditory Attention Speech Clarity Hearing Sensitivity Wrist-Finger Speed Sound Localization Time Sharing
Controlled Reaction	Rate Control Response Orientation Multilimb Coordination Reaction Time Control Precision Speed of Limb Movement Perceptual Speed Spatial Orientation

Analytical Ability	Mathematical Reasoning Number Facility Originality Category Flexibility Deductive Reasoning Visualization
Information Processing	Flexibility of Closure Speed of Closure Selective Attention Perceptual Speed Spatial Orientation Manual Dexterity Auditory Attention
Cognition	Problem Solving Inductive Reasoning Deductive Reasoning Memorization Fluency of Ideas Information Ordering
Verbal Ability	Oral Expression Oral Comprehension Written Comprehension Written Expression
Fine Motor Control	Finger Dexterity Manual Dexterity Arm-Hand Steadiness Near Vision Control Precision Visual Color Discrimination